

Integrated Human Anatomy and Physiology Lab Manual I: Fundamentals of Structure and Movement

Susmita Sengupta and Lakshmikanta Sengupta

De Anza College

Biology

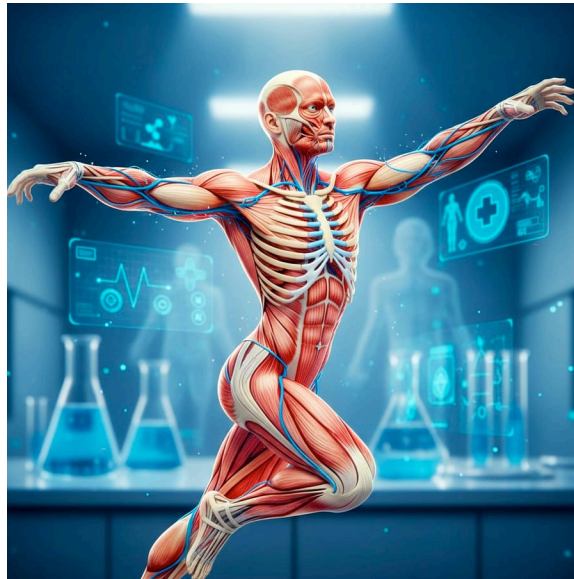
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Integrated Human Anatomy and Physiology Lab Manual I:

Fundamentals of Structure and Movement

Body Orientation, Cells, Tissues, Integumentary and Musculoskeletal Systems



Thumbnail: Anatomical illustration of the muscular system. (AI-generated image created with Nano Banana).

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Program Page



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Accessibility Statement

Accessibility

De Anza College is dedicated to creating learning materials that are accessible and benefit all students. Our materials follow the Web Content Accessibility Guidelines (WCAG) 2.1 Level AA. Our authors and contracted accessibility specialists checked all resources using this ASCCC OERI checklist, the accessibility tool in LibreTexts, WAVE, JAWS, and other more detailed checks for complex materials such as interactive components.

We selected LibreTexts as our preferred platform because of its [commitment to accessibility](#). In addition to the platform's inherent accessibility, we collaborated with the LibreTexts team to fix any accessibility issues we found.

Our Accessibility Review Process

Accessibility was built into the resource as it was written. This resource went through the following stages of review:

1. **Template check.** The project coordinator and instructional designers checked the first chapter for accessibility as a model to ensure later chapters meet accessibility standards.
2. **Progress checks.** The manuscript was checked at approximately 40%, 60%, and 80% completion to catch and correct accessibility issues in production.
3. **Specialist review.** Once the manuscript was complete, an accessibility expert conducted an accessibility check.
4. **Remediation.** The author and the project manager who conducted the earlier progress checks worked together to remediate the issues identified by the accessibility expert.
5. **Final check.** The resource underwent another full check by the accessibility expert before the book was deemed ready for publication.

This process combines ongoing checks during writing with a final specialist review, so issues are caught early and confirmed fixed before publication.

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- The name of the resource
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- A description of the problem you encountered
- The device, browser, and any assistive technology you were using (e.g., Windows 11, Google Chrome, JAWS screen reader)

Contact us: [De Anza ZTC team](#)

This statement was last updated August 2026

This resource was project-managed by **Jyothsna Viswanadha**, overseeing scope, and schedule; stakeholder coordination via monthly meetings; training and platform support (LibreTexts, troubleshooting, technical support); QA/accessibility check scheduling; and licensing and copyright governance.

A Note on Known Limitations

No accessibility check is perfect. We've made a genuine, sustained effort to catch and fix issues throughout the writing and review process described above, but some barriers may remain, especially in complex or interactive content. We'd rather be upfront about that than claim a standard of perfection we can't guarantee.

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About the Lab Manual

Philosophy and Approach

This first volume in a three-part series introduces aspiring health professionals to the foundational concepts of the Human Anatomy and Physiology I laboratory. The manual is designed for a CSU- and UC-transferable sequence and aligns with program outcomes for the Medical Laboratory Technology A.A. degree.

This student-centered lab manual includes nine labs that preserve the strengths of hands-on anatomical identification while incorporating guided inquiry. In addition to asking students to identify structures, the manual encourages them to explore how body systems function and why that knowledge matters in health-related contexts.

The labs are designed to reinforce and deepen concepts introduced in lecture, including cell chemistry, cell biology, histology, and the integumentary, skeletal, and muscular systems. Throughout the manual, students engage in active, hands-on exploration of anatomical structures and physiological concepts.

This manual supports learning by:

- emphasizing active investigation of structure and function
- encouraging collaboration through lab partners, small-group work, and guided discussion
- integrating observation, measurement, analysis, and simple experimental design when appropriate
- connecting laboratory activities to clinical relevance
- promoting the proper use and care of lab equipment, including microscopes
- providing scaffolding that prepares students for Parts II and III of the manual and for upper-division coursework after transfer

Framework

Students were placed at the center of the design of this lab manual. The primary goal was to support student success by making clear what students are expected to do, why the work matters, and how they can demonstrate mastery. To support this goal, the manual is organized with accessible steps, purpose-driven activities, and transparent criteria for success. This structure is intended to reduce barriers, build confidence, and guide students toward meaningful skill development.

Each lab begins with an introduction and clearly defined learning objectives. Background information helps bridge theory and practice by preparing students before they begin working with laboratory models, microscopes, and other equipment. This structure helps reduce cognitive load during lab procedures and makes the purpose of each step explicit by clarifying what students are doing, where they should focus, and why the task is important.

The sequence of labs is intentionally scaffolded. Early labs emphasize orientation, vocabulary development, and technical skills. Middle labs help students integrate learning across multiple levels of organization, such as cell, tissue, and organ. Later labs focus on system-level integration and functional anatomy. Across the manual, students build competency in:

- anatomical terminology
- microscopic identification of major tissue types
- identification of key bones, bone markings, and joints
- identification of major muscles
- description of basic body movements using correct anatomical terminology

Each lab also includes a glossary. Anatomy and physiology rely on a large number of specialized terms, many of which are derived from Latin or Greek. Including a glossary in each lab gives students a consistent and reliable reference point for unfamiliar vocabulary. This supports clearer communication and helps ensure that students and instructors share a common language when discussing body structures and functions.

Images and Accessibility

Images—including models, diagrams, micrographs, and clinical photographs—are essential to learning in anatomy and physiology laboratories. Because visual materials play a central role in student learning, this manual is designed to make those materials as clear, accessible, and instructionally meaningful as possible for all learners.

The manual includes high-resolution, clearly labeled visuals that support understanding of key topics such as:

- anatomical planes, directional terms, and body cavities
- cell structure and stages of cell division
- representative tissue micrographs with important features identified
- layers and structures of the skin
- bone classifications, compact and spongy bone structure, and cartilage
- major bones of the axial and appendicular skeleton, including key bone markings
- types of joints and body movements
- microscopic structure of skeletal muscle
- gross muscular anatomy, including major muscle groups and, where appropriate, origins and insertions

These visuals are selected to support clarity, accuracy, and transfer-level rigor while helping students connect structure to function.

To support accessibility in both print and digital formats, this manual uses:

- structured headings to improve navigation
- readable typography and consistent page organization
- high color contrast for text and visual clarity
- meaningful alternative text for instructional images and figures
- descriptive hyperlink text
- simple, tagged tables when tables are necessary
- captions and transcripts for media
- plain-language instructions that clarify expectations and reduce unnecessary cognitive load

Whenever possible, the manual uses Creative Commons–licensed visuals and references. This supports local adaptation, revision, and accessibility customization by instructors and institutions.

This manual reflects an equity-focused design philosophy. By providing zero-cost course materials, accessible formats from the outset, and inclusive learning supports, the manual is intended to promote equitable access, strengthen student persistence and success, and support program and accreditation expectations related to accessibility and inclusion.

Acknowledgements

The authors gratefully acknowledge funding from the California Community Colleges Chancellor's Office (CCCCO) through Zero Textbook Cost (ZTC) grants awarded to De Anza College.

This manual owes a special debt of gratitude to [Shagun Kaur](#), Communications Studies faculty member and ZTC Grants Coordinator at De Anza College. Her weekly coaching guided this project from outline to publication. Her mentorship, organized process, and unwavering encouragement were essential to bringing this manual to completion.

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We thank James Perla-Adams, Librarian and Open Educational Resources (OER) Coordinator at De Anza College, for his guidance and support in the development of this zero-cost, accessible lab manual. This project also benefited from De Anza's accessibility expertise, including support for meaningful alternative text for figures, high-contrast visual design, tagged PDF and HTML formats for screen-reader access, and a cleaner, keyboard-friendly layout aligned with Universal Design for Learning (UDL) principles.

Our sincere thanks also go to Jyothsna Viswanadha, Mathematics faculty member at De Anza College, for helping build equity and accessibility into every page. Her contributions included adding alternative text, improving visual contrast, supporting tagged

PDF and HTML formatting, and streamlining the layout so that students can access and navigate the manual more easily.

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About the Contributors

Author Images	Team Bios
	Author: Susmita Sengupta, PhD has over 29 years of teaching experience at both graduate and undergraduate levels, including the past two decades at Bay Area community colleges, where she currently teaches Human Anatomy, Physiology, and Human Biology. She has also taught Genetics, General Biology, Mammalian Cell Culture, and Gene Expression in Cell Culture. She has participated in professional development ranging from the Summer Institute of Functional Genomics and Bioinformatics at UC Davis (2005) to Instructional Skills Workshops at De Anza College (2018, 2020) and RSI training (Winter 2025). She was part of the NSF-funded CCB FEST project (2010–14) at San Francisco State University and currently serves on the Academic Advisory Committee of the Explorer's Guide to Biology. Her service includes roles on the Curriculum, Education Policies, Evaluation, and Professional Development Committees. Earlier, her postdoctoral research examined genetic impacts of the 1984 Bhopal Union Carbide disaster. She has authored over 26 peer-reviewed publications and developed lab manuals for her courses. Some of her selected publications are : Sengupta L.K. and Sengupta, S (2004) Molecular mechanisms, proteinopathies and therapeutic strategies in neurodegenerative disorders. <i>Current Genomics</i> 5 (4):327-346. Sengupta, L.K., Sengupta,S and Sarkar, M (2002) Pharmacogenetic applications of the post genomic era. <i>Current Pharmaceutical Biotechnology</i> 3(2): 141-150. Sengupta, S.,Sengupta, L.K and Bisen, P.S. (2001) Bioengineered crops: commercial and ethical considerations.<i>Current Genomics</i> 2 (2)181-97. Sengupta,S,Sengupta,L.K. and Bisen,P.S (1997) Phytolectins: the natural molecules with immense biotechnological potential. <i>Ind. J Exp. Biol.</i> 35:11-18. Ghosh,B.B.,Sengupta,S, Roy,A., Maity,S.,Ghose,S., Talukder,G and Sharma,A (1990) Cytogenetic studies in human populations exposed to gas leak in Bhopal, India. <i>Environ.Health Persp</i> 86:323-326. Goswami ,H.K., Chandorkar,M., K Bhattacharya,K, Sengupta,S,Sengupta,LK,et al (1990) Search for chromosomal variations among gas-exposed persons in Bhopal <i>Hum Genet</i> 84 (2)172-6.

Author Images	Team Bios
	Author: Lakshmikanta Sengupta, Ph.D. is a biology educator with 39 years of experience teaching and mentoring across postsecondary fields, including genetics, biotechnology, and human anatomy & physiology. He envisions educational institutions as vibrant communities, much like a living village, where learning and collaboration thrive. With rigorous academic training and experience, he translates complex biology into clear, engaging explanations. Dr. Sengupta actively encourages collaboration among educators and students to share best practices and improve the quality of educational materials available to all learners. He collaborated with the Community College Biology Faculty Enhancement through Scientific Teaching (CCB FEST), a program funded by the National Science Foundation (NSF), to coauthor research publications, including those in Proceedings of the National Academy of Sciences (PNAS), USA, and CBE—Life Sciences Education (Published by the American Society for Cell Biology). With a keen eye for detail, he uses photography to capture intricate aspects of life, including natural phenomena and anatomical structures. Cooking is another important passion that allows him to explore the science of nutrition and health. Gardening reflects his commitment to sustainability and the natural world.
	Accessibility and Editor: Jyothsna Viswanadha is a Mathematics Instructor at De Anza College. She has experience teaching community college mathematics courses, including developmental mathematics, calculus, and business calculus. She is committed to student-centered and equity-minded teaching. She has also taught in programs designed to help close equity gaps in mathematics education, including the Math Performance Success (MPS) program. Jyothsna supports the use of Open Educational Resources (OER) in her classes and has helped develop OER workbooks for Calculus III. As part of this work, she has transferred course content from existing files to LibreTexts, formatted and standardized images, formatted instructional labs and performed accessibility checks to support compliance with accessibility standards She is also committed to community service. She volunteers with organizations such as Vision Literacy and Assistance League to support underserved populations in reaching their educational goals.

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1: SCIENTIFIC INQUIRY - CONCEPT AND LABORATORY PRACTICE

Introduction

In this lab we will learn about a process called the Scientific inquiry investigation that involves a series of logical steps that supports the data's validity, reliability to arrive at explanations for various biological phenomena.

The **Association of American Medical Colleges (AAMC)** defines scientific inquiry: "Applies knowledge of the scientific process to integrate and synthesize information, solve problems, and formulate research questions and hypotheses; is facile in the language of the sciences and uses it to participate in the discourse of science and explain how scientific knowledge is discovered and validated."

Homeostasis means to maintain body functions within specific livable ranges, adjusting to internal and external changes. Homeo means resembling or of the same kind and stasis means standing still. Temperature, nutrient concentration, acidity, water, sodium, calcium, oxygen, as well as blood pressure, heart rate, and respiratory rate are some of the internal body variables that must remain within a certain range. When the body fails to maintain internal body variables within a certain range, normal function is interrupted, and disease or illness may result.

The infusion of inquiry-based approaches into the undergraduate biology and allied health pre-requisite curriculum is especially important in laboratory courses or within the laboratory component of a course, because students are applying the process of science in these courses and are learning to write in an inquiry-based way. Scientific inquiry is a key part of allied health anatomy and physiology courses, which help students develop an understanding of human body's structure and function. Students in these courses learn to apply scientific methods to analyze and interpret data, and to communicate biological concepts using scientific terminology.

Learning Objectives

1. Apply and evaluate inquiry skills to critically analyze and address scientific problems.
2. Demonstrate understanding and apply scientific inquiry processes and apply these concepts to real-world contexts.
3. Conduct scientific investigations collaboratively to answer biological questions using hypotheses, variables, measurement, data, charts, graphs, interpretation, and effectively communicate their findings.
4. Critically analyze the nature of science and evaluate the role of science in societal contexts and its implications.
5. Examine the role of scientific data in formulating public policy and substantiate the claim that scientific knowledge evolves over time as previous understandings are revised with new evidence and perspectives.

1.1: Background Information

1.2: Pre-Lab Activity

1.3: Activity 1

1.4: Activity 2

1.5: Glossary

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1.1: Background Information

Overview

In 1996, the [National Research Council](#) (NRC) defined inquiry, knowledge and understanding, and scientific literacy as “Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

Scientific Inquiry

Scientific inquiry is a systematic and methodical approach used to investigate questions and phenomena in the natural world. It involves several key components, including making observations, forming questions, developing hypotheses, conducting experiments, analyzing data, and drawing conclusions. This process is iterative, meaning that it often involves revisiting and refining hypotheses and experiments based on new findings or insights.

Key Steps in Scientific Inquiry

1. Observation is the process begins with careful and detailed observations, leading to questions about what is being observed.
2. Question formulation is based on observations, questions are developed to guide the investigation. These questions often address the "what," "why," "how," "when," and "where" of the phenomenon.
 - a. Before investigation, a scientist must define the question to be addressed. Defining a research question and understanding relevant prior research will influence how the scientific method is applied, making it an important first step in the research process. Researchers do experiments to answer questions about the world around us. The question should include a key starter like "how," "what," "when," "why," "where," "who," or "which". A winning strategy in human anatomy and physiology courses is to use medical abnormalities, pathologies and injuries to explain normal anatomical and physiological processes. The following are examples of simple research questions in human anatomy and physiology:
 - i. How does the presence of a specific muscle variation in the shoulder influence the range of motion in athletes during various sports activities?
 - ii. What role do osteoclasts and osteoblasts play in bone remodeling, and how can imbalances lead to skeletal disorders?
 - iii. How do different types of joints (e.g., ball-and-socket, hinge) enable various ranges and types of movement?
3. What is the impact of varying hydration levels on muscle performance and recovery in athletes?
4. To answer these questions, researchers begin by formulating testable hypotheses.
 - a. Hypothesis development is a testable and falsifiable statement that provides a possible explanation for the observations. It serves as the basis for experimentation. Research hypotheses are written as if/then statements that include dependent and independent variables, such as "If [I do this], then [this] will happen."
 - i. Writing hypothesis is a crucial element of scientific inquiry, guiding research and framing the investigation process. In an introductory college lab, particularly in human anatomy and physiology, crafting a well-structured hypothesis helps students focus their experiments and anticipate potential outcomes. A strong hypothesis is clear, testable, and based on existing knowledge, allowing for measurable and repeatable experimentation. Let's explore the components of a good hypothesis and how it differs from less effective examples.
 - ii. Good hypothesis is well-crafted hypothesis in human anatomy and physiology should be specific and testable, often structured in an "if-then" format that clearly outlines the expected relationship between variables. For example, "If caffeine consumption is increased, then the heart rate in adults will increase compared to when no caffeine is consumed." This hypothesis effectively identifies the independent variable (caffeine consumption) and the dependent variable (heart rate), providing a clear and measurable prediction that can be tested through experimentation.
 - iii. Incorrect Hypothesis: In contrast, a poorly-written hypothesis tends to be vague, untestable, or not based on prior research. For instance, "Caffeine affects the body in some way" lacks specificity and fails to define how the body is affected or what variables are being measured. This type of hypothesis does not guide the research effectively because it does not specify what to measure or how the effect will be evaluated. Without these key elements,

designing an experiment becomes challenging, and drawing meaningful conclusions is nearly impossible.

- iv. Hypotheses come in two forms: null hypotheses and alternative hypotheses. Each serves a distinct purpose in research, especially in fields like human anatomy and physiology.
 - The null hypothesis is a statement that assumes no effect or no difference between groups or variables. It serves as a default or baseline hypothesis that researchers aim to test against. For example, in a study examining the effect of exercise on heart rate, the null hypothesis might state, "Exercise has no effect on heart rate in adults." This hypothesis is crucial because it provides a point of comparison, allowing researchers to determine whether their experimental results are statistically significant.
 - The alternative hypothesis proposes a specific effect or difference, countering the null hypothesis. It represents the outcome that the researcher expects to find. Using the same example, the alternative hypothesis could be, "Exercise increases heart rate in adults." This hypothesis is often what researchers hope to prove through their study. It should be clear, testable, and directly related to the research question.
5. For the first research question above, the independent variable is the presence of a specific muscle variation: This is the variable that you manipulate or observe differences in. In this context, it refers to whether or not the athletes have a particular muscle variation in their shoulder. This variation could be anatomical or related to muscle size, attachment, or composition. The dependent variable: is the range of motion in the shoulder. This is the outcome or effect that you measure. It refers to how far the shoulder can move or rotate in various directions, which is quantified during different sports activities. This can include flexion, extension, abduction, adduction, and rotational movements.
6. Experiments are meticulously designed to test the hypothesis. This involves controlling variables, collecting data, and ensuring repeatability and reliability. Here's a structured approach to conducting a successful experiment in a lab setting. This involves controlling variables, collecting data, and ensuring repeatability and reliability.
 - a. Compile a comprehensive list of all materials and equipment needed for the experiment. This ensures you have everything required before starting.
 - b. Develop a clear and detailed experimental plan outlining the procedure. Identify the independent and dependent variables, and establish control conditions.
 - c. As you conduct the experiment, make detailed observations. Note any unexpected occurrences or variations in the process.
 - d. Systematically record your data in a well-organized format, such as tables or spreadsheets, to facilitate analysis. Review the data. Try to look at the results of your experiment with a critical eye. Ask yourself these questions:
 - i. Is it complete, or did you forget something?
 - ii. Do you need to collect more data?
 - iii. Did you make any mistakes?
 - e. Analyze the collected data to identify patterns, trends, or anomalies. Use statistical tools to determine the significance of your findings, Table 1.1.1.
 - f. Graphs and charts can be powerful tools for visualizing data and highlighting key insights, Table 1.1.2.
 - g. Make sure to clearly label all tables and graphs. Include the units of measurement (inches, grams, etc.). Place your independent variable on the x - *axis* of your graph and the dependent variable on the y - *axis*.
7. Drawing Conclusions or Inferences:
 - a. Interpreting Results: Analyze your data to determine whether it supports or refutes your hypothesis. Consider any patterns, correlations, or anomalies that might influence your conclusion.
 - b. Evaluating Hypotheses: Decide if your hypothesis was supported. If not, consider possible reasons and implications for further research.
 - c. Making Inferences: Use your findings to infer broader implications or applications in the field. Example: Concluding that a specific drug is effective in reducing symptoms could lead to its consideration for clinical trials.
8. Communication gives the results and conclusions are communicated to the scientific community through reports, publications, or presentations. This step is crucial for peer review and further validation. If many investigators working independently can validate the hypothesis by arriving at the same conclusions, the explanation becomes a theory.
9. Under experimental error when every experiment, no matter how carefully designed, is subject to some degree of error. Recognizing these errors is key to improving data accuracy and research outcomes. Here's a concise overview of the main types of errors you might encounter:
 - a. Mistakes made by the experimenter (Human error), such as misreading instruments or incorrect setup. These errors can often be minimized with careful attention and practice.
 - b. Errors stemming from flaws in design or instrumentation, leading to consistent deviations (Systemic error). Examples include:
 - i. Sampling Bias: Non-representative samples that limit the applicability of results.
 - ii. Selection Bias: Non-random assignment that skews results.
 - iii. Measurement Bias: Experimenter expectations influencing ratings.
 - iv. Unpredictable variations that occur by chance. While they can't be eliminated, their impact can be reduced through

repeated testing (Random Error).

10. Understanding and minimizing experimental error is crucial for achieving accurate and precise measurements, which are fundamental to scientific progress.

Table 1.1.1: Data Analysis Checklist

What Makes for a Good Data Analysis Chart?	For a Good Chart, You Should Answer "Yes" to Every Question
Is there sufficient data to know whether your hypothesis is correct?	
Is your data accurate?	
Have you summarized your data with an average, if appropriate?	
Does your chart specify units of measurement for all data?	
Have you verified that all calculations (if any) are correct?	

Table 1.1.2: Graph Chart

Graph Checklist	Yes/ No
<i>Have you selected the appropriate graph type for the data you are displaying?</i>	
<i>Does your graph have a title?</i>	
<i>Have you placed the independent variable on the x-axis and the dependent variable on the y-axis?</i>	
<i>Have you labeled the axes correctly and specified the units of measurement?</i>	
<i>Does your graph have the proper scale (the appropriate high and low values on the axes)?</i>	
<i>Is your data plotted correctly and clearly?</i>	

Safe Laboratory Practices and Procedures

Safety
is
a
fundamental
requirement

for
scientific
research
and
progress.
Here
are
some
safety
procedures
to
follow
in
scientific
inquiry:

- Follow
all
written
and
verbal
instructions.
Ask
for
assistance
if
you
need
guidance
or
help.
- Wear
clothing
and
shoes
that
cover
exposed
skin
and
protect
you
from
potential
splashes.
Tie
back
long
hair,
jewelry,
or
anything
that
may
catch
in
the
equipment.

- Know the locations and operating procedures for all safety equipment. This includes the eyewash station and safety shower.
- Know the locations of the nearest fire alarms and at least two ways out of the building. Never use an elevator in emergencies.
- Wear protective equipment: Wear a lab coat, gloves, and eye protection.
- Practice good personal hygiene. Wash your

*hands
after
removing
gloves,
before
leaving
the
laboratory,
and
after
handling
a
potentially
hazardous
material.*

- *Wash
your
hands
and
arms
with
soap
and
water
before
and
after
working
in
the
lab.*
- *Absolutely
NO
eating
or
chewing
gum.*
- *Avoid
contact
with
chemicals:
Avoid
smelling,
inhaling,
or
tasting
chemicals.*
- *Keep
your
work
area
clean:
Keep
your
work
area
clean
and*

*uncluttered,
and
regularly
wipe
down
benches
with
cleaners
or
disinfectants.*

- *Use
chemical
fume
hoods:
Use
chemical
fume
hoods
or
biosafety
cabinets
when
working
with
chemicals.*
- *Dispose
of
waste
properly:
Dispose
of
waste
materials
as
directed
in
the
experiment's
instructions.*
- *Observe
good
housekeeping.
Don't
block
emergency
exits:
Don't
block
emergency
showers,
eye
washes,
exits,
or
hallways.*
- *Report
damaged
electrical*

equipment
to
the
supervisor.

Do
not
use
damaged
electrical
equipment.

- Remove
PPE
(Personal
Protective
Equipment)
before
leaving
the
lab:
Remove
your
gloves
and
lab
coat
before
leaving
the
lab.

1.2: Pre-Lab Activity

Interpretation of Research Articles as Presented in the Popular Media

The introductory case study activities set the stage for a detailed examination and practice of the scientific inquiry process, providing a foundation to appreciate the meticulous and iterative nature of scientific research. Focused on real-world issues, we will aim to illustrate the critical steps involved in scientific investigation, from formulating a hypothesis to communicating results. By following the journey of inquiry, we will highlight the importance of curiosity, critical thinking, and rigorous methodology in the pursuit of scientific understanding. We hope to inspire a deeper appreciation for the scientific method and its role in driving innovation and discovery. Read the information presented below and answer the questions that follow.

Case - "The Strange Case of BeriBeri"

In 1887, a strange nerve disease attacked the people in the Dutch East Indies. The disease was beriberi. Symptoms of the disease included weakness and loss of appetite, victims often died of heart failure. Scientists thought the disease might be caused by bacteria. They injected chickens with bacteria from the blood of patients with beriberi. The injected chickens became sick; however, so did a group of chickens that were not injected with bacteria. They injected chickens with bacteria from the blood of patients with beriberi. The injected chickens became sick; however, so did a group of chickens that were not injected with bacteria.

Dr. Eijkman designed a new experiment based on his own observations. One hundred chickens were fed whole grain rice and lived in the same environment (light, temperature, water, and living space). Then the researchers separated 50 chickens marked with a yellow dye on the wings (represented the experimental group). Other 50 chickens were set as the control group. The experimental group were fed polished rice. The control group were fed the whole grain rice. Dr. Eijkman researched this interesting case and found that polished rice lacked thiamine, a vitamin necessary for good health.

Post Reading Questions to Demonstrate a Deeper Understanding

1. What was the original testable hypothesis in the experiment?
2. What was the manipulated (independent) variable and the responding (dependent) variable in the original experiment?
3. What was the testable hypothesis proposed by Dr. Eijkman?
4. What was the manipulated (independent) variable and the responding (dependent) variable in Dr. Eijkman's experiment?
5. Define what you understand by the term 'Control group'.
6. Describe the importance of the control group in scientific inquiry.

During the lab session, students will share their responses with peers to make a collaborative discussion.

1.3: Activity 1

Crack the Code: How to Ace the Scientific Method

The Ratios and Proportions of the Human Body

Height is required for the assessment of growth and nutritional status, as well as for predictions and standardization of physiological parameters. Anthropometry, or the measurement of body parameters, helps diagnose malnutrition and other health problems. It is a vital part of pediatric evaluations as well as the assessment of an adult. Body height is one of the main anthropometric measurements obtained in children. The measured value is compared to a reference population and monitored over time to ensure adequate growth. Researchers have observed a correlation between the length of the upper and lower limbs and the height of an individual. The World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have implemented standardized procedures for measuring body height to ensure reliability and accuracy.

Overview and Introduction

An example of a human body ratio is a person's arm span the distance from the middle fingertip of the left hand to that of the right hand when stretching out both arms horizontally—to their height. This ratio is approximately a one to one ratio, meaning that a person's arm span is about equal to their height. There are many more human body ratios; some are independent of age, and others change as we grow from a baby to an adult.

In this lab experiment, students will explore the fascinating concepts of body ratios and proportions of the length of the arms to the height of the body, to gain insights into how proportions relate to overall health, physical appearance, and even athletic performance. This activity will involve direct measurements of body segments and the application of mathematical calculations to derive ratios. By engaging in this activity, students will develop skills in both measurement, data analysis and presentation, essential components in the field of anatomy and physiology.

Hypothesis for testing: The length of a person's upper limb is equal to 0.4 (40%) of the height of the person.

Materials: Meter stick or measuring tape; calculator.

Procedure

1. Select volunteers for the measurements.
2. Instruct volunteers to stand, with heels, head, and back against a wall.
3. Use a flat object (like a book or ruler) placed on top of the head at a right angle to the wall to mark the height accurately.
 - Measure each subject's height (distance from the floor to the mark on the wall) accurately using a meter stick or measuring tape in centimeters (cm).
4. Measure volunteers's upper limb length (arm length) in centimeters (cm).
 - Have the subject stand erect with their arm hanging loosely by their side.
 - Measure from the acromial landmark (most superior lateral point of the shoulder joint) to the tip of the middle finger.
5. Calculate Expected and Actual Percentages: For each subject, calculate the expected upper limb length using the hypothesis ($\text{Height} \times 0.4$) and the actual percentage of height ($\text{Measured Upper Limb Length} / \text{Height}$).
6. Record Data: Record the information collected for each volunteer in the Table 1.3.1.

Tabular Representation of Data Set

This table presents the collected data from the lab experiment aimed at testing the hypothesis that the length of a person's upper limb is approximately 40% of their height. The various columns allow for a comprehensive analysis of each subject's measurements, facilitating comparisons between measured values and expected outcomes. Print and fill the Table 1.3.1 as you work with the activity.

Table 1.3.1: Upper Limb Length vs. Height: Recorded Data

Subject ID/Number	Measured Height (Round to nearest cm)	Measured Upper limb length (Round to nearest cm)
1		
2		
3		
4		

Deriving Relationships Between Expected and Actual Data

Deriving relationships between expected and actual data is a fundamental aspect of scientific analysis. This process helps researchers understand how closely their observations align with theoretical predictions, providing insights into the validity of their hypotheses.

- The expected (predicted) correlation between upper limb length and height is determined using the following equation.
 - $\text{Height} \times 0.4 = \text{expected upper limb length}$
- The observed (actual) correlation to be used to test the hypothesis is determined by:
 - $\text{Length of the upper limb/height} = \text{actual percentage of height}$

Data presentation on a graph and drawing conclusion

A graph is an excellent way to visually represent the relationship between height and upper arm length. By plotting the data on a graph, you can easily see patterns, trends, and correlations that might not be immediately obvious from the raw numbers.

Key steps

- Create a graph by plotting Upper Limb Length on the x - axis (horizontal) and Height on the y - axis (vertical).
- Draw a line representing the hypothetical relationship (0.4 upper limb length to height).
 - Plot the collected data points for each volunteer on the graph.
 - Draw a line of best fit through the plotted data of your subjects.
- Analyze and Conclude:
 - Visually compare the distribution of the collected data points with the line representing the hypothesis.
 - Interpreting the graph
 - Positive correlation - A positive slope on the trend line indicates that as height increases, upper limb length generally also increases.
 - Outliers - Individuals whose data points fall significantly away from the trend line may have unusually long or short upper limbs relative to their height.
- Conclusion - Does the distribution of the volunteers' measured upper limb lengths support or disprove the original hypothesis - "The length of a person's upper limb is equal to 0.4 (40%) of the height of the person." Explain your answer. If your measurements disprove the original hypothesis, suggest reasons why this might be so.

1.4: Activity 2

Homeostasis

Understanding the Concept of Homeostasis Following the Scientific Inquiry Method

Homeostasis, as currently defined, is a self-regulating process by which biological systems maintain stability while adjusting to changing external conditions. This concept explains how an organism can maintain more or less constant internal conditions that allow it to adapt and to survive in the face of a changing and often hostile external environment. A set point is the physiological value around which the normal range fluctuates. A normal range is the restricted set of values that is optimally healthful and stable. Many medical conditions and diseases result from altered homeostasis. In this activity, we will study the impact of low and moderate intensity physical workouts on homeostasis by observing changes in vital signs such as pulse rate and respiratory rate. Vital signs are measurements of the body's most basic functions. The four main vital signs routinely monitored by medical professionals include the following:

1. Body temperature in degrees Celsius ($^{\circ}\text{C}$) or degrees Fahrenheit ($^{\circ}\text{F}$) : According to the American Academy of Family Physicians, fever is indicated when body temperature rises one degree or more over the normal temperature of 98.6°F (or one degree over the individual's baseline temperature). Hypothermia is defined as a reduction in body temperature below 95°F .
2. Pulse rate in beats per minute (bpm): The pulse rate is a measurement of the heart rate, or the number of times the heart beats per minute. As the ventricles of the heart contract and pump blood through the arteries, the arteries expand and contract with the flow of the blood. Taking a pulse not only measures the heart rate, but also can indicate heart rhythm (strength of heart contraction). The normal resting pulse for healthy adults, ranges from 60 to 100 beats per minute. The pulse rate may fluctuate with exercise, illness, injury, and emotions. Females ages 12 and older, in general, tend to have faster heart rates than do males. Athletes such as runners, who do a lot of cardiovascular conditioning, may have heart rates near 40 beats per minute.
3. Rate of breathing (per minute): Respiration rate or rate of breathing in breaths per minute (bpm): The respiration rate is the number of breaths a person takes per minute. Normal respiration rates for an adult person at rest range from 12 to 18 breaths per minute. The rate is usually measured when a person is at rest and simply involves counting the number of breaths for one minute by observing how many times the chest rises. Respiration rates may increase with fever, illness, trauma, and other medical conditions. Comparing patients' vital sign measurements to the normal range of values is useful for detecting changes in the physiology or medical problems.
4. Blood pressure is a crucial vital sign that reflects the force of blood pushing against the artery walls. Normal blood pressure for adults is typically around 120/80 mmHg, but this can vary based on age, health, and other factors. Along with other vital signs like pulse, respiration, and temperature, blood pressure provides a snapshot of a person's overall health and can indicate potential medical issues.

Exercise causes many factors of homeostasis to kick in to maintain internal equilibrium. How exercise affects some of these parameters can be determined by comparing vital sign measurements to the standard reference range of values.

Group Discussion

Work in groups to design and perform an experiment to demonstrate mastery of the Scientific Inquiry process including asking questions; formulating a testable hypothesis; designing an appropriate experiment; collecting, analyzing, and interpreting data; and drawing conclusions.

1. Title of Investigation (reading the title the reader can get an idea about the research): be imaginative.
2. Research question
3. Proposed testable hypothesis
4. Materials - Stop watch
5. Brainstorm to
 - Decide on a form of light physical activity - (hints: light physical activities include: walking slowly in the room, making

the bed, washing dishes etc.).

- Record agreed upon light physical activity.
- Decide on a form of moderate exercise - (hint: Jumping rope or jumping jack, step-ups, sit-ups, squats, or push-ups for 10 minutes).
- Record agreed upon moderate physical activity.

Note: you must first record (like heart rate, breathing rate etc - check the list above) the baseline information (control data set).

- What is the dependent variable for this experiment?
- What is the independent variable for this experiment?

Procedure

Before beginning the experiment, rest for 5 minutes, record your pulse rate in radial artery (wrist).

Control Phase

1. Take three separate 30 sec measurements.
2. Calculate the beats per minute by multiplying each value by 2.
3. Record the data.
4. Control Pulse (beats per minute):
 - Trial 1: bpm.
 - Trial 2: bpm.
 - Trial 3: bpm.
5. Calculate the average of the three values.
6. Record the average control pulse.
7. Record average control pulse bpm.

Exercise Phase with Light Exercise:

- Perform light exercise for 10 minutes.
- Record pulse and breathing rate at the 2nd, 5th, and 10th minute.
- Record data in the Master Table.
- Rest for 2 minutes after exercise.
- Record the same sets of data in the Master Table.

Exercise Phase with Moderate Exercise:

- Repeat the same procedure for moderate exercise for 10 minutes.
- Record pulse and breathing rate at the 2nd, 5th, and 10th minute.
- Record data in the Master Table.
- Rest for 2 minutes after exercise.
- Record the same sets of data in the Master Table.

Note: Take precautions to avoid injury during the workout. If there is any physical disability, select exercises compatible with your abilities.

Master Table: Data during various intervals of light and moderate exercise and control.

Instructions: Choose a light exercise like jumping jacks, brisk walk, e.t.c.

Table 1.4.1: Data during various intervals of light exercise and control

Time Interval	Breathing (inhalation & exhalation) Rate/per minute	Radial artery pulse rate (beats per minute)
After 5 minutes Rest		
2nd min during exercise		

Time Interval	Breathing (inhalation & exhalation) Rate/per minute	Radial artery pulse rate (beats per minute)
5th min during exercise		
10th min of exercise		

Stop Exercise, Start Resting and Collect Post Exercise Data.

Table 1.4.2: Data during various intervals of light exercise and control

Time Interval	Breathing (inhalation & exhalation) Rate/per minute	Radial artery pulse rate (beats per minute)
After 5 minutes Rest		
2nd min during exercise		
5th min during exercise		
10th min of exercise		

Rest for 5 minutes and get ready for the moderate exercise. (Preferable the same volunteer for the group for both light and moderate exercise).

Instructions: Choose a moderate exercise and record data during various intervals of moderate exercise and control.

Table 1.4.3: Breathing and Pulse Rates During Moderate Exercise at Specific Time Intervals

Time Interval	Breathing (inhalation & exhalation) Rate/per minute	Radial artery pulse rate (beats per minute)
After 5 minutes Rest		
2nd min during exercise		
5th min during exercise		
10th min of exercise		

Stop Exercise, Start Resting and Collect Post Exercise Data.

Table 1.4.4: Breathing and Pulse Rates During Moderate Exercise at Specific Time Intervals

Time Interval	Breathing (inhalation & exhalation) Rate/per minute	Radial artery pulse rate (beats per minute)
After 5 minutes Rest		
2nd min during exercise		
5th min during exercise		
10th min of exercise		

Post-Lab Data Analysis

- What is the average resting pulse rate? Most adults are between 60-90 beats/min. How do your data/values compare?
- What is the average respiratory rate? Most adults are between 60-90 beats/min. How do your data/values compare?
- What happens to the pulse rate with light and moderate exercise?
- Use the data to describe how the pulse rate and respiratory rate changed with light and moderate exercise compared to the control.
- What happened to the pulse rate and respiratory rate after exercise is finished? Did you observe restoration of resting pulse

rate it immediately or not? Explain reasoning for these observations.

Conclusion and Communication

1. Restate the initial question and hypothesis - Briefly remind the reader of the research question and the initial hypothesis you were testing.
2. Interpret results in relation to the hypothesis - Explain whether your data supports or rejects your hypothesis and why.
3. Acknowledge limitations - Mention any potential limitations or sources of error in your experiment that could affect the interpretation of the results.

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Key Term and Definitions

- **Analysis** - Interpreting data collected during a study. Researchers examine data to find patterns, relationships, and trends that can help them draw meaningful conclusions.
- **Bias** - A failure to maintain accuracy and objectivity in research methods. Common sources of bias include sampling errors, measurement inaccuracies, and researcher subjectivity.
- **Control/control group** - A standard of comparison for checking or verifying the results of an experiment. Test subjects randomly assigned to not receive the experimental treatment.
- **Control center** - compares values to their normal range; deviations cause the activation of an effector
- **Controlled experiment** - An experiment that tests only one factor at a time by using a comparison of a control group and an experimental group.
- **Controlled variables** - all those things that are kept the same.
- **Conclusion** - statement that sums up what you learn from an experiment. Determination of whether the hypothesis should be accepted or rejected.
- **Data** (singular: datum): Facts, numbers, or values obtained in an experiment
- **Dependent variable** - The variable that responds to the independent variable. The dependent variable is the one being measured in the experiment.
- **Effector** - organ that can cause a change in a value.
- **Error** - a measure of the difference between a measured or calculated value and a true value.
- **Ethics** - Principles that guide research conduct, emphasizing integrity, respect for participants, and minimizing harm.
- **Experiment** - the science activity that tests the hypothesis.
- **Experimental Group** - Test subjects randomly assigned to receive the experimental treatment.
- **Hypothesis** - educated guess or prediction of what you think the outcome will be. A prediction of whether the independent variable will have an effect on the dependent variable or a prediction of the nature of the effect.
- **Independent variable** - The variable that is manipulated or changed by the researcher. Changing the independent variable from one value to another (e.g., different drug doses, different amounts of time).
- **Negative feedback** - homeostatic mechanism that tends to stabilize an upset in the body's physiological condition by preventing an excessive response to a stimulus, typically as the stimulus is removed.
- **Normal range** - range of values around the set point that do not cause a reaction by the control center.
- **Observe** - to gather information using the 6 senses (common sense, sight, smell, taste, hearing, touch).
- **Positive feedback** - mechanism that intensifies a change in the body's physiological condition in response to a stimulus.
- **Procedure** - a list of steps telling what to do for the experiment.
- **Problem** - a question stating what the scientist is trying to find out.
- **Quantitative observation (QN)** - to gather information that uses numbers or measurement (23 centimeters, 60 to 100 beats per minute) (N for 'number')
- **Qualitative observation (QL)** - to gather information that does NOT use numbers or measurement (recording, interpreting, and analyzing of non-numeric data with an attempt to uncover the deeper meanings of human experiences and behaviors.)
- **Range** - the difference between the largest data value, and the smallest data value.
- **Sensor** - (also, receptor) reports a monitored physiological value to the control center.
- **Set point** - ideal value for a physiological parameter; the level or small range within which a physiological parameter such as blood pressure is stable and optimally healthful, that is, within its parameters of homeostasis.
- **Trial** - each test performed in an experiment.
- **X-axis** - horizontal axis (independent variable).
- **Y-axis** - vertical axis (dependent variable).

2: MASTERING THE LANGUAGE OF ANATOMY

Introduction

In this lab, we embark on an exciting journey to explore the interconnected fields of anatomy and physiology. In this lesson you will review the basic organization scheme of the human body and start to develop the language of anatomy commonly used to precisely describe the location of structures of the human body.

Anatomy focuses on the structure of the body, including the location, arrangement, and relationships of body parts, examines everything from the microscopic level (cells and tissues) to the gross level (organs and systems), helps in understanding how different parts of the body fit together and where they are located.

Physiology is the scientific study of the interplay of the principles of chemistry and physics of the structures of the body, deals with the functions of the body, including how organs, systems, and cells work together to maintain life. Knowledge of physiology is important in health and disease, allowing for the development of treatments and interventions. As an example, patients may suffer from different respiratory conditions but exhibit the same symptoms. A patient with asthma may have narrowed airways due to inflammation and increased mucus, while a patient with COPD may exhibit the same symptoms due to lung tissue damage or loss of elasticity. A thorough understanding of physiology can help nurses identify the source, determine the correct treatment, and relieve the symptoms. This is one simple example of how extensive physiology education helps nurses care for patients and alleviate discomfort.

Kinesiology, another field of choice in healthcare may be defined as the study of the principles of anatomy (active and passive structures), physiology, and mechanics concerning human movement. Physical activity includes exercising for the improvement of health and fitness; learning movement skills; and engaging in activities of daily living, work, sport, dance, and play. The study of kinesiology leads to a variety of careers such as teaching; research; coaching; fitness leadership; and delivering other services related to sports medicine, health promotion, high-performance athletic competition, rehabilitation, and managing sport-related enterprises.

Learning Objectives

- Differentiate between anatomy and physiology by defining key terms and explaining how they complement one another in understanding the human body.
- Describe the anatomical position and explain its significance as a reference point in anatomy.
- Apply anatomical terminology to identify and describe body directions, regions, planes, and major organs within the body cavities.
- Identify anatomical structures using models, diagrams, and virtual dissection tools to build practical skills.
- Analyze clinical scenarios by evaluating the surface location, serous membranes, relative position, and plane of section of injuries or conditions.

2.1: Background Information

2.2: Activity 1

2.3: Activity 2

2.4: Activity 3

2.5: Activity 4

2.6: Activity 5

2.7: Activity 6

2.8: Activity 7

2.9: Activity 8

[2.10: Activity 9](#)

[2.11: Activity 10](#)

[2.12: Glossary](#)

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2.1: Background Information

Overview

A strong foundational knowledge of anatomy is crucial to practicing nursing/physical therapy/kinesiology—or administering medical care in any capacity. When administering an intramuscular shot to a patient, the nurse must locate the correct muscle and injection site. This requires an understanding of the location and size of the muscle, as well as the nerves and blood vessels in the area. They must understand that there are many layers of tissue through which the needle must pass: skin, subcutaneous tissue, and fascia (which varies in thickness per the patient's age, weight, and general health).

Some of these structures are very small and can only be observed and analyzed with the assistance of a microscope. Other larger structures can readily be seen, manipulated, measured, and weighed. Gross anatomy is the study of the larger structures of the body, those visible without the aid of magnification and will be a major focus of this lab component of this course. Macro- means “large,” thus, gross anatomy is also referred to as macroscopic anatomy. In contrast, micro- means “small,” and microscopic anatomy is the study of structures that can be observed only with the use of a microscope or other magnification devices and will be a major focus in the lecture component of this course. Microscopic anatomy includes cytology, the study of cells and histology, the study of tissues.

Latin and Greek roots, prefixes, and suffixes form the basis of anatomical language, providing a universal way for scientists to communicate about the human body. The body is divided into various regions, such as the head, neck, trunk, upper limbs, and lower limbs, which are further divided into subregions and parts.

The body contains several cavities, including dorsal and ventral cavities, which house and protect internal organs. The abdominopelvic cavity is the largest cavity and is divided into four quadrants and nine regions for precise description of organ locations.

The planes of the body are imaginary lines used to divide the body into different sections for anatomical study. These include the mid-sagittal, parasagittal, frontal, transverse/horizontal, and oblique planes.

Language of Anatomy

Health education is a continuum of learning experiences that enables students, as individuals and as members of society, to make informed decisions, modify behaviors, and change social conditions in ways that are health-enhancing and increase health literacy.

Anatomists and health care providers use terminology to precisely talk about the anatomy of the human body that can seem overwhelming at first. The purpose of this language is to reduce confusion, increase precision, and efficiency, and minimize medical errors. For example, if you tell a friend that you have a scar “above the wrist” is it located on the forearm two or three inches away from the hand? Or is it at the base of the hand? Is it on the palm side or the back-side? By using precise anatomical terminology, including anatomical position, regional terms, directional terms, body planes, and body cavities, we can eliminate ambiguity and increase precision.

Anatomical terms are made up of roots, prefixes, and suffixes. The root of a term often refers to an organ, tissue, or condition, whereas the prefix or suffix often describes the root. For example, in the disorder hypertension, the prefix “hyper-” means “high” or “over,” and the root word “tension” refers to pressure, so the word “hypertension” refers to abnormally high blood pressure.

- The prefix (P) appears at the beginning of the medical term and adds meaning to the word root.
- The word root (WR) is the core of many medical terms and refers to the body part or body system to which the term is referring.
- The suffix (S) is at the end of the medical term and usually indicates a procedure, condition, or disease. When defining a medical term, start the definition with the suffix. For example, consider the common medical condition tonsillitis. The word root “tonsil” refers to the tonsils, an anatomical part of the body found in the throat. The suffix “-itis” refers to inflammation. Therefore, the definition of the medical term tonsillitis is “inflammation of the tonsils.”
- Combining vowel (CV) is typically the letter “o” that helps with pronunciation. A combining vowel can connect a word root and a suffix or two word roots. When a word root is combined with a combining vowel, the word part is referred to as a combining

form (CF).

Examples of Medical Term by its Components

- Arthropathythe word root “arthr-” that refers to a joint.
 - “o” he combining vowel (CV)
 - the suffix (S) “-pathy” that refers to a disease.

When combining the meaning of these components together, the medical term 'Arthropathy' means “disease of a joint.”

- Osteoarthritis
 - Analyze Components: oste/o/arthr/itis
 - oste is a word root (WR) that means “bone”.
 - /o/ is a combining vowel (CV).
 - arthr is a word root (WR) that means “joint”.
 - -itis is a suffix (S) that means “inflammation”.

When combining the meaning of these components together, the medical term 'Osteoarthritis' means "Inflammation of bone joint”.

Anatomical Position

To further increase precision, anatomists standardize the way in which they view the body. Just as maps are normally oriented with north at the top, the standard body “map,” or anatomical position, is that of the body standing upright, with the feet at shoulder width and parallel, toes forward. The upper limbs are held out to each side, and the palms of the hands face forward as illustrated in Figure 2.1.1. Using this standard position reduces confusion. It does not matter how the body being described is oriented, the terms are used as if it is in anatomical position. For example, a scar in the “anterior (front) carpal (wrist) region” would be present on the palm side of the wrist. The term “anterior” would be used even if the hand were palm down on a table. The standard anatomical position is agreed upon by the international medical community. They are references for the way a body is placed. As with other anatomical terms, for example, body planes, directions, and relationships, this word must be viewed in context. Healthcare practitioners cannot discuss patients’ bodies without having a general awareness of anatomical position, which is particularly important in medicine.

In anatomical position, a person is standing upright with head in neutral on top of the body, eyes directed straight ahead, shoulders relaxed down the back, chest broad and open, upper limbs at the sides with the palms facing forward and thumbs pointing away from the body, hips level, knees straight ahead and feet on the floor (hip width).

When referencing a structure that is on one side of the body or the other, we use the terms “anatomical right” and “anatomical left.” Anatomical right means that the structure is on the side that a person in an anatomical position would consider their right-hand side (not necessarily on the right of the viewer) and anatomical left means that the structure is the side that a person in an anatomical position would consider their left-hand side (which likewise is not necessarily the left side of the viewer).

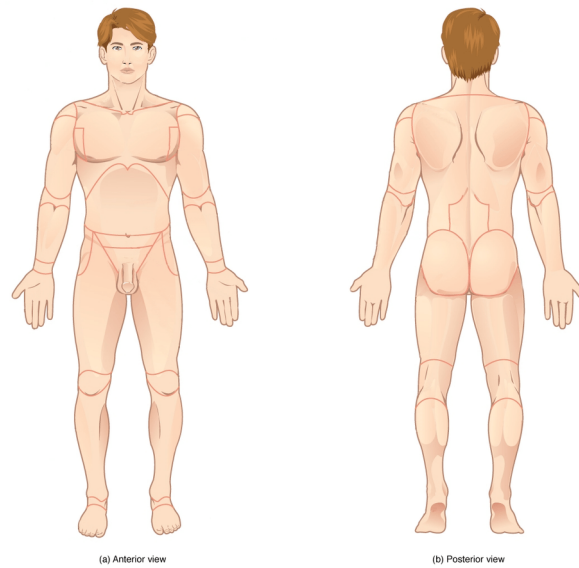


Figure 2.1.1: Standard Anatomical Position: The body is standing upright, facing forward. The feet are slightly apart and parallel. The arms are at the sides with the palms facing forward, and the thumbs pointing away from the body. (a) A front view (anterior) showing the face, chest, abdomen, and legs; (b) A back view (posterior) showing the back, buttocks, and legs. (CC BY-NC-ND 4.0; PHED 301 Students via [Anatomical Position](#) and [Advanced Anatomy 2nd Ed](#)).

Additionally, the terms supine (a face up orientation) and prone (a face-down orientation) are used to describe a body that is lying down as illustrated in Figure 2.1.2. These terms are sometimes used in describing the position of the body during specific physical examinations or surgical procedures. The basis for the standard anatomical position in humans comes from the supine (face up) position used for examining human cadavers during autopsies. Dissection of cadavers was one of the primary ways humans learned about anatomy throughout history, which has tremendously influenced the ways by which anatomical knowledge has developed into the scientific field of today. Anatomical position is designed to remove ambiguity when describing anatomical structures.

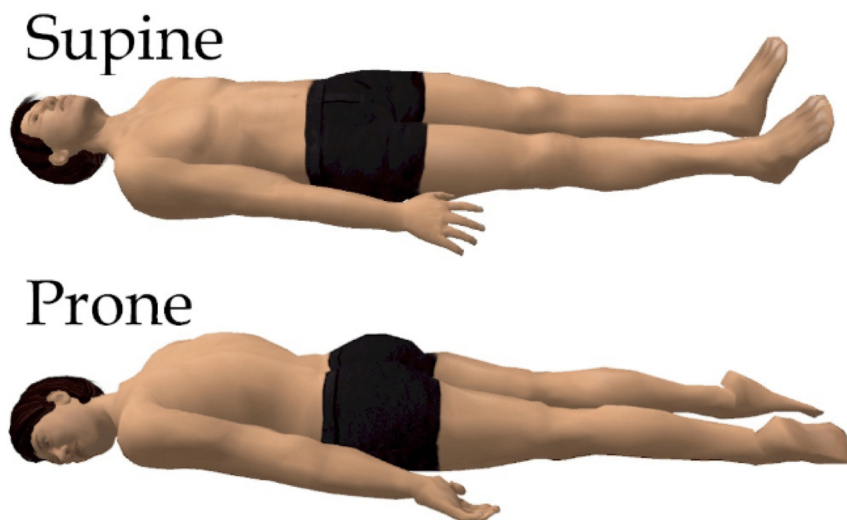


Figure 2.1.2: Alternate Anatomical Positions: Supine refers to a body lying on its back (face up), while prone refers to a body lying on its belly (face down). (CC BY-NC-ND 4.0; PHED 301 Students via [Anatomical Position](#) and [Advanced Anatomy 2nd Edition](#)).

Regional Surface Anatomy Terms

The human body's regions have specific terms to help increase precision in language. First, there are two major regions of the body, the axial region and the appendicular region. The axial body runs right down the center (axis) and consists of everything

except the limbs, meaning the head, neck, thorax (chest and back), abdomen, and pelvis. The appendicular body consists of appendages, otherwise known as upper and lower extremities (which we call arms and legs).

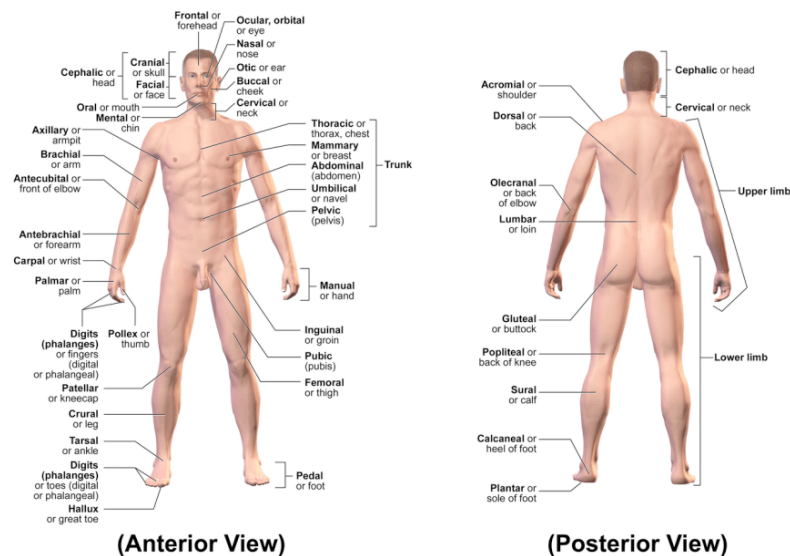


Figure 2.1.3: Regions of the Human Body. The human body is shown in anatomical position in an (a) anterior view and a (b) posterior view. The regions of the body are labeled in bold. (CC BY 3.0; via [Blausen Medical](#)).

The Figure 2.1.3 includes two side-by-side anatomy diagrams that present regional anatomical terminology from the front, or anterior, view and the back, or posterior, view.

Anterior view:

- The head and neck regions shown are cephalic, or head; cranial, or skull; facial, or face; frontal, or forehead; ocular or orbital, or eye; nasal, or nose; otic, or ear; buccal, or cheek; oral, or mouth; mental, or chin; and cervical, or neck.
- The trunk regions shown are thoracic, or chest; mammary, or breast; abdominal, or abdomen; umbilical, or navel; and pelvic, or pelvis.
- Directly below the trunk are inguinal, or groin, and pubic, or pubis.
- The upper-limb regions shown are axillary, or armpit; brachial, or arm; antecubital, or front of elbow; antebrachial, or forearm; carpal, or wrist; manual, or hand; palmar, or palm; digits or phalanges, or fingers; and pollex, or thumb.
- The lower-limb regions shown are femoral, or thigh; patellar, or kneecap; crural, or lower leg; tarsal, or ankle; pedal, or foot; digits or phalanges, or toes; and hallux, or great toe.

Posterior view:

- The back-of-body regions shown are cephalic, or head; cervical, or neck; acromial, or shoulder; dorsal, or back; olecranal, or back of elbow; lumbar, or loin; gluteal, or buttock; popliteal, or back of knee; sural, or calf; calcaneal, or heel of foot; and plantar, or sole of foot.

Directional Terms

Medical records are detailed snapshots of a patient at a particular time and are important when pictures of injuries are not possible. To create an accurate description, clinicians use relative terms to indicate that the lesion is close to something else to serve as a point of reference. Clinicians use specific directional terms to describe the locations of body structures relative to other structures. Do remember that these terms are relative! The following pairs of terms are used to make comparisons. Each term is used to orient a first structure or feature with respect to the position of a second structure or feature.

Anatomists use a standard group of terms to describe directions concerning the human body. Do remember that these terms are relative! These terms are essential for describing the relative locations of different body structures. For instance, an anatomist might describe one band of tissue as “inferior to” another or a physician might describe a tumor as “superficial to” a deeper body structure. Learning these terms now is critical to avoid confusion when you are studying or describing the locations of particular

body parts in this course and in any future study of the human body.

- Anterior (or ventral) - the front or direction toward the front of the body. For example, the toes are found on the anterior portion of the foot.
- Posterior (or dorsal) - the back or direction toward the back of the body. For example, the spinal column is posterior to the sternum.
- Superior (or cranial) - a position above or higher than another part of the body. For example, the eyes are superior to the mouth. Superior and cranial can often be used interchangeably though cranial is used to specifically refer to a structure near or toward the head. In quadrupeds the terms sometimes cannot be used interchangeably.
- Inferior (or caudal) - a position below or lower than another part of the body. For example, the pelvis is inferior to the abdomen. Inferior and caudal can often be used interchangeably though caudal is used to specifically refer to a structure near or toward the tail (in humans, the coccyx, or lowest part of the spinal column). In quadrupeds the terms sometimes cannot be used interchangeably
- Lateral - the side or direction toward the side of the body. For example, the thumb is lateral to the other digits.
- Medial - the middle or direction toward the middle of the body. For example, the big toe is the most medial toe.
- Proximal - Describes a position in a limb that is nearer to the point of attachment or the trunk of the body. For example, the upper arm is proximal to the wrist.
- Distal - a position in a limb that is farther from the point of attachment or the trunk of the body. For example, the foot is distal to the thigh.
- Superficial - a position closer to the surface of the body. For example, the skin is superficial to the bones.
- Deep - a position farther from the surface of the body. For example, the brain is deep to the skull.
- Contralateral - structures found on opposite sides of the body (right vs. left side). For example, the right foot is contralateral to the left arm.
- Ipsilateral - structures found on the same side of the body. For example, the right hand and right shoulder are ipsilateral.

Note

Superior and inferior are only used in reference to the trunk and abdomen. The terms proximal and distal are frequently misconstrued as superior and inferior. The terms proximal and distal are only to be used in reference to structures of the arms and legs (limbs) in reference to their proximity to the trunk (torso). For example: the elbow is distal to the shoulder, or the shoulder is proximal to the elbow.

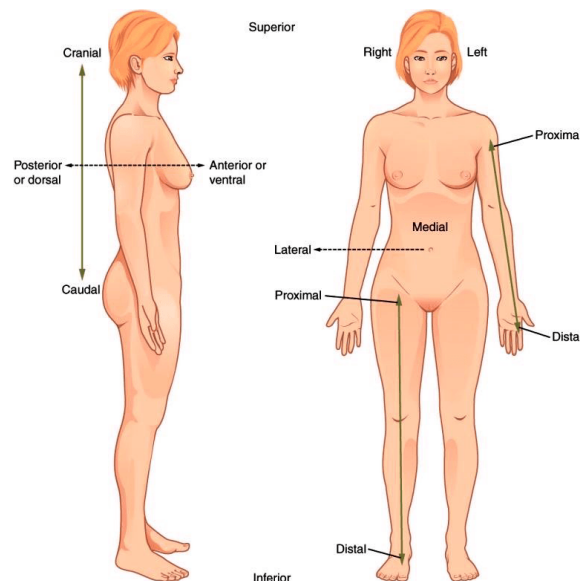


Figure 2.1.4: Diagram showing anatomical directional terms on a human body, including cranial, caudal, posterior (dorsal), anterior (ventral), superior, inferior, right, left, proximal, distal, medial, and lateral. (CC BY-SA 4.0; Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel

Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, via [OpenStax](#) and [Anatomy & Physiology](#)).

The Figure 2.1.4 shows paired directional terms such as anterior or ventral/posterior or dorsal, cranial and caudal, superior/inferior, proximal/distal, are shown as applied to the human body. This illustration shows two diagrams: a side view and an anterior view. Each diagram shows directional terms using double-sided arrows. The cranial caudal arrow runs vertically behind the torso and lower abdomen. The cranial arrow is pointing toward the head while the caudal arrow is pointing toward the tail bone. The posterior/anterior arrow is running horizontally through the back and chest. The posterior or dorsal arrow is pointing toward the back while the anterior, or ventral arrow, is pointing toward the abdomen. On the anterior view, the proximal/distal arrow is on the right arm. The proximal arrow is pointing up toward the shoulder while the distal arrow is pointing down toward the hand. The lateral-medial arrow is a horizontal arrow on the abdomen. The medial arrow is pointing toward the navel while the lateral arrow is pointing away from the body to the right.

Body Planes and Sections

While surface anatomy terms describe the external anatomy of the body, clinicians and health personnel also need to localize the extent of injury internally. The directional references allow the body to be divided along three imaginary planes. These planes, and the sections that they produce, provide an opportunity to explore the three-dimensional relationships between anatomical structures (Figure 2.1.5, Figure 2.1.6). Diagnostic imaging, which uses noninvasive techniques such as ultrasound, X-rays, CT scans, and MRI imaging, is used to view internal structures. Planes and sections are also used to describe how incisions should be made during surgery or when describing the plane of a section in a histology sample Figure 2.1.6.

A section is a two-dimensional surface of a three-dimensional structure that has been cut. Modern medical imaging devices enable clinicians to obtain “virtual sections” of living bodies, which we call these scans. However, body sections and scans can be correctly interpreted only if the viewer understands the plane along which the section was made. A plane is an imaginary two-dimensional surface that passes through the body. There are three planes commonly referred to in anatomy and medicine.

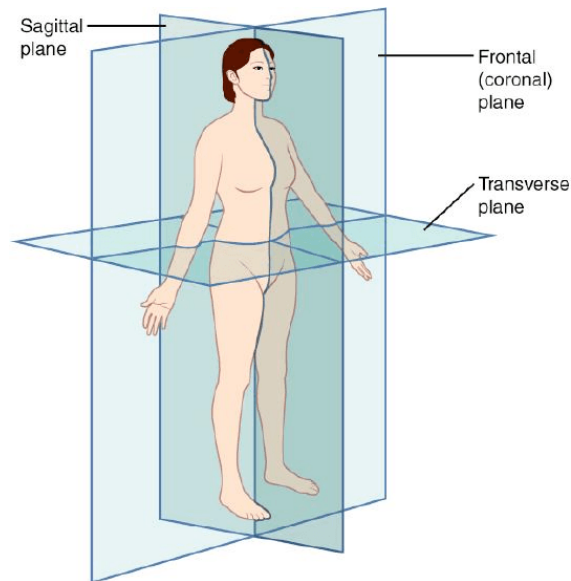


Figure 2.1.5: The different sectional planes used to expose internal structures. There are three basic planes: sagittal, coronal, and transverse. A human in the anatomical position, can be described using a coordinate system with the z - axis going from front to back (coronal/frontal plane), the x - axis going from left to right (sagittal plane), and the y - axis going from up to down (transverse plane). (CC BY 3.0; via [Wikimedia Commons](#)).

Figure 2.1.5 is a diagram of a human body with three labeled anatomical planes:

- Sagittal plane divides the body or an organ vertically into right and left sides. If this vertical plane runs directly down the middle of the body, it is called the mid-sagittal or median plane.
- Parasagittal plane is a vertical cut that is off-center that separates the left of the specimen from the right in unequal portions. It does not matter whether it is the left side or the right side that is larger, as long as they are not equal.
- Frontal plane divides the body or an organ into an anterior (front) portion and a posterior (rear) portion. The frontal plane is sometimes referred to as a coronal plane.

- Transverse plane divides the body or organ horizontally into upper and lower portions. Transverse planes produce images referred to as cross sections.
- Oblique plane is an anatomical plane that cuts the body at an angle, rather than in the coronal, sagittal, or transverse planes. Helps visualize structures like the spine and pelvis that are hard to see from other planes.

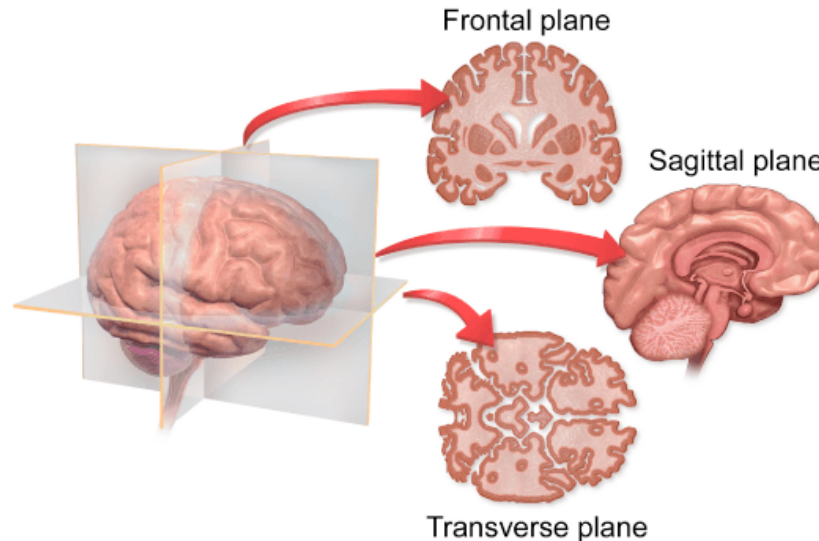


Figure 2.1.6: Planes of the human brain. The three planes most commonly used in anatomical and medical imaging are the sagittal, frontal (or coronal), and transverse plane. (CC BY 3.0; Blausen Medical via WikiJournal of Medicine).

Figure 2.1.6 displays a human brain with three labeled sectioning planes, each showing how the brain can be divided:

1. Frontal Plane: A vertical cut from side to side, dividing the brain into front and back sections.
2. Sagittal Plane: A vertical cut from front to back, dividing the brain into left and right sections.
3. Transverse Plane: A horizontal cut, dividing the brain into upper and lower sections.

Each plane is accompanied by a cross-sectional view to illustrate how the brain appears when sliced along that plane. Let me know if you'd like this description in a downloadable format or adapted for educational use!

Body Cavities and Serous Membranes

The body maintains its internal organization by means of membranes, sheaths, and other structures that separate compartments. The dorsal (posterior) cavity and the ventral (anterior) cavity are the largest body compartments (Figure 2.1.7). These cavities contain and protect delicate internal organs, and the ventral cavity allows for significant changes in the size and shape of the organs as they perform their functions. The lungs, heart, stomach, and intestines, for example, can expand and contract without distorting other tissues or disrupting the activity of nearby organs.

- The posterior (dorsal) cavity has two main subdivisions:
 - In the posterior (dorsal) cavity, the cranial cavity houses the brain, protected by the bones of the skulls and cerebrospinal fluid.
 - The spinal cavity (or vertebral cavity) encloses the spinal cord, protected by the vertebral column and cerebrospinal fluid.
- The anterior (ventral) cavity has two main subdivisions:
 - The thoracic cavity is the more superior subdivision of the anterior cavity, and it is enclosed by the rib cage. The diaphragm forms the floor of the thoracic cavity and separates it from the more inferior abdominopelvic cavity. Within the thoracic cavity there are smaller cavities:
 - The right and left pleural cavities contain the right and left lungs, respectively.
 - The mediastinum is medial to the pleural cavities and contains the heart, major blood vessels going to and from the heart, trachea, esophagus, and thymus.
 - The pericardial cavity is found within the mediastinum and surrounds the heart.
 - The abdominopelvic cavity is inferior to the thoracic cavity and houses the digestive organs, the pelvic cavity, and the reproductive organs. It is the largest cavity in the body. While no membrane physically divides the abdominopelvic cavity, it

can still be helpful to divide it into two cavities:

- The abdominal cavity is between the diaphragm and superior border of the hip bones. It contains most of the digestive organs, along with the kidneys and ureters of the urinary system.
- The pelvic cavity is inferior to the abdominal cavity. It contains the internal reproductive organs, along with the urinary bladder and urethra of the urinary system.

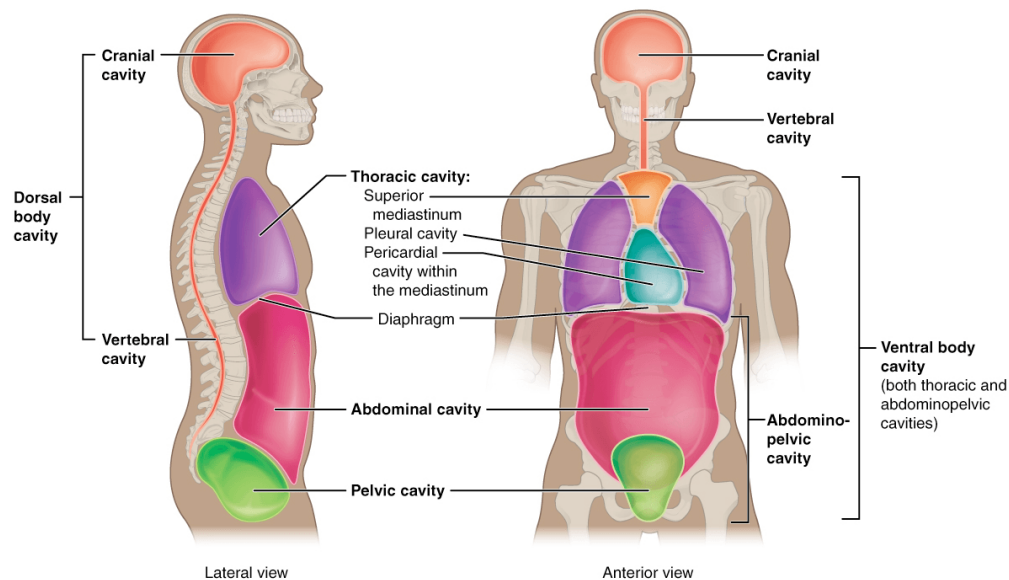


Figure 2.1.7: The ventral cavity includes the thoracic and abdominopelvic cavities and their subdivisions. The dorsal cavity consists of the cranial and spinal cavities. (CC BY 4.0; Kimberlee Carter; Marie Rutherford; and Connie Stevens via [Building a Medical Terminology Foundation 2e](#)).

Figure 2.1.7 is displaying lateral and anterior views of the human body, highlighting the body cavities in. The cranial cavity, a large bean-shaped cavity occupying most of the upper skull, contains the brain. The vertebral cavity, a narrow thread-like space, runs from the cranial cavity down the length of the spinal cord, together forming the dorsal body cavity. The thoracic cavity is depicted, consisting of three sub-cavities: the two pleural cavities located on either side of the body, anterior to the spine and lateral to the breastbone, and the superior mediastinum, a wedge-shaped cavity situated between the upper regions of the pleural cavities. The pericardial cavity, located in the center of the chest below the superior mediastinum, outlines the shape of the heart. The diaphragm separates the thoracic cavity from the abdominal cavity, which occupies the lower half of the trunk, anterior to the spine. Below the abdominal cavity, anterior to the buttocks, is the funnel-shaped pelvic cavity, located inferior and anterior to the abdominal cavity. The abdominal and pelvic cavities collectively are referred to as the abdominopelvic cavity, while the thoracic, abdominal, and pelvic cavities together comprise the ventral body cavity.

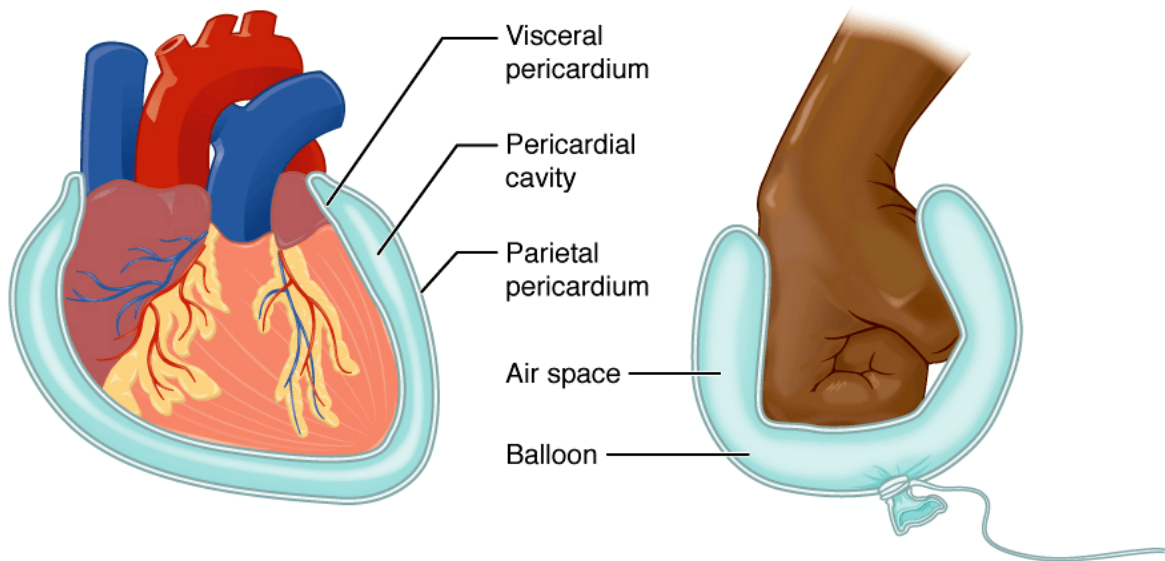


Figure 2.1.8: Serous membrane lines the pericardial cavity and reflects back to cover the heart much like an under inflated balloon would form two layers surrounding a fist. (CC BY 4.0 via OpenStax).

The Figure 2.1.8 illustrates the pericardium on the left next to an analogy of a hand punching a balloon on the right. The pericardium is a two-layered sac that surrounds the entire heart except where the blood vessels emerge on the heart's superior side. The pericardium has two layers because it folds over itself in the shape of the letter U. The inner layer that borders the heart is the visceral pericardium while the outer layer is the parietal pericardium. The space between the two layers is called the pericardial cavity. The heart sits in the cavity much like a fist punching into a balloon. The balloon surrounds the lower part of the fist with a two-layered sac, with the top of the balloon, where it contacts the fist, being analogous to the visceral pericardium. The bottom of the balloon, where it is tied off, is analogous to the parietal pericardium. The air within the balloon is analogous to the pericardial cavity.

Abdominal Regions and Quadrants

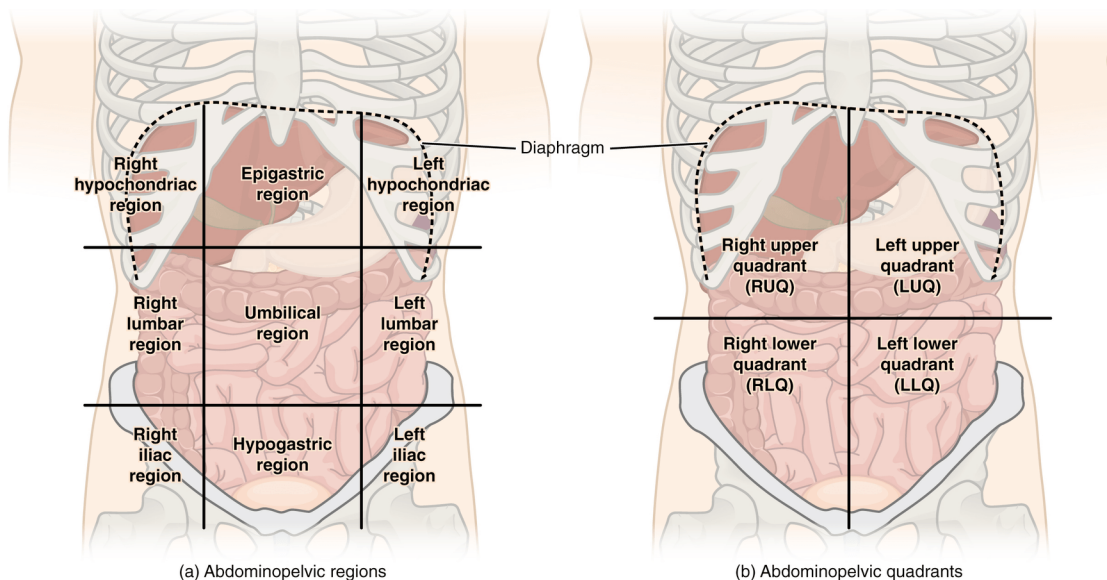


Figure 2.1.9: Regions and Quadrants of the Peritoneal Cavity. There are (a) nine abdominal regions and (b) four abdominal quadrants in the peritoneal cavity. (CC BY-SA 4.0; Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, via OpenStax and Anatomy & Physiology).

Figure 2.1.9 compares two common systems used to describe abdominal locations. A dashed curved line near the top of both panels indicates the approximate level of the diaphragm.

Panel (a) divides the abdomen into a 3-by-3 grid with these labeled regions:

- Top row: right hypochondriac; epigastric; left hypochondriac
- Middle row: right lumbar; umbilical; left lumbar
- Bottom row: right iliac; hypogastric; left iliac

Panel (b) uses a cross to divide the abdomen into four labeled quadrants:

- Right upper quadrant (RUQ)
- Left upper quadrant (LUQ)
- Right lower quadrant (RLQ)
- Left lower quadrant (LLQ)

To promote clear communication, for instance about the location of a patient's abdominal pain or a suspicious mass, health care providers typically divide up the cavity into either nine regions or four quadrants. The abdominopelvic cavity extends from just inferior to the diaphragm to the iliac region on the pelvic floor. This cavity contains the organs of the digestive, excretory, and reproductive systems, and holds parts of the endocrine and circulatory systems. Many times, a patient complains of non-specific abdominal pain. The standard way of dividing the abdomen is to use the umbilicus as a point of reference. Using the mid-sagittal and transverse planes through the umbilicus, we divide the abdominopelvic region into four equal parts, called quadrants. There is a Right Upper Quadrant (RUQ), a Left Upper Quadrant (LUQ), a Right Lower Quadrant (RLQ), and a Left Lower Quadrant (LLQ).

Patients are often not very good at describing the exact location of abdominal pain but can localize it to a quadrant. Sometimes an organ is located exclusively in one quadrant, and other times parts of the organ can be found across different quadrants. For example, the stomach is found mostly in the Left Upper Quadrant but also has a small portion that is in the Right Upper Quadrant.

Unfortunately, from a clinical perspective, the four quadrants are often not specific enough. When a more specific location is needed, clinicians divide the abdominopelvic cavity into nine regions, much like a tic-tac-toe board. Because each region is smaller, fewer organs belong to each region. The regions are evenly divided into thirds, and the center "box" has the umbilicus in the middle. This is the umbilical region. Lateral to the umbilical region on the patient's right side is the right lumbar region and on the left is the left lumbar region. Superior to the right lumbar region is the right hypochondriac region, and inferior to the right lumbar region is the right iliac region. Superior to the left lumbar region is the left hypochondriac region and inferior to the left lumbar region is the left iliac region. Superior to the umbilical region is the epigastric region and inferior to the umbilical region is the hypogastric region. You will need to learn both the names and positions of quadrants and regions and accurately identify the organs found in each.

2.2: Activity 1

Anatomy and Physiology

Define the terms 'Anatomy' and 'Physiology' to demonstrate your thoughts (your own understanding, no Google answer, no copy/paste). Fill the table in.

Table 2.2.1 Understanding the Concepts of Anatomy and Physiology

Term	Definition (In My Own Words)
Anatomy	
Physiology	

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2.3: Activity 2

Demonstrate and Describe Anatomical Position

To begin learning the anatomy of the human body, it is important to have reference points to locate specific structures of the body. Imagine that a doctor asked you to clean an area of a patient's skin on the lateral aspect of the brachial region, just proximal to the elbow. Would you know what the doctor was talking about? When describing the location of a certain body part, does it matter whether the person is sitting, standing, or lying down?

- Describe standard human anatomical position as if you are teaching a student.
- Observe the volunteer demonstrating Anatomical Position and complete the sentence by filling in the blank:
 - "A careful observation of the volunteer in anatomical position reveals that all the joints [like elbow joint] are forming 180 degree angle excepting which joint?"
- Discussion Question: Why do you think it is important for all health care personnel to learn about anatomical position. Explain.
- Engagement: Anatomy education relies on a specialized vocabulary largely derived from Latin and Greek. This can pose challenges for students, particularly those with diverse linguistic backgrounds, potentially hindering their learning outcomes. This activity incorporates culturally responsive teaching strategy that connects anatomical terminology to students' prior knowledge and linguistic strengths, ultimately enhancing comprehension and motivation.

Share the term of the organ(s) in a language other than English (Mandarin, Spanish, Tagalog, Hindi/Korean or other). Spell the word in English in the space and state which language is that.

Table

Organ
Names
in
Multiple
Languages

Heart

Lungs

Liver

Brain

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2.4: Activity 3

Anatomical Adjectives Unveiled: Mapping Body Regions

In this activity, you'll engage with anatomical terminology by identifying the body part or region associated with each anatomical adjective. This exercise will help you solidify your understanding of anatomical language, which is crucial for accurately describing the human body in medical and scientific contexts.

Review the Table. You'll find a list of anatomical adjectives, each followed by the noun form in parentheses. Use everyday language to describe the part or region next to each adjective. For example, if you see "Brachial (Arm)," you would write "Arm" next to "Brachial."

Pair up with a classmate to quiz each other on different terms. Discuss any confusing terms as a group to clarify understanding. Use diagrams or models to visualize each body region as you label the terms. Fill in the table.

Table 2.4.1: Anatomical Adjectives and Their Everyday Language Equivalents.

Anatomy adjectives (noun)	Everyday language (English)	Anatomy adjectives (noun)	Everyday language (English)
Abdominal (abdomen)		Acromial (acromion)	
Antebrachial (antebrachium)		Antecubital (antecubitis)	
Auricle (auris)		Axillary (axilla)	
Brachial (brachium)		Buccal (bucca)	
Carpal (carpus)		Cephalic (cephalus)	
Cervical (cervicis)		Coxal (coxa)	
Cranial (cranium)		Crural (crus)	
Digital (digit)		Dorsal (dorsa)	
Facial (facies)		Femoral (femur)	
Frontal (frons)		Gluteal (gluteus)	
Inguinal (inguen)		Lumbar (lumbus)	
Mammary (mamma)		Manual (manus)	
Mental (mentis)		Nasal (nasus)	
Olecranal (olecranon)		Oral (oris)	
Ocular (oculus)		Palmar (palma)	
Patellar (patella)		Pelvic (pelvis)	
Plantar (planta)		Popliteal (popliteus)	
Pubic (pubis)		Sacrum (sacral)	
Sural (sura)		Tarsal (tarsus)	
Thoracic (thorax)		Umbilical (umbilicus)	

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2.5: Activity 4

Mastering Anatomy: Applying Directional Terms in the Human Body

The objective of this activity is to enhance understanding and application of anatomical directional terms through hands-on activities and collaborative learning.

Review the key directional terms: anterior, posterior, superior, inferior, medial, lateral, proximal, and distal. Discuss their significance in describing locations and relationships between body parts.

Read the engaging prompts that encourage critical thinking and application of anatomical terms. Pair up with a classmate. Take turns describing the location of one body part relative to another using directional terms and fill the following table.

Table 2.5.1: Application of Anatomical Directional Terms in Human Body Positioning

Statement	Ap
Apply directional terms, describe the position of the eyes in relation to the tip of the nose.	
Explain how the antecubital region is positioned relative to the olecranal region using directional term.	
Discuss the spatial relationship between bones and the skeletal muscles that move them, employing the directional term.	
Describe the position of the patellar region in relation to the tarsal region with appropriate directional terms.	
How does the sternal region relate anatomically to the mammillary regions? Use directional terms in your explanation.	
Describe the anatomical position of the umbilical region compared to the mental region using directional terms.	
Explain the position of the nose in relation to the umbilical region using anatomical directions.	
Identify the regions of the hand that meet when you clap and describe their location. Clap your hands and observe the parts that make contact, noting their anatomical names.	
Articulate the position of the elbow in relation to the wrist using directional terms.	
Articulate the position of the elbow in relation to the shoulder using directional terms.	
Describe the anatomical relationship between the trachea and the esophagus with appropriate terminology.	

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2.6: Activity 5

Exploring Anatomical Planes and Directions with Gummy Bear

This lab activity aims to help students understand and apply anatomical terminology related to body planes/sections (sagittal, frontal, transverse), regional terms, and directional terms (superior, inferior, anterior, posterior, etc.) using a fun and engaging approach with gummy bears. After finishing the activity, take photos and put them into a presentation. Fill in the table by drawing in the space provided.

Materials needed are:

- 4 Gummy bears per student (Large Cinnamon Bears work best!)
- 1 Plastic knife per student
- Cutting board or protective surface
- 4 Post it note per student
- Colored pins

Table 2.6.1: Gummy Bear Dissections Along Anatomical Planes with Drawings and Descriptions

What you need to do	Draw in the space
Take one gummy bear and a blade. Cut through the mid-sagittal plane of the bear. Draw a picture of the two parts of the gummy bear after it has been cut and label and describe cut in the next column.	
Take a second gummy bear. Now make a cut through the frontal or coronal plane. Draw this diagram and label and describe cut in the next column.	
Take a third gummy bear and cut through a transverse or horizontal plane. Draw this diagram and label and describe cut in the next column.	
Take a fourth gummy bear and cut through a parasagittal plane. Draw this diagram and label and describe cut in the next column.	

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2.7: Activity 6

Exploring Anatomical Planes with Laboratory Models

This lab activity is designed to help students identify and understand the sagittal, transverse, and frontal planes using anatomical models. By engaging with physical laboratory models, students will enhance their spatial awareness and reinforce their understanding of anatomical terminology. Visit each lab station equipped with different anatomical models: a torso model, head model, and brain model created by the instructor, identify the sagittal, transverse, and frontal planes.

1. Laboratory Station Marked A -
2. Laboratory Station Marked B -
3. Laboratory Station Marked C -

2.8: Activity 7

Mapping the Human Body: Labeling Body Cavities and Structures

This activity aims to reinforce your understanding of human anatomy by identifying and labeling body cavities and their associated structures.

1. Begin by refreshing your knowledge of major body cavities: cranial, thoracic, abdominal, pelvic, and spinal. Understand the key structures located within each cavity, such as the brain in the cranial cavity or the heart in the thoracic cavity.
2. Examine the provided images that depict various body cavities. Using the background information, label each cavity accurately. Ensure you identify the boundaries and major structures within each cavity.

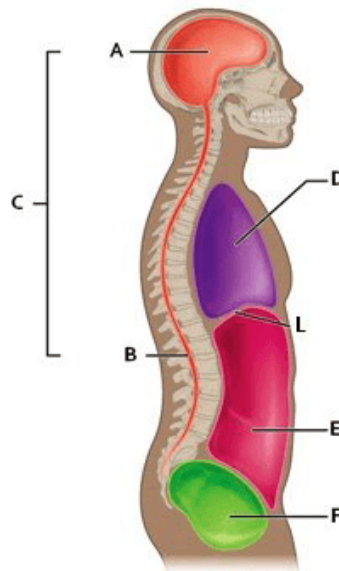


Figure 2.8.1: Diagram of human body right lateral view. (CC BY 4.0; Kimberlee Carter; Marie Rutherford; and Connie Stevens via [Building a Medical Terminology Foundation 2e](#)).

Figure 2.8.1 is a labeled side-view anatomical diagram of the human body, focusing on the **central nervous system** and **major internal organs**. The diagram uses color and letter labels to identify key components:

- A: Brain – located in the head, shown at the top of the central nervous system.
- B: Spinal cord – depicted in red, running vertically along the spine.
- C: Entire central nervous system – includes both the brain and spinal cord, extending from the head to the lower back.
- D: Purple-colored organ – likely a lung, located in the chest area.
- E: Pink-colored organ – likely part of the digestive system, positioned below the lungs.
- F: Green-colored organ – another digestive system component, located near E.
- L: Area near D – possibly another lung or a related respiratory structure.

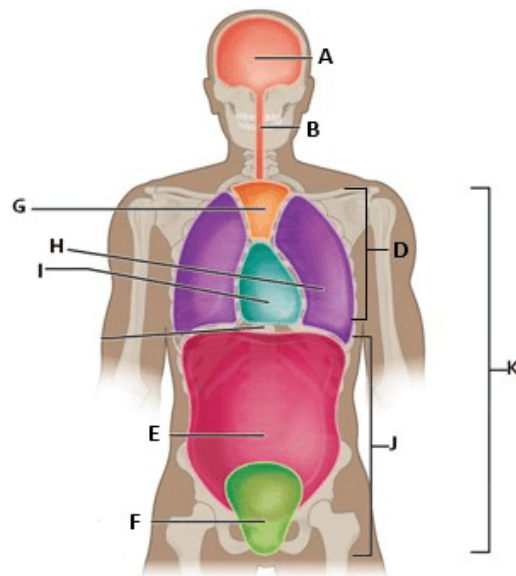


Figure 2.8.2: Diagram of human body frontal view. (CC BY 4.0; Kimberlee Carter; Marie Rutherford; and Connie Stevens via [Building a Medical Terminology Foundation 2e](#)).

Figure 2.8.2 is a labeled anatomical diagram of the human body, focusing on internal organs within the thoracic and abdominal cavities. The following parts are identified:

- A: Brain – located in the head.
- B: Trachea – the airway connecting the throat to the lungs.
- D: Right Lung – positioned on the right side of the chest.
- G: Left Lung – positioned on the left side of the chest.
- H: Heart – located centrally between the lungs.
- I: Diaphragm – a muscle beneath the lungs that separates the thoracic and abdominal cavities.
- E: Stomach – located below the diaphragm, part of the digestive system.
- F: Small Intestine – shown below the stomach.
- J: Large Intestine – surrounding the small intestine.
- K: A bracket indicating the thoracic cavity, which contains the lungs, heart, and trachea.

Table 2.8.1: Identification of Anatomical Cavities and Structures Using Vocabulary Labels A–L

Apply vocabulary (cavity and structure)	
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	

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2.9: Activity 8

Exploring Abdominal Anatomy: Mapping the Quadrants

This lab activity is designed to help you identify the four quadrants of the abdominal area using torso models. You will learn to associate each quadrant with the organs located within it, enhancing your understanding of abdominal anatomy and its significance in medical diagnostics and treatment planning. Review the concept of dividing the abdomen into four quadrants: Right Upper Quadrant (RUQ), Left Upper Quadrant (LUQ), Right Lower Quadrant (RLQ), and Left Lower Quadrant (LLQ). Work with the torso models to identify the 4 quadrants of the abdominal area indicated by letters (A, B, C, D) in the image. Name the organs you will find in each quadrant.

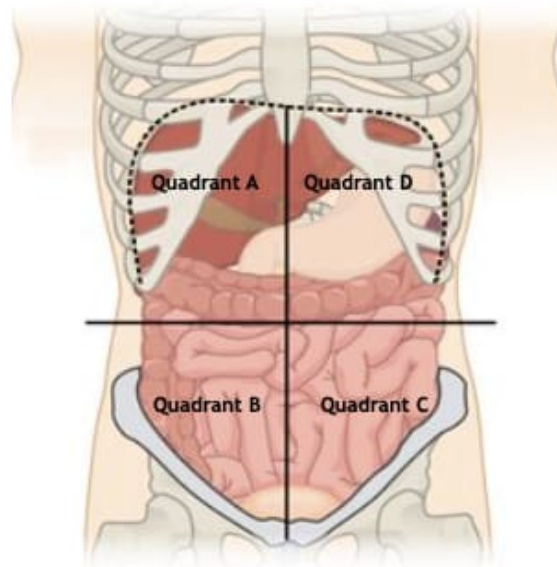


Figure 2.9.1: Anatomical model of the human torso displaying internal organs in the abdominopelvic quadrants including the liver, gall bladder, stomach, small intestine, large intestine and urinary bladder.(CC BY-SA 4.0; via [Quadrants and Regions of Abdomen](#)).

Figure 2.9.1 is a labeled anatomical diagram of the human abdomen divided into four quadrants by intersecting horizontal and vertical lines. The quadrants are:

- Quadrant A: Upper left
- Quadrant B: Lower left
- Quadrant C: Lower right
- Quadrant D: Upper right

Visible anatomical features include parts of the rib cage, liver, stomach, intestines, and pelvis. The diagram is used to help identify organ locations within abdominal quadrants and fill in the table.

Table 2.9.1: Identification of Abdominal Quadrants and Associated Organs

Name the quadrant		Name the organs you will find in this quadrant
A		
B		
C		
D		

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2.10: Activity 9

Mapping the Nine Abdominopelvic Regions: Exploring Abdominal Anatomy

This lab activity is designed to deepen your understanding of the nine regions of the abdominal cavity and the organs located in each. By using models and diagrams, you'll enhance your spatial awareness and anatomical knowledge.

Instructions:

- Utilize the torso model to visualize and comprehend the boundaries of each anatomical region.
- Carefully identify the organs located within each region. Keep in mind that some organs may span multiple regions, so be attentive to their positions.
- Fill in the table.

Table 2.10.1: Abdominopelvic Regions and Their Associated Organs

Abdominopelvic region	Organs in Each Region
Right Hypochondriac	
Epigastric	
Left Hypochondriac	
Right Lumbar	
Umbilical	
Left Lumbar	
Right Iliac (Inguinal)	
Hypogastric	
Left Iliac (Inguinal)	

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2.11: Activity 10

Checkpoint: Applying Anatomical Knowledge to Clinical Scenarios

This lab activity is designed to assess your understanding of anatomical cavities, directional terms, and planes by applying this knowledge to clinical scenarios. You will identify which body cavities need to be accessed for specific surgical procedures and describe anatomical locations using precise terminology. Fill in the table.

Examples - Major cavity: Dorsal or Ventral cavity; Sub-cavity: Thoracic cavity, Cranial cavity; Serous membranes : Pleura

Table 2.11.1: Surgical Scenarios and Associated Anatomical Regions

Scenario	Major Cavity	Sub-Cavity	Serous Membrane
Lung Tumor surgery			
Brain Tumor surgery			
Gastric bypass surgery			
Cardiac surgery			
Removal of Gallbladder			

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Key Term and Definitions

1. **Antecubital** – relating to the region of the arm in front of the elbow
2. **Axial** – situated on or along or in the direction of an axis
3. **Buccal** – relating to or toward the cheek
4. **Calcaneal** – relating to the heel bone or heel
5. **Cranial cavity** – the cavity enclosed by the cranium
6. **Crural** – relating to the leg from the knee to the ankle, also known as shin
7. **Cubital** – relating to the elbow
8. **Dorsum** – the back of the body of a vertebrate or any analogous surface
9. **Gluteal** – relating to or near the gluteus muscles
10. **Hallux** – also known as the big toe or great toe, is the innermost toe on the foot
11. **Mediastinum** – the part of the thoracic cavity between the lungs that contains the heart and aorta and esophagus and trachea and thymus
12. **Orbital cavity** – the bony cavity in the skull containing the eyeball
13. **Otic** – relating to near the ear
14. **Palmar** – relating to the palm of the hand or the sole of the foot
15. **Patellar** – near or relating to the patella or kneecap (anterior)
16. **Pelvic cavity** – the space bounded by the bones of the pelvis and containing the pelvic viscera
17. **Pericardial** – located around the heart or relating to or affecting the pericardium
18. **Pericardial cavity** – the space between the layers of the pericardium that contains fluid that lubricates the membrane surfaces and allows easy heart movement
19. **Perineal** – relating to the perineum (diamond-shaped area between the anus and the vulva or scrotum)
20. **Peroneal** – relating to the fibula or the outer part of the leg below the knee
21. **Pleural cavity** – the cavity in the thorax that contains the lungs and heart
22. **Pollex** – the thick short innermost digit of the upper limb
23. **Sacral** – relating to or near the sacrum
24. **Serosa** – a thin membrane lining the closed cavities of the body
25. **Serous membrane** – a thin membrane lining the closed cavities of the body
26. **Sternal** – relating to or near the sternum
27. **Tarsal** – relating to or near the tarsus of the foot

3: INTRODUCTION TO THE MICROSCOPE

Introduction

In this lab, students will be introduced to the fundamental aspects of microscopy, a crucial tool in the study of human anatomy and physiology. Understanding the parts and working principles of a microscope is essential for observing the intricate details of cells and tissues, which are foundational to grasping more complex biological concepts. This lab will guide students through the identification of microscope components, the principles of their operation, proper care and maintenance, and step-by-step instructions for effective use.

Microscopes allow for the magnification and resolution of structures not visible to the naked eye, playing a vital role in biological sciences. Proper knowledge of microscope use and maintenance ensures accurate observation and extends the lifespan of the equipment. This lab experience will provide students with practical skills in handling and utilizing microscopes, which are indispensable in both educational and professional settings.

Learning Objectives

- Identify Microscope parts such as the eyepiece, objective lenses, stage, focus knobs and others.
- Explain working principles of microscopy, including concepts of magnification, resolution, and illumination and explain the role of each component in the imaging process.
- Demonstrate Proper Microscope Care for cleaning and storing microscopes, ensuring their longevity and optimal performance.
- Analyze and Document Observations (capture clear images) and notes on their observations.

3.1: Background Information

3.2: Lab Procedures - Operating a Microscope

3.3: Activity 1

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3.5: Activity 3

3.6: Activity 4

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3.8: Activity 6

3.9: Glossary

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3.1: Background Information

Overview

The first microscope was developed in 1590 by Dutch lens grinders Hans and Zacharias Jansen. In 1667, Robert Hooke described the microscopic appearance of cork and used the term cell to describe the compartments he observed. Anton van Leeuwenhoek was the first person to observe living cells under the microscope in 1675—he described many types of cells, including bacteria.

Since then more sophisticated and powerful scopes have been developed that allow for higher magnification and clearer images. Microscopy is used by scientists and health care professionals for many purposes, including diagnosis of infectious diseases, identification of microorganisms (microscopic organisms) in environmental samples (including food and water), and determination of the effect of pathogenic (disease-causing) microbes on human cells. This exercise will familiarize you with the microscopes we will be using to look at various types of microorganisms throughout the semester.

Microscopes vary in design and application, each type offering unique advantages suited to specific tasks. Understanding the differences between microscope types, as well as key concepts such as magnification and resolution, provides a solid foundation for their effective use.

Types of Microscopes and Their Applications

Light (Compound) Microscope

It is called a “compound microscope” because the light passes through a series of lenses that refract light and magnify the final virtual image you see when you look through the ocular lenses. The user can control the amount of light passing through the image by adjusting the light intensity knob or by changing the width of the opening of the substage iris diaphragm. The objective lens closest to the specimen magnifies the image first. This image is then further magnified by the eyepiece lens, allowing the observer to see a detailed view of the specimen. The contrast between regions of the specimen comes from the difference between light absorbed by the sample and light passing through it. This type of microscope is essential for examining cells, tissues, and microorganisms, making it a staple in introductory biology and anatomy courses.

- Advantages - Affordable, easy to use, and capable of viewing live specimens.
- Limitations - Limited resolution due to the wavelength of light, generally up to 200 nanometers.

Electron Microscope

Electron microscopes are advanced imaging tools that use a beam of electrons, rather than light, to create detailed images of specimens. They offer much higher resolution and magnification compared to light microscopes, allowing scientists to observe the fine details of cell structures and materials at the nanometer scale. There are two primary types of electron microscopes, Transmission Electron Microscope (TEM) and Scanning Electron Microscope (SEM) each with distinct functionalities and applications. TEMs are used to study the internal structure of cells, organelles (including mitochondria, ribosomes), and macromolecules. They provide detailed images of the cell's ultrastructure, such as mitochondria and ribosomes. SEMs scan a focused beam of electrons across the surface of a specimen. The electrons interact with the surface atoms, producing various signals that are used to construct an image.

- Advantages - High resolution, capable of imaging at the nanometer scale. TEMs allow for the visualization of virus morphology and structure, aiding in the study of virus-host interactions and the development of antiviral drugs.
- Limitations - Expensive, requires non-living specimens due to the vacuum environment.

Fluorescence Microscope

A fluorescence microscope is a specialized type of light microscope. Fluorescence microscopy relies on the principle of fluorescence, where a substance absorbs light at one wavelength and emits light at a different, typically longer, wavelength, allowing researchers to visualize specific components within cells and tissues using fluorescent markers. The microscope

illuminates the specimen with a specific wavelength of light using a light source, often a mercury vapor lamp, xenon lamp, or LED. Specimens are treated with fluorescent dyes or proteins that bind to specific cellular components. Common dyes include fluorescein, rhodamine. Used to label and visualize specific proteins, nucleic acids, and other cellular components, helping to study cellular processes such as division, signaling, and interaction. Medical Diagnostics: Employed in techniques like immunofluorescence to detect pathogens or characterize tissue samples.

- Advantages: Allows for the observation of specific structures within a cell, can be used to track processes in live cells.
- Limitations: Requires appropriate fluorescent markers, may involve complex preparation.

Table 3.1.1: Comparison of Transmission Electron Microscope (TEM) and Scanning Electron Microscope (SEM) - Unveiling the Microscopic World

Feature	TEM	SEM
Resolution	Higher (up to 0.1 nanometers)	Lower (around 1 nanometer)
Image Type	2D internal structure	3D surface morphology
Specimen Preparation	Thin sections, complex preparation	Minimal, often requires coating
Applications	Internal cell structure, molecules	Surface structure, forensic analysis
Specimen Environment	Ultra-thin, non-living	Surface only, non-living

Bright Field Light Microscope

We will use bright field light microscopes, a type of compound microscope because the light passes through a series of lenses that refract light and magnify the final virtual image you see when you look through the ocular lenses.. Specifically, it is the most common type of compound light microscope used in various biology classrooms, medical labs, and other settings to observe a variety of samples, including cells, tissues, and microorganisms, often after staining to enhance contrast. This is a specific type of light microscopy where the specimen is illuminated from below, typically a halogen lamp or a light-emitting diode (LED) light and the light transmitted through the sample creates a dark image on a bright background, hence the name “bright field.”. The user can control the amount of light passing through the image by adjusting the light intensity knob or by changing the width of the opening of the substage iris diaphragm.

Exploring Parts of the Microscope

The simplest optical microscope is the magnifying glass, which is good to about ten times (10 times) magnification. The compound microscope has two systems of lenses for greater magnification: the ocular, or eyepiece lens, that one looks into, and the objective lens, or the lens closest to the object.

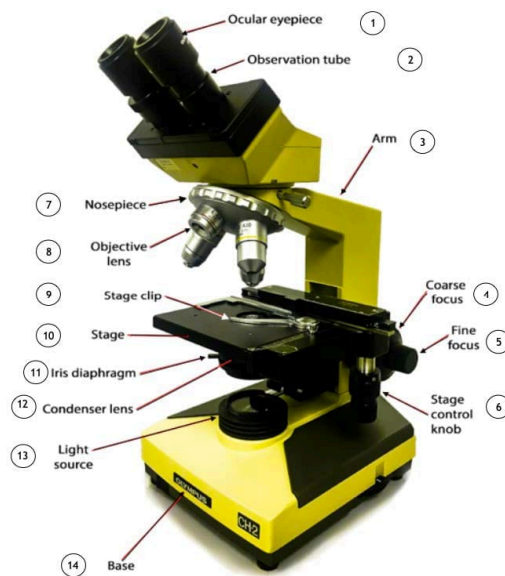


Figure 3.1.1: Components of a typical bright field light microscope. (CC BY 4.0; via LibreTexts).

In Figure 3.1.1, the bright field light microscope is displayed and the list below captures a detailed description of all the labeled parts:

1. **Ocular Eyepieces:** The lenses of the eye pieces (oculars) on your microscope magnify ten times. One of your oculars may have a pointer that can be moved by rotating the eye piece. The eyepiece of most binocular microscopes can be adjusted to match the distance between the eyes of different observers (inter-pupillary adjustment).
 - **Diopter Adjustment:** Useful as a means to change focus on one eyepiece so as to correct for any difference in vision between your two eyes.
2. **Observation Tube:** The assembly on a microscope that houses the eyepieces and directs the light path from the objective lenses to the observer's eyes or a camera.
3. **Arm:** In microscopy, the "arm" typically refers to the structural backbone of a standard microscope.
4. **Coarse Focus:** Serves the essential function of rapidly adjusting the focus of the microscope's objective lens in larger increments, to bring the specimen into a rough focus range. It helps researchers and students locate the specimen on the slide and get it roughly in focus before fine-tuning the focus using the fine adjustment knob.
5. **Fine Focus:** While the coarse adjustment knob facilitates initial focusing by rapidly moving the objective lens closer to or farther away from the specimen, the fine adjustment knob serves a more refined purpose. Its primary function is to fine-tune the focus of the microscope to achieve optimal clarity and detail. The fine objective knob may be used with all objective lenses.
6. **Stage Control Knob:** Allows precise X-Y positioning of a slide, enabling users to scan specimens horizontally and vertically. Typically located below the stage on the side, one knob manages front-to-back movement while the other manages side-to-side, centering the specimen for optimal viewing.
7. **Nosepiece:** This is the disc-like part that holds two or more objective lenses and can be rotated to easily change power.
8. **Objective Lenses:** The critical optical component closest to the specimen, responsible for primary magnification and image resolution. It gathers light from the specimen to create a magnified real image, typically ranging from 4 times to 100 times magnification, including specialized oil-immersion lens for high resolution imaging. The microscopes are parfocal, meaning that after you adjust the focus or change the objective, the image will remain in view.
 - **Scanning objective:** This lens magnifies four times ; it's used to center the object in the field of view. You will not be drawing at this lowest power, but it serves to orient your slide initially. This is the only objective with which you should use the coarse focus knob.
 - **Low power objective:** This lens magnifies ten times (total magnification = ocular X objective = $10 \times 10 = 100$ times total magnification). Focus with the coarse adjustment knob on scanning power first, then move the nosepiece so that the low power objective is in place.
 - **High power objective:** This lens magnifies 40 times (total magnification is 400 times). Use this objective only after centering an object with the low power objective. You should only use the fine focus knob when this objective is in place.
9. **Stage Clip:** Small metallic clip used to secure specimens to a microscope stage.
10. **Stage:** The surface or platform on which you place the microscope slide is the stage. Note the opening (stage aperture) in the center of the stage. A mechanical stage allows you to move the slide horizontally and vertically.

11. Iris Diaphragm: regulates the amount of light passing from the light source through the specimen and through the lens system of the microscope. The lever that projects from the side of the diaphragm opens and closes these plates, thereby regulating the amount of light.
12. Condenser Lens: The condenser consists of a series of lenses that focus light onto the specimen. It is moved up and down by a knob at its side or by a lever projecting from the condenser housing. By properly adjusting the condenser, you can greatly improve the clarity of the specimen. A filter holder may be attached to the bottom of the condenser. It usually contains a blue filter.
13. Light Source (Illuminator): An illuminator, is the light source built into the base of the microscope and controlled by an on/off switch. You can control the amount of light entering the specimen by adjusting the diaphragm.
14. Base: The bottom portion of the microscope and the only part that touches the tabletop. When carrying the microscope, the upper part of the stand (the arm) is held by one hand and the other hand should be placed under the base to support the microscope's weight.

Resolution vs. Magnification

Two parameters are especially important in microscopy: magnification and resolution.

- Magnification measures how much larger a microscope (or set of lenses within a microscope) causes an object to appear. For instance, the light microscopes typically used in high schools and colleges magnify up to about 400 times actual size. So, something that was 1 mm wide in real life would be 400 mm wide in the microscope image.
- The resolution of a microscope or lens is the smallest distance by which two points can be separated and still be distinguished as separate objects. The smaller this value, the higher the resolving power of the microscope and the better the clarity and detail of the image. If two bacterial cells were very close together on a slide, they might look like a single, blurry dot on a microscope with low resolving power, but could be told apart as separate on a microscope with high resolving power. The smaller the wavelength of light, the better the resolving power. Resolving power is also impacted by the numerical aperture of the objective lens that is being used to magnify the specimen.

Parfocal Lenses

Our microscopes are parfocal. What does this mean? Once you have focused on any of the objectives (we always start with 4 times), the other objectives will also be (mostly) in focus. You do not need to make major focus adjustments after changing objectives - usually the fine focus knob can be used to make small adjustments and obtain a crisp, clear image. In fact, you should never use the coarse focus once you've obtained an in-focus image using the 4 times objective.

Microscope Care

1. Always carry the microscope upright and use two hands. Place one hand on the arm of the scope and support the base with the other. Our individual and joint responsibility is to ensure that the microscopes remain in good working condition.
2. Be gentle. Sliding the microscope on the table could jar lenses and other parts loose. The microscope seems like a simple instrument, but each lens (eyepiece and objective) is actually made up of several other lenses; jerky movements may misalign lenses.
3. Always use clean hands when handling your microscope. Do not touch the lenses with your fingers, and do not remove any of them.
4. Use only lens paper and lens cleaner to clean all of the lenses (not Kleenex, Kimwipes, or cloth). Clean lenses regularly and oculars when they are dirty.
5. Never let an objective lens touch the glass slide. If you lose the image, go back to the scanning lens (4 times) or 10 times objective and refocus.

On completion of the laboratory exercise, return the microscope to its cabinet in its original condition. The following steps are recommended:

1. Clean all lenses with dry, clean lens paper. If necessary, use a drop of lens cleaning fluid.
2. Place the low-power objective in position and close the stage and objectives together.
3. Center the mechanical stage.
4. Coil the electric wire around the body tube and the stage.
5. Carry the microscope to its position in its cabinet as described above.

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3.2: Lab Procedures - Operating a Microscope

General Operating Procedure Guidelines

The following step-by-step operating procedure should be carefully observed:

1. Plug in and turn on the in-base illuminator.
2. Raise the nosepiece using the coarse adjustment knob. This provides greater access to the stage when the slide is in position.
3. Rotate the nosepiece so that the 10 times objective is in operating position. You should feel a definite position stop for the objective. Turn the nosepiece clockwise and counter-clockwise until you are familiar with this position stop.
4. Open the iris diaphragm approximately half way.
5. Place the slide in the stage slide holder securely. Be sure the slide has the specimen side up. Roughly center the specimen over the light coming from the condenser.
6. Move the microscope condenser by means of the condenser rack and pinion knob until the top of the condenser is approximately the thickness of a piece of paper beneath the slide.
7. Lower the objective using the coarse control knob until it reaches a stop. Do not force the knob. The stop should be obvious if you are moving the controls gently. Again, become familiar with the feel of the position stop.
8. View through the eyepieces and without disturbing the coarse adjustment setting, slowly rotate the fine adjustment knob in the appropriate direction until the specimen detail is in sharpest possible focus.
9. Adjust the interpupillary distance between the two eyepieces by sliding the eyepiece plates in or out.
10. Once the specimen detail is in sharp focus using the 4 times (scanning) objective, it is then possible to rotate the nosepiece to other objectives without changing the position of the coarse adjustment knob. Very little refocusing with the fine adjustment is required, it will be in focus with all of the lenses (parfocal).
11. Make certain that the portion of the specimen you wish to view is exactly centered in the field of the low-power objective. This is necessary because the microscopic field of view is smaller under high magnification than under low magnification.
12. Remember that the iris diaphragm setting must be changed whenever a different objective is used. As magnification increases the condenser iris diaphragm is opened as required. With these microscopes you are effectively increasing the light reaching the higher power objective. Adjustment of the condenser iris diaphragm results in proper contrast for viewing specimens under varying magnifications.
13. Try the highest magnification, the 100 times - oil immersion objective. To focus with the oil immersion lens, proceed in the following manner:
 - Revolve the nosepiece so that there is no objective directly over the specimen. This allows enough space so that a drop of immersion oil may be placed on the specimen.
 - Place one drop of immersion oil in the center of the circle of light formed on the specimen slide.
 - Turn the nosepiece until the 100 times objective snaps into place. The objective should be in the oil but must not touch the slide.
 - Rotate the fine adjustment knob to obtain a sharp focus of the specimen.
14. **Note:** Make sure the immersion oil has been cleaned from the lens with lens cleaner fluid before returning the microscope to the storage space.

Context: Created by Technology Innovations for Learning & Teaching and the Department of Biology at Fresno State, this informative video consists of four segments designed as a basic tutorial for students enrolled in Biology courses. It guides viewers on how to set up and use lab microscopes in a step-by-step manner, ensuring they gain a solid understanding of this essential laboratory tool.

Video Length: 4 minutes and 23 seconds.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

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3.3: Activity 1

Calculating Total Magnification

Microscopes are essential tools in biology and other sciences, allowing us to explore the minutest details of specimens. Total magnification helps us understand how much larger the microscope makes an object appear compared to its actual size. Remember with a compound light microscope you are magnifying with two lenses, so to calculate the total magnification you multiply the ocular lens magnification by the objective lens magnification. The magnification of objective lenses typically ranges from 4 times to 100 times, with each lens's magnification clearly labeled on its metal casing. The ocular and objective lenses work in tandem to produce a magnified image, allowing for detailed observation of specimens.

The total magnification is the product of the ocular magnification times the objective magnification: Look at the side of the objective lens currently in use to find its magnification. The ocular lens magnification is typically 10 times, however, can vary to 15 times or 20 times.

Formula

Total Magnification = Objective Lens Magnification × Eyepiece Lens Magnification

Table 3.3.1: Calculating Total Magnification

Objective Lens	Objective Lens Magnification	Ocular Lens Magnification	Total Magnification
Scanning lens (red band)			
Low-power lens (yellow band)			
High-power lens (blue band)			
Oil-immersion lens (white band)			

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3.4: Activity 2

Measuring and Calculating Field of View (FOV)

The field of view (FOV) or field diameter is the observable area visible through an optical instrument. It is the distance across the image as seen through the microscope. It is typically measured as the diameter of the viewed area in millimeters for microscopes. The field of view is greater at lower magnifications. For example, at 10 times magnification 20mm might fill your field of view, whereas at 40 times magnification you might only see 5mm. It is always important to center the part of the specimen you are focusing on before moving up in magnification, otherwise it might not be in your new field of view.

For scanning and low power lenses, you can often directly measure the field of view by placing a thin, transparent ruler with millimeter (mm) markings on the stage and counting the millimeters across.

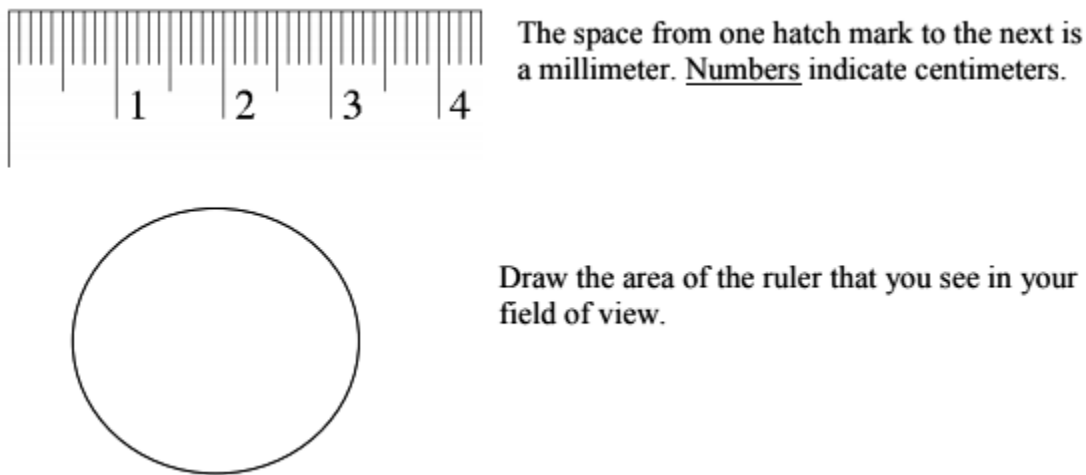


Figure 3.4.1: Metric ruler. The space from one hatch mark to the next is a millimeter (mm). The numbers indicate centimeters. (CC BY 4.0; Genovesi, Blinderman, and Natale via LibreTexts)

Figure 3.4.1 contains a ruler and a circle with instructional text. The ruler is marked from 0 to 4 centimeters, with each centimeter divided into 10 millimeter hatch marks. The text above the ruler states: "The space from one hatch mark to the next is a millimeter. Numbers indicate centimeters." Below the ruler, there is a circle and additional instructional text: "Draw the area of the ruler that you see in your field of view." For higher magnification lenses (where the field of view is smaller than 1mm), you'll need to calculate it. One common method uses the following formula:

Formula

$$HighPowerFOV = (LowPowerMagnification \cdot LowPowerFOV) \div HighPowerMagnification \quad (3.4.1)$$

For example, using the formula 3.4.1, if your low power FOV is 2mm with 40 times the magnification, and you switch to 400 times the magnification, the new FOV would be $(40 \cdot 2) \div 400 = 0.2mm$.

Procedure

1. Place a thin, transparent ruler with millimeter (mm) markings on the stage ensuring the metric side is facing up and the ruler is positioned directly under the scanning objective lens (4 times). Hold it in place with the stage clip.
2. Focus on the ruler using the coarse and fine focus knobs. Adjust the light source and diaphragm for optimal visibility.
3. Count the number of millimeter lines visible within the field of view. You may need to estimate fractions of a millimeter if the line doesn't perfectly align with the edge of the field.
4. Repeat this with 10 times the objective lens.

5. Record field size measurements in millimeter (mm) for 4 times and 10 times objective lenses. Compute the field size in micrometers (μm). conversion factor: $1mm = 1000\mu m$.
 - Scanning lens (4 times) = (mm), = (μm).
 - Low power lens (10 times) = (mm), = (μm).
6. The formula 3.4.2 is used to solve for the unknown high power FOV by substituting known values. For example, if your low power FOV at 10 times is $4mm$ and you want to find the FOV at 40 times, then calculation would be: $(10times \div 40times) = (HighPowerFOV \div 4mm)$. Solving for High Power FOV, you get $1mm$.
7. Calculate the field size values of your microscope for 40 times and 100 times objective lenses.
 - High power lens (40 times) = (mm), = (μm).
 - Oil immersion lens (100 times) = (mm), = (μm).

Formula

$$(\text{Low Power Magnification} \div \text{High Power Magnification}) = (\text{High Power FOV} \div \text{Low Power FOV})$$

The diameter of a microscope's field of view (FOV) is calculated by dividing the field number (FN) by the objective lens magnification. The field number is usually printed on the eyepiece and represents the diameter of the field of view in millimeters when using the eyepiece alone.

Formula

$$\text{Field Of View} = (\text{Field Number}) \div (\text{Objective lens magnification you are using})$$

If the eyepiece has a field number of 22 and the objective lens is 40 times, FOV can be calculated using the formula 3.4.3 as $FOV = 22 \div 40 = 0.55mm$.

3.5: Activity 3

Estimating the Size of a Specimen

The size of a specimen can be estimated if you know how many specimens (such as bacteria or cheek cells) appear to fit across the field of view and the measurement of the field of view. Cell morphology (size and shape) can be used in the clinical setting to determine if abnormalities are present and to discern different types of cells from each other. Enlarged cells can indicate conditions like cancer where cells rapidly proliferate and become larger than normal. Shrunken cells may be seen in conditions like cellular atrophy where cells deteriorate and shrink in size.

Procedure

1. Use your field of view (FOV) from Activity 2 to fill in the field diameters for the views shown below. Remember that total magnification = (ocular lens magnification) x (objective lens magnification).
2. Look below at Cell A and estimate how many cells will fit across the entire field. Make note of this number under the black circle. Repeat this step for Cell B and Cell C.
3. Use the formula to estimate the size of Cell A, Cell B, and Cell C. Write your answers in the spaces provided.
4. To estimate the size of a cell, you can use the formula:
Estimated Cell Size = (Field Diameter) ÷ (Number of Cells that Fit Across the Entire Field). This simple calculation allows you to get a rough measurement of cell size based on how many cells can be viewed within the microscope's field of view.
5. Do all estimates match exactly? If not, explain why not.

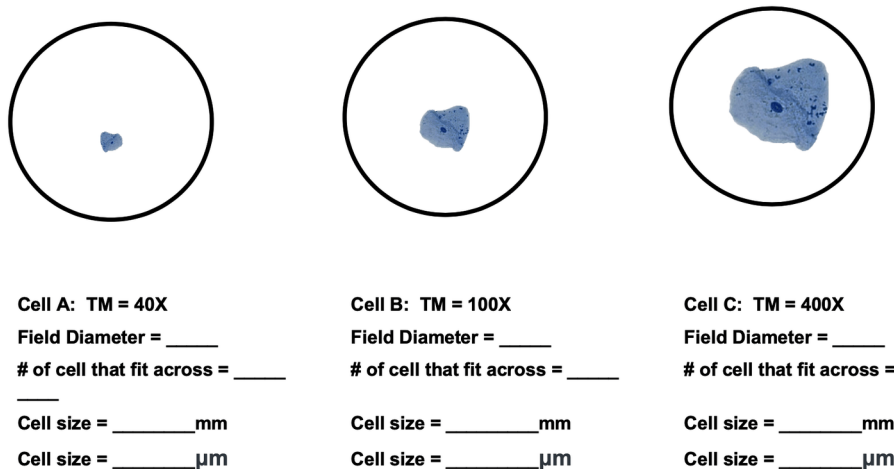


Figure 3.5.1: Estimated Cell Size. (CC BY Robinson via LibreTexts).

Figure 3.5.1 displays three circular microscope fields of view, each containing a single blue cell. The fields are labeled:

- Cell A: Total Magnification (TM) = 40 times
- Cell B: TM = 100 times
- Cell C: TM = 400 times

Below each field are blank spaces for students to fill in:

- Field Diameter
- Number of cells that fit across the field
- Cell size in millimeters (*mm*)
- Cell size in micrometers (*μm*)

Table 3.5.1: Comparison of cell observations at 40 times, 100 times, and 400 times magnification

Cell A, Total magnification = 40 times	Cell B Total magnification = 100 times	Cell C, Total magnification = 400 times
Field of view Scanning (activity 2) =	Field of view Low power (activity 2) =	Field of view High power (activity 2) =
FOV =	FOV =	FOV =
Number of cells that fit across =	Number of cells that fit across =	Number of cells that fit across =
Estimated Cell size (mm) =	Estimated Cell size (mm) =	Estimated Cell size (mm) =
Estimated Cell size (μm) =	Estimated Cell size (μm) =	Estimated Cell size (μm) =

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3.6: Activity 4

Comparing Real Image with Magnified Virtual Image - Inversion Phenomenon

The 'Letter e' microscope lab activity is designed with specific learning objectives to introduce students to the basic functions and handling of a compound microscope. Students will understand how optical systems affect image orientation and size, specifically how images are inverted and reversed focusing on the letter 'e.'

Materials needed are compound microscope, prepared slide with the letter 'e' and lens paper.

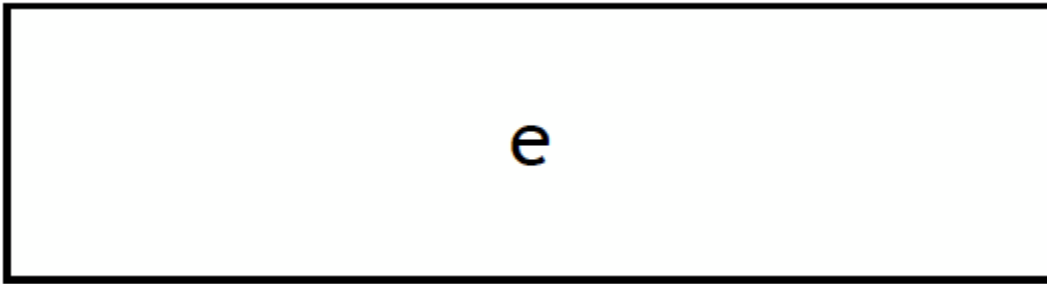


Figure 3.6.1: Microscope view of the letter 'e' used to demonstrate image inversion and orientation in optical systems.

Procedure

1. Look at the unmagnified "e" on the slide by eye. Rotate the slide around in your hand so that the "e" is right side up. Now clip the slide onto the microscope stage with the stage clips so that the "e" is facing you right side up when you look at it with your unaided eye.
2. Ensure the letter is centered over the opening on the stage as in the figure below.
3. Rotate the nosepiece to position the scanning objective lens (typically 4 times) over the slide.
4. Using the coarse focus knob, slowly raise the stage until the letter 'e' comes into view.
5. Once the letter is visible, use the fine focus knob to sharpen the image for better clarity.
6. Look through the eyepiece and observe how the letter 'e' appears. Note that the image may be inverted and reversed due to the optics of the microscope.
7. Record observation in the circle (assuming it represents the microscopic field of view) below.

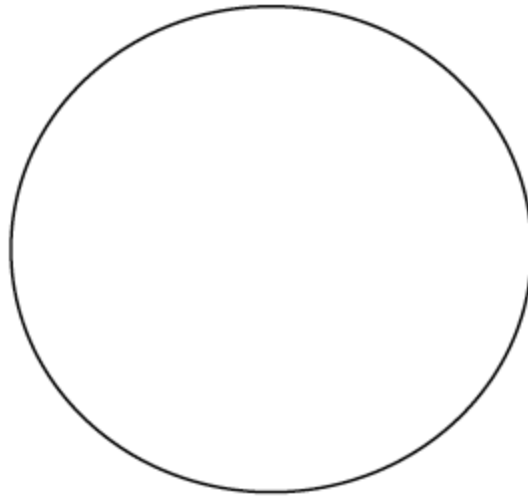


Figure 3.6.2: Diagram used for students to record how the letter 'e' appears under 40 times magnification in a microscope lab activity.

1. How does the letter "e" appear to move in the microscope when you:
 - Move the letter "e" to the right.
 - Move the letter "e" to the left.
 - Move the letter "e" towards you.
 - Move the letter "e" away from you.
2. Rotate the nosepiece to switch to a low power objective lens (10 times). Be sure to refocus using the fine focus knob as higher magnifications require more precise adjustments.
3. Record observation in the circle below.

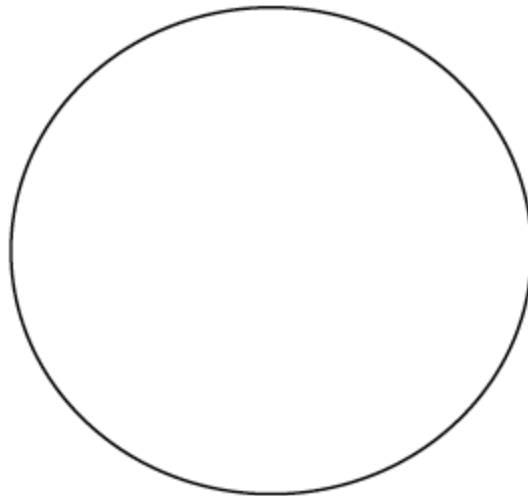


Figure 3.6.3: Diagram used for students to record how the letter 'e' appears under 100 times magnification in a microscope lab activity.

1. Rotate the nosepiece to switch to high power objective lens (e.g., 40 times). Be sure to refocus using the fine focus knob as higher magnifications require more precise adjustments.
2. Record observation in the circle below.

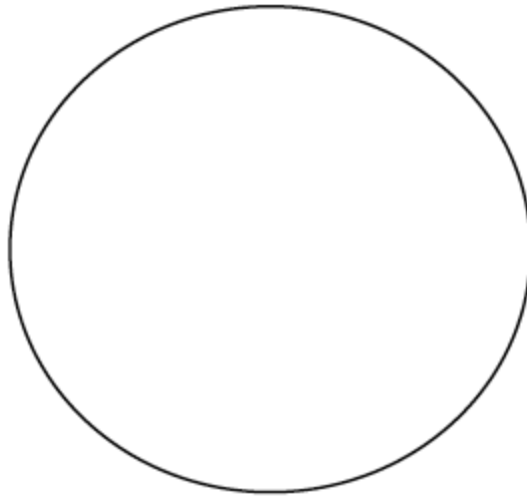


Figure 3.6.4: Diagram used for students to record how the letter 'e' appears under 400 times magnification in a microscope lab activity.

Reflect on Observations in this Activity by Answering the Question Prompts

Share your reflections with classmates to gain different perspectives and insights.

1. How did the inversion of the letter 'e' affect your initial perception of the image? Did it surprise you?
2. Why do you think the image appears inverted when viewed through a microscope? Write a brief explanation of the inversion phenomenon based on your observations.
3. What was the most challenging part of understanding image inversion, and how did you overcome it?

3.7: Activity 5

Exploring Depth: Unraveling Layers with Three Colored Threads Under the Microscope

The colored threads activity under a microscope demonstrates depth perception and depth of field. By observing how different colored threads, stacked on top of each other, come into and out of focus at varying magnifications, one can understand how the microscope's lenses allow us to perceive depth. At low magnification, all threads may appear relatively sharp, but as magnification increases, only one thread will be in focus at a time, requiring adjustments to the fine focus knob to view different layers.

Obtain a prepared slide with three different colored threads. View the slide under scanning (4 times) and then low power (10 times) objective lens. You should note that you could only focus on one colored thread at one time. Determine which thread is on top by lowering your stage all the way, then slowly raising it until the thread comes into focus. The first thread to come into focus is the one on top.

- Which color thread is on top?
- Which color thread is in the middle?
- Which color thread is on the bottom?

3.8: Activity 6

Discussion Questions About Microscope Lab

Discussions allow students to articulate their observations, interpret their findings, and compare them to expected outcomes or class averages. This process helps them solidify their comprehension and identify areas requiring further clarification or investigation.

1. What was the most surprising thing you learned about how a microscope works?
2. How do you think the skills learned in using a microscope might apply to real-world situations or careers?
3. What challenges did you encounter while using the microscope, and how did you overcome them?
4. What strategies can you develop to improve your efficiency and accuracy in using a microscope?

Key Terms and Definitions

- **Aperture:** The opening in the condenser that regulates the amount of light passing through the specimen. A larger aperture allows more light, potentially improving brightness but potentially reducing contrast.
- **Arm:** The structural part of the microscope that connects the base to the body tube. Used for carrying the microscope.
- **Base:** The bottom part of the microscope providing stability and support.
- **Body Tube (Head):** The cylindrical structure connecting the eyepiece to the objective lenses.
- **Bright field Microscopy:** The most common type of microscopy, where light passes directly through the specimen.
- **Condenser:** A lens system located beneath the stage that focuses light onto the specimen. Adjusting the condenser affects brightness and contrast.
- **Coarse Adjustment Knob:** A large knob used for making large adjustments to the focus, typically used with lower magnification objectives.
- **Darkfield Microscopy:** A technique where only scattered light from the specimen reaches the objective, resulting in a bright specimen against a dark background. Useful for observing unstained specimens.
- **Diaphragm (Iris Diaphragm):** An adjustable opening within the condenser that controls the amount of light reaching the specimen. Similar to the aperture, but directly within the condenser.
- **Eyepiece (Ocular Lens):** The lens at the top of the microscope through which the user views the specimen. Typically 10x magnification.
- **Field of View (FOV):** The circular area visible through the microscope eyepiece. FOV decreases as magnification increases.
- **Fine Adjustment Knob:** A smaller knob used for making precise adjustments to focus, especially at higher magnifications.
- **Fluorescence Microscopy:** A technique that uses fluorescent dyes or proteins to label specific structures within a specimen. The specimen is illuminated with specific wavelengths of light, causing the labeled structures to emit light at longer wavelengths.
- **Focusing:** the process of moving the lens configuration (eyepiece and objective or digital sensor and objective) in relation to the specimen to achieve a sharp image.
- **Illuminator:** The light source of the microscope. Can be a built-in lamp or external light source.
- **Interpupillary distance (IPD)** – in binocular microscopes and stereoscopes, the measurement, or the potential range of adjustment, available between the exit pupils, as measured in millimeters.
- **Magnification:** The process of enlarging the image of an object. Total magnification is the product of the eyepiece and objective lens magnifications (e.g., 10x eyepiece and 40x objective = 400x total magnification).
- **Mount:** The preparation of a specimen for microscopic examination, including mounting the specimen on a slide and adding a coverslip if necessary.
- **Nosepiece (Revolving Turret):** The rotating part that holds the objective lenses.
- **Numerical Aperture (NA):** A measure of a lens's ability to gather light and resolve fine detail. Higher NA values indicate better resolution.
- **Objective Lenses:** Lenses with different magnifications (e.g., 4x, 10x, 40x, 100x) located on the nosepiece.
- **Parfocal:** a microscope that, once focused with one objective, remains in focus when the objective is rotated.
- **Phase-Contrast Microscopy:** A technique that enhances contrast in transparent specimens by manipulating the phase of light waves passing through the specimen. Useful for observing living cells.
- **Resolution:** The ability to distinguish two closely spaced objects as separate entities (the level of clarity/detail present in an image). Limited by the wavelength of light used. In digital microscopy, the resolution refers to the amount of pixels on the sensor, and is expressed in MP (megapixels).
- **Stage:** The platform where the microscope slide is placed.
- **Stage Clips:** Metal clips on the stage that hold the slide in place.
- **Staining:** The application of dyes to enhance contrast and visualize specific structures within a specimen.
- **Working Distance:** The distance between the objective lens and the specimen when the specimen is in sharp focus. Decreases as magnification increases.

4: CELLULAR ODYSSEY- UNRAVELING EUKARYOTIC STRUCTURE AND FUNCTION

Introduction

In this lab, students will explore and discover the fundamental structures and functions of eukaryotic cells, focusing on the relationship between a cell's components and its overall activities. They will also examine cell division (mitosis) and the cell cycle, learning how these processes are regulated and how disruptions can lead to disease.

Learning Objectives

- Identify and describe the major components of eukaryotic cells (plasma membrane, cytoplasm, nucleus, and organelles) using microscopy and diagrams.
- Analyze the structure-function relationships of key cellular organelles (e.g., mitochondria, endoplasmic reticulum, Golgi apparatus, ribosomes, lysosomes) and evaluate their roles in cellular processes.
- Describe and interpret the structure and function of the cell membrane, including its role in transport and communication.
- Summarize the phases of the cell cycle (G1, S, G2, M) and assess their significance in regulating cell division.
- Identify the stages of mitosis (prophase, metaphase, anaphase, telophase) and cytokinesis, identifying key events in each phase using microscopy and diagrams.
- Explain the role of checkpoints in regulating the cell cycle and preventing errors in DNA replication and chromosome segregation.
- Describe the consequences of cell cycle dysregulation and its link to cancer development.
- Calculate the mitotic index and explain its significance in assessing the growth rate of cell populations and detecting cancerous tissues.

4.1: Background Information

4.2: Activity 1

4.3: Activity 2

4.4: Activity 3

4.5: Activity 4

4.6: Activity 5

4.7: Glossary

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4.1: Background Information

Overview: Cell Theory

All living organisms are composed of cells. This is one of the tenets of the Cell Theory, a basic theory of biology, which states that, all life is composed of cells. Cells are the fundamental units which possess all the characteristics of living things, and new cells can only come into existence by the division of previously existing cells. The expanded version of the cell theory can also include:

- Cells carry genetic material passed to daughter cells during cellular division
- All cells are essentially the same in chemical composition
- Energy flow (metabolism and biochemistry) occurs within cells

The human body, a marvel of biological engineering, is an assortment of $3.7 \pm 0.8 \times 10^{13}$ cells, each a self-contained unit performing specialized functions. Understanding cell anatomy and physiology is fundamental to comprehending the overall function of tissues, organs, and organ systems. This laboratory module will explore the intricate structures and processes within human cells, emphasizing the critical link between a cell's structure and its specific role in maintaining homeostasis. We will examine key organelles such as mitochondria, responsible for energy production (ATP synthesis); the endoplasmic reticulum, crucial for protein and lipid synthesis; and the Golgi apparatus, essential for protein modification and transport. The nucleus, housing the genetic blueprint (DNA), dictates cellular activities and directs protein synthesis. Disruptions in cellular structure or function can lead to a wide range of pathological conditions, underscoring the importance of understanding normal cellular processes.

A cell's size and shape are closely related to its function. For example, red blood cells need to be small so they can fit through capillaries, while neurons need to be long so they can transmit signals. Through an understanding of how cells function, we can discover how human ailments, such as cancer and AIDS, can be possibly treated. The following is an overview of cell size in human body:

- Sperm cells: These are the smallest human cells, measuring approximately 2.3 to 3.5 micrometers μm
- Red blood cells: These cells have a diameter about 7.5 to 8.7 micrometers μm and are 1.7 to 2.2 μm thick. Their small size and biconcave shape help them squeeze through narrow capillaries.
- Skin cells: Typically skin cells range from 25 to 40 square micrometers (μm^2) in area.
- White blood cells: These cells are approximately 30 micrometers μm in diameter and play a key roles in the immune system.
- Neurons: Neurons can reach lengths of up to 1 meter, making them the largest human cells by length. Their elongated shape is crucial for transmission signals throughout the body.
- Egg cells: Also known as oocytes, these are the largest spherical cells in the human body, with a volume of roughly 4 million cubic micrometers (μm^3).

Human cells have many parts, including membranes, fluids, and structures, that work together to perform specific functions required for homeostasis.

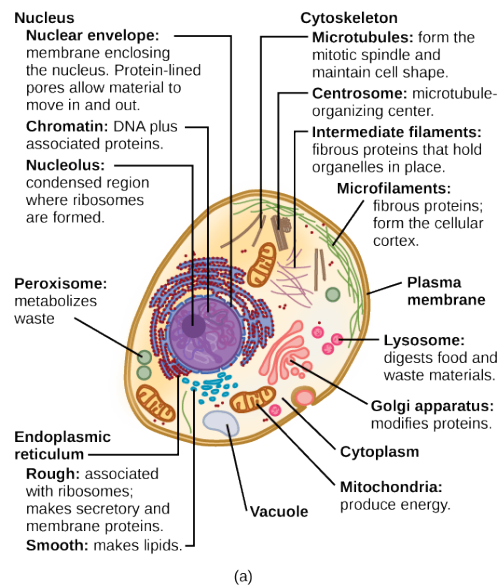


Figure 4.1.1: Structure of Cell: The cell is the basic unit of life, and the cell study led to the cell theory's development. (CC BY; Charles Molnar and Jane Gair via [Concepts of Biology - 1st Canadian Edition](#)).

Figure 4.1.1 is a labeled diagram of an animal cell, showing its internal structures and organelles. The following components are identified:

Nucleus Center of the Cell:

- Nuclear envelope - membrane enclosing the nucleus. Protein-lined pores allow material to move in and out: The control center of the cell containing genetic material.
- Chromatin - DNA plus associated proteins: DNA material within the nucleus.
- Nucleolus - condensed region where ribosomes: Produces ribosomes.
- Peroxisome - metabolizes waste: breaks down fatty acids and detoxifies harmful substances.
- Endoplasmic reticulum
 - Smooth Endoplasmic Reticulum - associated with ribosomes; makes secretory and membrane proteins: Involved in lipid synthesis and detoxification.
 - Rough Endoplasmic Reticulum - makes lipids: studded with ribosomes and involved in protein synthesis.
- Vacuole: Stores nutrients and waste products.

Cytoskeleton and Cell Structure:

- Mitochondria - produce energy: Organelles that produce energy for the cell.
- Cytoplasm: The fluid that fills the cell and surrounds the organelles.
- Golgi Apparatus - modifies proteins: Modify, sort, and package proteins and lipids for delivery.
- Lysosome - digests food and waste materials: Contains enzymes that break down waste materials.
- Plasma Membrane: The outer boundary of the cell that controls what enters and exits.
- Microfilament - fibrous proteins; form the cellular cortex: Fibrous proteins that help form the cellular cortex and support the cell surface.
- Intermediate Filament - fibrous proteins that hold organelles in place: Parts of the cytoskeleton that help maintain cell shape and support movement.
- Centrosome - microtubule-organizing center: An area involved in organizing microtubules and cell division.
- Microtubule - form the mitotic spindle and maintain cell shape.

While Figure 4.1.1 is not indicative of any one human cell, it is a typical example of an animal cell containing the primary organelles and internal structures. In the illustration, the plasma membrane is labeled as a border, in the cytoplasm; mitochondria, microtubule, centrosome, microfilament, microtubule, lysosome, smooth endoplasmic reticulum (has no ribosome attachment to their membrane), secretory vesicle, peroxisome, vacuole, cytoplasm, Golgi vesicle, Golgi apparatus, rough endoplasmic reticulum (ribosomes attached on their membrane), cytoplasmic ribosomes, which freely floats within the cytosol, intermediate filaments, and nucleus are drawn and labeled. Within the nucleus, chromatin and nucleolus are also drawn and labeled.

Exploring Cell Membrane Structure

Modern descriptions of the cell are intimately related to the notion of cell membranes. The cell membrane is not only the boundary of the unit of life, it is also a specific compartment that harbors many essential cell functions including communication with the environment, transport of molecules and certain metabolic functions. Nowadays, the consensual model to depict the membrane structure and functions is called the “fluid mosaic model”.

Explore and use the information and pictures below to learn about the components of the cell membrane and their functions. You should review the molecular structure and functions of each part of the cell membrane. Why does a cell membrane need to be composed, primarily, of lipids? What would happen if cell membranes were made of water-soluble compounds?

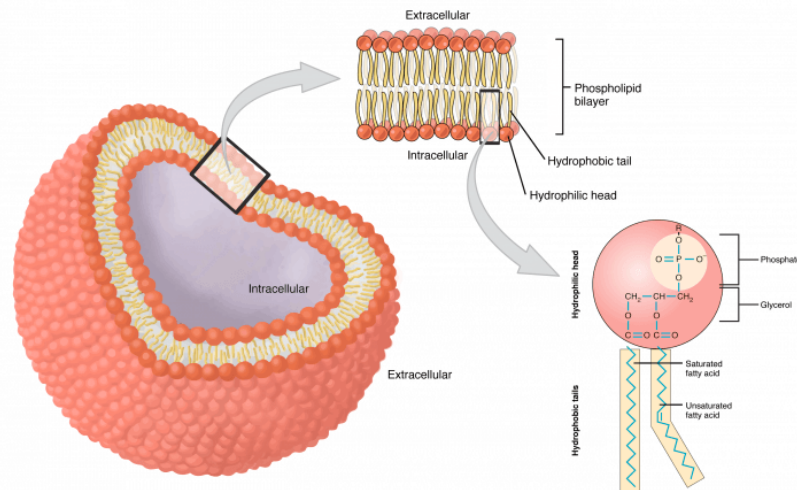


Figure 4.1.2: Phospholipid Structure and Bilayer: A phospholipid molecule consists of a polar phosphate “head,” which is hydrophilic and a non-polar lipid “tail,” which is hydrophobic. Unsaturated fatty acids result in kinks in the hydrophobic tails. The phospholipid bilayer consists of two adjacent sheets of phospholipids, arranged tail to tail. The hydrophobic tails associate with one another, forming the interior of the membrane. The polar heads contact the fluid inside and outside of the cell. (CC BY-SA 4.0; Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, and OpenStax via [Anatomy & Physiology](#)).

Figure 4.1.2 a detailed diagram of a phospholipid bilayer, which forms the basic structure of cell membranes. It includes three levels of detail:

1. Overall Bilayer Structure:
 - The bilayer separates the extracellular (outside the cell) and intracellular (inside the cell) environments.
 - It consists of two layers of phospholipids arranged with their hydrophilic heads facing outward and hydrophobic tails facing inward.
2. Zoomed-In Section:
 - Shows how individual phospholipids are arranged in the bilayer.
 - The hydrophilic heads (water-attracting) face the watery environments inside and outside the cell.
 - The hydrophobic tails (water-repelling) face each other in the center of the bilayer.
3. Individual Phospholipid Molecule:
 - Labeled components include:
 - Phosphate group (hydrophilic head)
 - Glycerol backbone
 - Saturated fatty acid tail (straight)
 - Unsaturated fatty acid tail (kinked)

Water is an important vehicle helps move a diverse array of molecules throughout the body. In the human body, water is distributed into two compartments: inside cells, called Intra Cellular Fluid (ICF), and outside cells, called Extra Cellular Fluid (ECF). Extracellular fluid includes both the fluid component of the blood, known as plasma, and the Interstitial Fluid (IF) that surrounds all cells not in the blood. The human cell membrane is a dynamic, selectively permeable barrier composed of a phospholipid

bilayer studded with a variety of proteins. The hydrophobic lipid tails of one layer face the hydrophobic lipid tails of the other layer, meeting at the interface of the two layers. The hydrophilic phospholipid heads face outward, one layer exposed to the interior of the cell and one layer exposed to the exterior these border the intracellular and extracellular fluid, respectively.

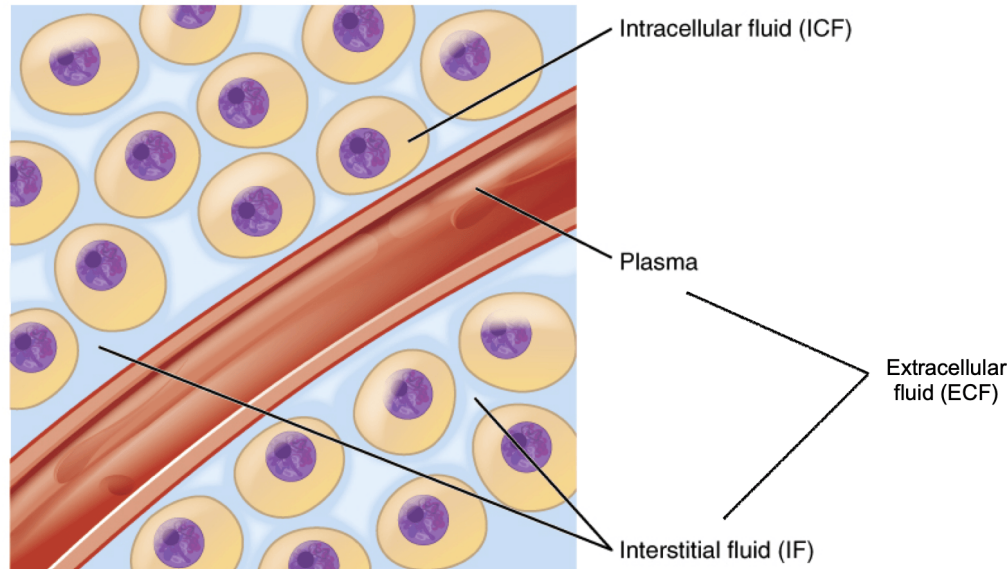


Figure 4.1.3: Fluid compartments in the human body. The intracellular fluid (ICF) is the fluid within cells. The extracellular fluid (ECF) includes both the blood plasma and the interstitial fluid (IF) between the cells. (CC BY 4.0; via OpenStax).

Figure 4.1.3 is a cross-sectional diagram showing how fluids are distributed in the body, focusing on cells and a nearby blood vessel.

- Cells are shown as circles with centers (nuclei).
- A blood vessel is depicted as a tubular structure.
- The diagram labels three types of fluids:
 1. Intracellular Fluid (ICF) is found inside the cells.
 2. Interstitial Fluid (IF) is located in the space between cells and outside the blood vessel.
 3. Plasma is the fluid component inside the blood vessel.

Cell Membrane Proteins: Structure - Function Relationships

The membrane proteins are not merely embedded within the membrane; their structure is intimately linked to their function. Integral membrane proteins, spanning the entire bilayer, often have hydrophobic regions interacting with the lipid core and hydrophilic regions exposed to the aqueous environments on either side. These proteins frequently serve as channels, transporters, or receptors, facilitating the movement of ions and molecules across the membrane or mediating cell signaling. Peripheral membrane proteins, on the other hand, are loosely associated with the membrane surface, often interacting with integral proteins or membrane lipids. They often play roles in structural support, enzymatic activity, or intracellular signaling pathways. The specific arrangement of amino acids within a membrane protein dictates its three-dimensional structure, which in turn determines its ability to bind specific ligands, transport specific molecules, or interact with other cellular components, thus highlighting the critical structure-function relationship of these essential molecules. Alterations in membrane protein structure, whether through genetic mutations or environmental factors, can have profound effects on cell function and overall health.

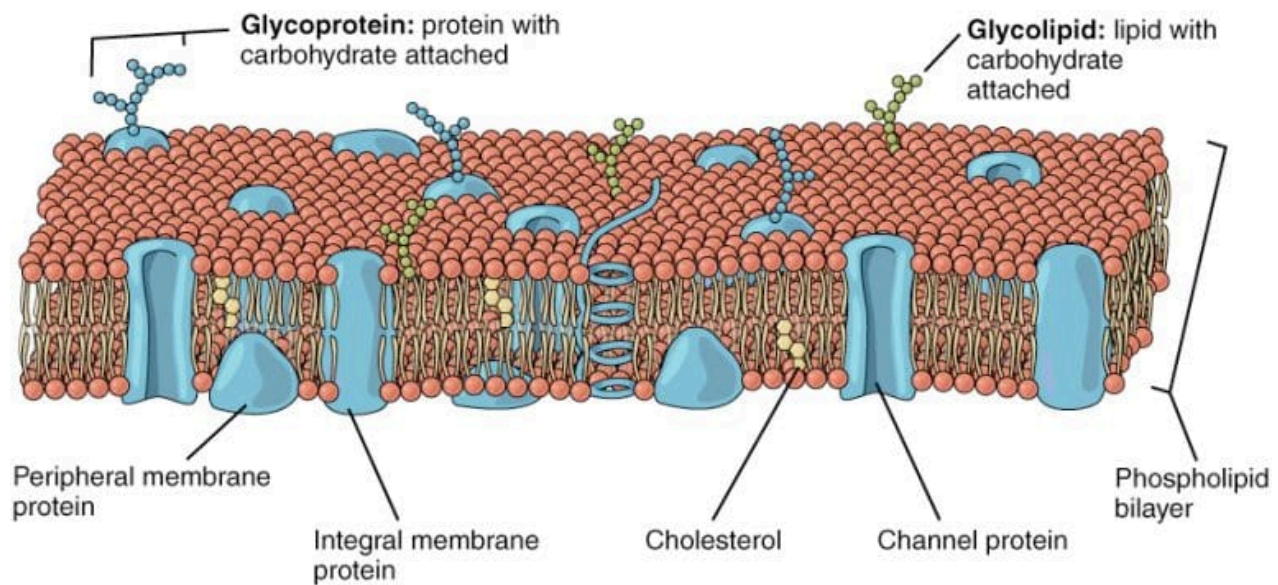


Figure 4.1.4: Cell Membrane: The cell membrane of the cell is a phospholipid bilayer containing many different molecular components, including proteins and cholesterol, some with carbohydrate groups attached. (CC BY-SA 4.0; Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, and OpenStax. via [Anatomy & Physiology](#))

Figure 4.1.4 is a detailed diagram of a cell membrane, highlighting its structure and key components:

- **Phospholipid Bilayer:** The foundational structure of the membrane, made of two layers of phospholipids with hydrophilic (water-attracting) heads facing outward and hydrophobic (water-repelling) tails facing inward.
- **Integral Membrane Protein:** A protein embedded within the bilayer, often spanning across it.
- **Peripheral Membrane Protein:** A protein attached to the surface of the membrane, not embedded within the bilayer.
- **Channel Protein:** A type of integral protein that forms a passageway for specific molecules to enter or exit the cell.
- **Cholesterol:** Molecules interspersed within the bilayer that help maintain membrane fluidity and stability.
- **Glycoprotein:** A protein with a carbohydrate chain attached, involved in cell recognition and signaling.
- **Glycolipid:** A lipid with a carbohydrate chain attached, also involved in cell recognition and communication.

Cholesterol makes up approximately 40% of the cell membrane and up to 90% of the cell's cholesterol is contained within the membrane. Functionally, cholesterol aids in fluidity and stability of the membrane. Functionally, cholesterol aids in fluidity and stability of the membrane. Membrane protein functions are summarized below.

- **Transport proteins:** Selectively allow particular materials to pass into or out of the cell.
 - Examples: Sodium- potassium pump (for Na^+ and K^+), Aquaporins (for water).
- **Enzymes:** Catalyze (speed up) chemical reactions within the membrane.
- **Receptors:** A type of recognition protein that can selectively bind a specific molecule outside the cell, which then begins a chemical reaction within the cell.
- **Attachment points for cytoskeleton:** Anchors for the proteins of the cytoskeleton, so they are stable.
- **Cell recognition proteins:** serve to mark a cell's identity so that it can be recognized by other cells
 - Examples: Glycoproteins that determine blood types or the glycocalyx that serves as the cell's "name tag".

Cell Organelle Structure-Function Relationships

An organelle is a structure within the cytoplasm of a eukaryotic cell that is enclosed within a membrane and performs a specific job. Organelles are involved in many vital cell functions. Organelles in animal cells illustrated in Figure 4.1.1 include the nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, vesicles. Ribosomes are not enclosed within a membrane, but they are still commonly referred to as organelles in eukaryotic cells.

- **Nucleus:** Large, double-membraned; contains DNA and nucleolus. Stores genetic material, controls cellular activities, and directs protein synthesis.
- **Nucleolus:** Dense region within the nucleus. Important in ribosome biogenesis. This involves synthesizing ribosomal RNA

(rRNA) and assembling the ribosome subunits, which are crucial for protein synthesis.

- Plasma Membrane (Cell Membrane): Flexible, phospholipid bilayer with proteins. Controls entry and exit of substances, enables cell communication.
- Cytoplasm: Semi-fluid matrix inside the cell. Site for metabolic activities; holds organelles.
- Cytoskeleton: Network of protein filaments (microtubules, microfilaments). Maintains cell shape, enables movement, and organizes organelles.
- Ribosomes: Small, non-membranous complexes of RNA and protein; free-floating or attached to ER. Cellular machinery responsible for making proteins.
- Rough Endoplasmic Reticulum (Rough ER): Membranous network studded with ribosomes. Synthesizes and processes proteins for secretion or membrane insertion.
- Smooth Endoplasmic Reticulum (Smooth ER): Network without ribosomes. Synthesizes lipids, detoxifies chemicals.
- Golgi Apparatus: Stacks of flattened membranes. Modifies, sorts, and packages proteins and lipids for delivery.
- Mitochondria: Double-membraned, with inner folds (cristae). Generates ATP through cellular respiration (cell's energy center).
- Lysosomes: Membrane-bound sacs filled with enzymes. Breaks down waste, digests macromolecules ("cellular cleanup").
- Peroxisomes: Small, membrane-bound organelles with oxidative enzymes. Breaks down fatty acids and detoxifies harmful substances.
- Vesicles: Small, membrane-bound bubbles. Transport materials within the cell.
- Centrosome/Centrioles: Microtubule organizing centers (centrioles in animal cells). Organize spindle fibers during cell division.

Cellular Transport - An Overview

Cells are not isolated entities; they constantly interact with their surroundings, exchanging nutrients, waste products, and signaling molecules. This exchange is meticulously controlled by the cell membrane, a selectively permeable barrier that regulates the passage of substances. Cellular transport mechanisms, the processes by which substances cross this membrane, are crucial for maintaining cellular homeostasis and enabling a wide range of cellular functions. These mechanisms can be broadly categorized as passive transport, which does not require energy input, and active transport, which does require energy. Understanding these processes is fundamental to understanding how cells function and interact within their environment.

Passive transport processes rely on the inherent properties of molecules and their concentration gradients. Simple diffusion involves the movement of small, non-polar molecules directly across the lipid bilayer of the membrane, from regions of high concentration to regions of low concentration.

Facilitated diffusion utilizes membrane proteins to assist the movement of larger or polar molecules that cannot easily cross the lipid bilayer. Osmosis, a special case of diffusion, refers to the movement of water across a selectively permeable membrane in response to a difference in solute concentration. Active transport, in contrast, moves substances against their concentration gradients, requiring energy, typically in the form of ATP. This lab will provide opportunities to observe and analyze these different transport mechanisms.

Conceptualizing the relationships between cell division (mitosis) and cell cycle

Mitosis is a process ubiquitous to life, and a foundational topic necessary for the understanding of advanced topics like growth and development, reproduction, and many disease processes. The cell cycle is an ordered series of events involving cell growth and cell division that produces two new daughter cells. Cells on the path to cell division proceed through a series of precisely timed and carefully regulated stages of growth, DNA replication, and division that produce two genetically identical cells. The cell cycle has two major phases: interphase and the mitotic phase. The mitotic phase is the shortest part of the cell cycle. The rest of the cell cycle, interphase, accounts for about 90% of the cell cycle.

Interphase

During interphase the cell is busy. The cell grows in size, new organelles are made, and the DNA of the chromosomes are copied in preparation for mitosis and cytokinesis. By studying molecular events in cells, scientists have determined that interphase can be divided into 4 steps: Gap 0 (G_0), Gap 1 (G_1), S (synthesis) phase, Gap 2 (G_2).

- G_0 phase - Cells in the G_0 phase are not actively preparing to divide. Some cells enter G_0 temporarily, after exiting a cell cycle, until an external signal triggers the onset of G_1 . Other cells that never or rarely divide, such as mature cardiac muscle and nerve cells, remain in G_0 permanently.

- G_1 or gap 1 phase - the cell grows larger and the number of organelles increases.
- S phase or synthesis phase - the cell replicates its DNA. DNA replication only occurs if the cell is programmed to proceed beyond G_1 . At this point the cell possesses twice as much DNA as it normally does and will need to divide.
- G_2 or gap 2 phase - after more growth occurs in the Gap 2 (G_2) phase, the cell is ready to divide and enters mitosis and finally results in the formation of two daughter cells Figure 4.1.1

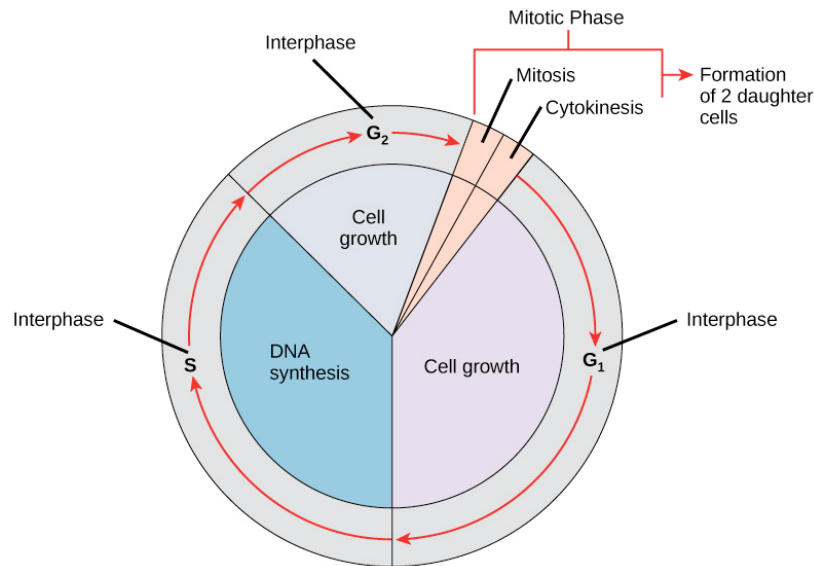


Figure 4.1.5: The cell cycle consists of interphase (G_1), S, (G_2) and the mitotic phase (mitosis and cytokinesis), leading to two daughter cells. (CC BY 4.0; via OpenStax).

Figure 4.1.5 illustrates a cell moves through a series of phases in an orderly manner. During interphase, (G_1) involves cell growth and protein synthesis, the S interphase involves DNA replication and the replication of the centrosome, and (G_2) interphase involves further cell growth and protein synthesis. The mitotic phase follows interphase. Mitosis is nuclear division during which duplicated chromosomes are segregated and distributed into two daughter cells. Usually the cell will divide after mitosis in a process called cytokinesis in which the cytoplasm is divided and two daughter cells are formed.

Mitosis

Mitosis (M Phase) is the process of cell division wherein the chromosomes replicate and get equally distributed into two daughter cells. The chromosome number in each daughter cell is equal to that in the parent cell, i.e., diploid ($2n$). Mitosis enables cellular growth and repair in multicellular organisms. The five phases of mitosis are:

1. Prophase - The nuclear envelope starts to break into small vesicles, and the Golgi apparatus and endoplasmic reticulum fragment and disperse to the periphery of the cell. The nucleolus disappears. The centrosomes begin to move to opposite poles of the cell. The microtubules that form the basis of the mitotic spindle extend between the centrosomes, pushing them farther apart as the microtubule fibers lengthen. The sister chromatids begin to coil more tightly and become visible under a light microscope.
2. Metaphase - The remnants of the nuclear envelope disappear. The mitotic spindle continues to develop as more microtubules assemble and stretch across the length of the former nuclear area. Chromosomes become more condensed and visually discrete. Each sister chromatid attaches to spindle microtubules at the centromere via a protein complex called the kinetochore, chromosomes are lined up at the metaphase plate.
3. Anaphase - the sister chromatids break apart, and the chromosomes begin moving to opposite ends of the cell. By the end of anaphase, the 2 halves of the cell have an equivalent collection of chromosomes.
4. Telophase - Chromosomes become more polarized and begin to de-condense. Nuclear envelope material surrounds each set of chromosomes, the mitotic spindle breaks down, essentially creating two distinct nuclei within the cell, marking the near completion of cell division before cytokinesis.

Cytokinesis

Not an actual stage of mitosis, cytokinesis begins in late anaphase to complete the mitotic phase. During this process the cytoplasm begins to separate. In animal cells, the cell membrane simply pinches at the equator of the cell until 2 new cells are formed.

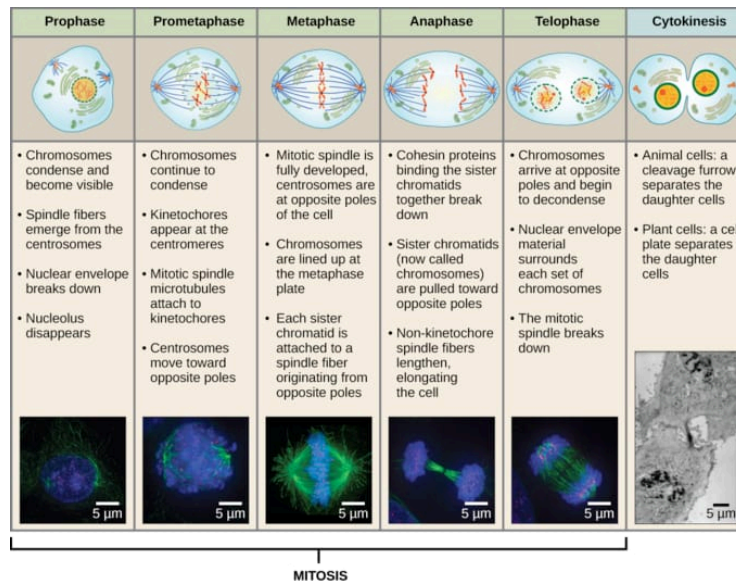


Figure 4.1.6: Stages of the Cell Cycle: Karyokinesis (or mitosis) is divided into five stages: prophase, prometaphase, metaphase, anaphase, and telophase. The images at the bottom were taken by fluorescence microscopy (hence, the black background) of cells artificially stained by fluorescent dyes: blue fluorescence indicates DNA (chromosomes) and green fluorescence indicates microtubules (spindle apparatus). (CC BY-SA 4.0; 10.2B: The Mitotic Phase and the G_0 Phase via LibreTexts).

Figure 4.1.6 is a detailed diagram showing the stages of mitosis, the process by which a cell divides to form two daughter cells. Each stage includes both a drawing and a microscopic image. The stages are:

1. Prophase:
 - Chromosomes condense and become visible.
 - Spindle fibers begin to form from centrosomes.
 - The nuclear envelope breaks down.
 - The nucleolus disappears.
2. Prometaphase:
 - Chromosomes continue to condense.
 - Kinetochores form at the centromeres.
 - Spindle microtubules attach to kinetochores.
 - Centrosomes move to opposite poles of the cell.
3. Metaphase:
 - The mitotic spindle is fully formed.
 - Chromosomes align at the center of the cell (metaphase plate).
 - Each sister chromatid is connected to spindle fibers from opposite poles.
4. Anaphase:
 - Proteins holding sister chromatids together break down.
 - Chromatids (now individual chromosomes) are pulled to opposite poles.
 - The cell elongates as nonkinetochore fibers lengthen.
5. Telophase:
 - Chromosomes reach the poles and begin to decondense.
 - New nuclear envelopes form around each set of chromosomes.
 - The mitotic spindle disassembles.
6. Cytokinesis:
 - In animal cells, a cleavage furrow forms to separate the daughter cells.
 - In plant cells, a cell plate forms to divide the cells.

Control of the Cell Cycle

The length of the cell cycle is highly variable even within the cells of an individual organism. In humans, the frequency of cell turnover ranges from a few hours in early embryonic development to an average of two to five days for epithelial cells, or to an entire human lifetime spent in (G_0) by specialized cells such as cortical neurons or cardiac muscle cells. There is also variation in the time that a cell spends in each phase of the cell cycle. When fast-dividing mammalian cells are grown in culture (outside the body under optimal growing conditions), the length of the cycle is approximately 24 hours. In rapidly dividing human cells with a 24-hour cell cycle, the (G_1) phase lasts approximately 11 hours. The timing of events in the cell cycle is controlled by mechanisms that are both internal and external to the cell.

Regulation at Internal Checkpoints

It is essential that daughter cells be exact duplicates of the parent cell. Mistakes in the duplication or distribution of the chromosomes lead to mutations that may be passed forward to every new cell produced from the abnormal cell. To prevent a compromised cell from continuing to divide, there are internal control mechanisms that operate at three main cell cycle checkpoints at which the cell cycle can be stopped until conditions are favorable. These checkpoints occur near the end of (G_1), at the (G_2)-M transition, and during metaphase.

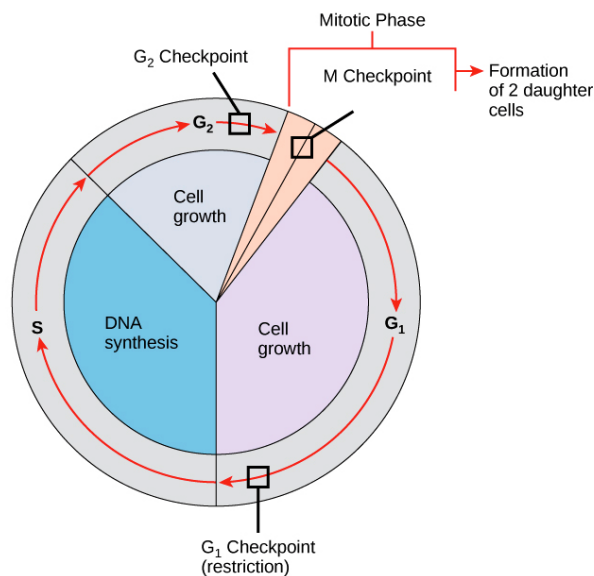


Figure 4.1.7: The cell cycle is controlled at three checkpoints. Integrity of the DNA is assessed at the (G_1) checkpoint. Proper chromosome duplication is assessed at the (G_2) checkpoint. Attachment of each kinetochore to a spindle fiber is assessed at the M checkpoint. (CC BY-SA 4.0; via OpenStax).

Figure 4.1.7 is a diagram of the cell cycle, which describes the sequence of events a cell goes through as it grows and divides. The cycle is shown in a circular format with arrows indicating the direction of progression. It includes the following phases:

1. (G_1) Phase (First Gap):
 - The cell grows and carries out normal functions.
 - (G_1) Checkpoint (also called the restriction point) ensures the cell is ready to proceed to DNA synthesis.
2. S Phase (Synthesis):
 - The cell replicates its DNA, preparing for division.
3. (G_2) Phase (Second Gap):
 - The cell continues to grow and prepares for mitosis.
 - (G_2) Checkpoint checks for DNA damage and ensures all DNA is replicated.
4. Mitotic Phase (M Phase):
 - The cell undergoes mitosis and cytokinesis, resulting in two daughter cells.
 - M Checkpoint ensures chromosomes are properly aligned and attached before division.

The (G_1) Checkpoint

The (G_1) checkpoint determines whether all conditions are favorable for cell division to proceed. The (G_1) checkpoint, also called the restriction point, is the point at which the cell irreversibly commits to the cell-division process. In addition to adequate reserves and cell size, there is a check for damage to the genomic DNA at the (G_1) checkpoint. A cell that does not meet all the requirements will not be released into the S phase.

The (G_2) Checkpoint

The (G_2) checkpoint bars the entry to the mitotic phase if certain conditions are not met. As in the (G_1) checkpoint, cell size and protein reserves are assessed. However, the most important role of the (G_2) checkpoint is to ensure that all of the chromosomes have been replicated and that the replicated DNA is not damaged.

The M Checkpoint

The M checkpoint occurs near the end of the metaphase stage of mitosis. The M checkpoint is also known as the spindle checkpoint because it determines if all the sister chromatids are correctly attached to the spindle microtubules. Because the separation of the sister chromatids during anaphase is an irreversible step, the cycle will not proceed until the kinetochores of each pair of sister chromatids are firmly anchored to spindle fibers arising from opposite poles of the cell.

Cancer as a Disease of Uncontrolled Cell Division

Uncontrolled cell division is a hallmark characteristic of cancer; essentially, when the cell cycle isn't properly regulated, cells can divide excessively, resulting in the formation of a tumor mass.

- Normal Cell Cycle Regulation - In a healthy body, the cell cycle is tightly regulated by various proteins and checkpoints that ensure cells divide only when necessary and stop if there are errors in DNA replication.
- Impact of Loss of Control - When these regulatory mechanisms fail due to genetic mutations, cells can bypass checkpoints and continue dividing without stopping, leading to abnormal cell proliferation and tumor formation.

Key points to remember

Oncogenes and Tumor Suppressor Genes

The genes that code for the positive cell cycle regulators are called proto-oncogenes. Proto-oncogenes are normal genes that, when mutated in certain ways, become oncogenes, genes that cause a cell to become cancerous. Like proto-oncogenes, many of the negative cell cycle regulatory proteins were discovered in cells that had become cancerous.

Tumor suppressor genes are segments of DNA that code for negative regulator proteins, the type of regulators that, when activated, can prevent the cell from undergoing uncontrolled division. The collective function of the best-understood tumor suppressor gene proteins, Rb, p53, and p21, is to put up a roadblock to cell cycle progression until certain events are completed.

A cell that carries a mutated form of a negative regulator might not be able to halt the cell cycle if there is a problem. Tumor suppressors are similar to brakes in a vehicle: Malfunctioning brakes can contribute to a car crash. Mutated p53 genes have been identified in more than one-half of all human tumor cells.

4.2: Activity 1

Investigating Eukaryotic Cell Organelles

Examine the eukaryotic cell model and name the cell organelles/structures labeled with letters A-O. This activity will help you understand the functions and importance of each organelle within the cell. Record identification in the table.

Use the following prompts to guide your identification:

- What organelle does this letter represent?
- Can you describe its function within the cell?
- C through O: Continue this process for each labeled section.

After documenting your findings, discuss your observations with a classmate or in a group. Share your insights on how each organelle contributes to the overall function and health of the cell.

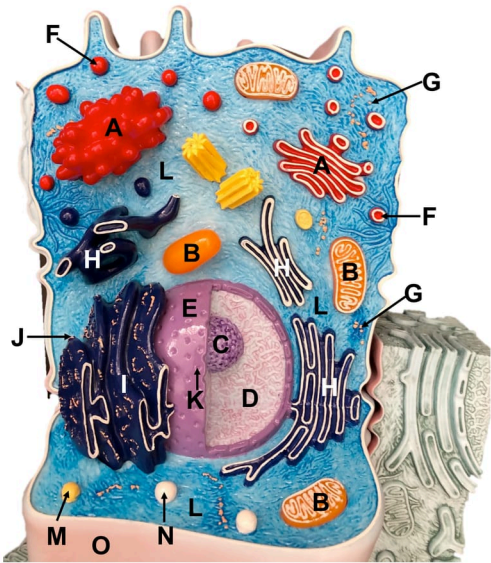


Figure 4.2.1: This image is a 3D model of an animal cell, with various organelles labeled using letters(CC BY-NC-SA 4.0; Rosanna Hartline via Eukaryotic Cells)

Figure 4.2.1 showcases a detailed model of a eukaryotic cell, with labeled letters indicating specific organelles. Each organelle plays a crucial role in cellular function, from energy production in the mitochondria to protein synthesis in the ribosomes. This model serves as a valuable tool for students to identify and understand the functions of various components within a eukaryotic cell.

Cell Organelle Identification Table

Below is a table for you to record the identification of the cell organelles and structures labeled with letters A-O on the image above. Fill in the table with the names of each organelle based on your examination of the eukaryotic cell model.

Table 4.2.1: Identification of cell organelles labeled A–O in a eukaryotic cell diagram.

Identifying Letter	Organelle Name
A	
B	

Identifying Letter	Organelle Name
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	
N	
O	

4.3: Activity 2

Collaborative Learning on Cell Organelles

There are diverse ways students can be engaged in group activities where they analyze the structure and function of each organelle, discuss how they interact with each other within the cell, and justify their reasoning by applying real-world analogies, ultimately leading to a deeper understanding of cellular processes through collaborative problem-solving. Collaborative activities encourage students to articulate their ideas, listen to others' perspectives, and effectively share knowledge. Analyzing scenarios and defending their reasoning helps students develop critical thinking skills by evaluating information and applying it to different contexts.

Objective

In this collaborative learning activity, students will use their prior knowledge and engage in group discussions to explore the complex interactions between organelles within a cell.

1. Each group will answer the following questions, drawing analogies to enhance understanding.
2. Take turns discussing each question within your group. Aim to reach a consensus on your answers. Use the prompts given under discussion questions to guide your discussions.
3. Record Your Group's Answers. Designate one member from each group to record your answers and prepare to share them with the class.

Discussion Questions

1. The nucleus is a large, round/oval structure usually located near the center of the cell. It is the control center for all the activities of the cell. As an analogy, what organization or place does the nucleus resemble in a Cell City? Why do you think so?
2. The endoplasmic reticulum consists of a network of a tube-like passageway that proteins from the ribosomes are transported through. As an analogy, what organization or place does the endoplasmic reticulum resemble in a Cell City?
3. The ribosomes are small grain-like bodies made mostly of RNA and produced in the nucleolus. Proteins are synthesized at the ribosomes. As an analogy, what organization or place do the ribosomes resemble in a Cell City?
4. How would a cell be affected if its mitochondria became nonfunctional or damaged?
5. Why must the cell membrane be selective in its permeability?
6. Provide an explanation as to why a cell ultimately dies when its lysosomes are ruptured.

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4.4: Activity 3

Cellular Transport Basics

The cell membrane is selectively permeable, allowing only a limited number of materials to diffuse through its lipid bilayer. All materials that cross the membrane do so using passive (non-energy requiring) or active (energy-requiring) transport processes. Apply the information provided in the introductory pages answer the following to evaluate attainment of learning goal on cellular transport basics.

1. Why can generally only very small, hydrophobic molecules cross the cell membrane by simple diffusion?
2. Glucose is the most important carbohydrate fuel in the body. The concentration of glucose inside and outside of a human cell can vary depending on the cell's metabolic activity and the availability of glucose in the environment. For example, after eating, glucose concentration is usually higher outside the cell. Imagine a hypothetical cell with a higher concentration of glucose inside the cell than outside. Answer the following questions about this cell, assuming all transport across the membrane is passive, not active.
3. Can glucose simply diffuse across the cell membrane? Why or why not?
4. Assuming that there are glucose transport proteins in the cell membrane, which way would glucose flow – into or out of the cell? Explain your answer.
5. If the concentration of glucose was equal inside and outside of the cell, do you think there would be a net flow of glucose across the cell membrane in one direction or the other? Explain your answer.

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4.5: Activity 4

Identification of Phases of Mitosis

1. Observe the 4 figures representing random sequence of mitosis.
2. Identify the specific stage of mitosis, justify identification by distinctive features for the stage and fill in Table 4.5.1.

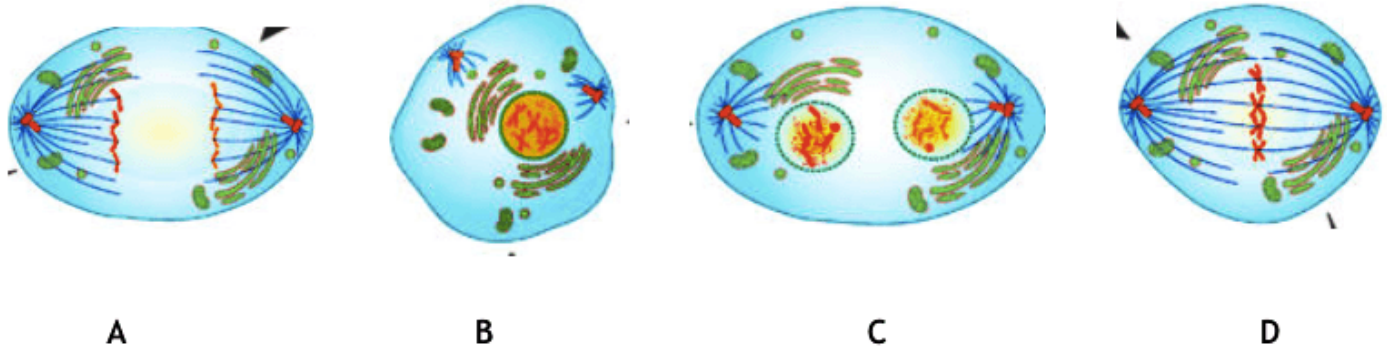


Figure 4.5.1: Stages of mitosis in a cell; A is metaphase, B is prophase, C is telophase, D is anaphase.

Figure 4.5.1 displays four stages of mitosis in a cell, labeled A through D. In image A (metaphase), chromosomes are aligned at the center of the cell between spindle fibers extending from opposite poles. In image B (prophase), chromatin condenses into visible chromosomes and the nuclear envelope disintegrates while spindle fibers begin to form. In image C (telophase), two new nuclei form around separated chromatids at each pole of the cell as it begins to divide. In image D (anaphase), sister chromatids are pulled apart by spindle fibers towards opposite poles.

Table 4.5.1: Phases of Mitosis Labeled A, B, C, and D with Their Features.

Identifying Letter	Phase of Mitosis	At least two distinctive features (textbook/other resource)
A		
B		
C		
D		

4.6: Activity 5

Calculating Mitotic Index: A Key Tool in Cancer Research

Objective

Understand the mitotic index and learn how to calculate it as a tool to assess cell division, which is crucial in cancer research.

As mentioned in the background information section, cancer comprises many different diseases caused by a common mechanism: uncontrolled cell growth. Despite the redundancy and overlapping levels of cell-cycle control, errors do occur. One of the critical processes monitored by the cell-cycle checkpoint surveillance mechanism is the proper replication of DNA during the S phase. Even when all of the cell-cycle controls are fully functional, a small percentage of replication errors (mutations) will be passed on to the daughter cells. If changes to the DNA sequence occur within a coding portion of a gene and are not corrected, a gene mutation results. Cancers start when a gene mutation gives rise to a faulty protein that plays a key role in cell reproduction.

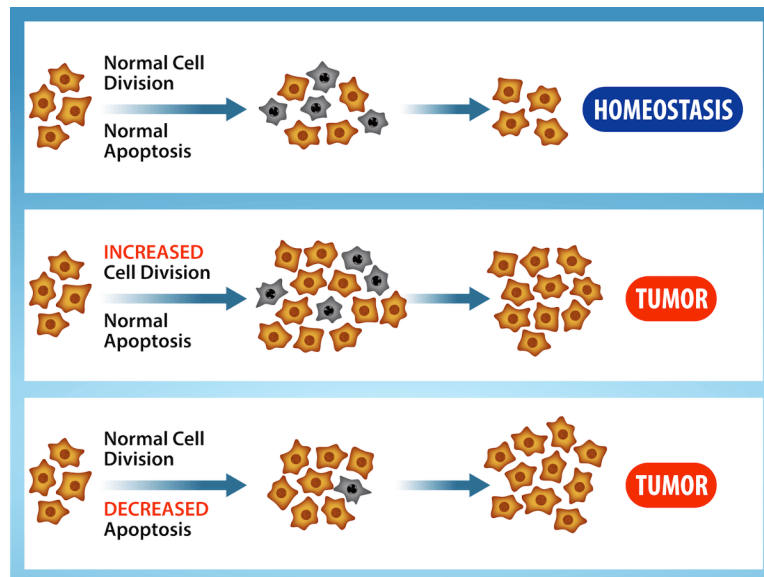


Figure 4.6.1: Cell Division and Apoptosis. In an adult organism, normal cell division is balanced by apoptosis (programmed cell death) to maintain a constant cell number in homeostasis. An increase in cell division or a decrease in apoptosis leads to a rise in the number of cells and tumor formation. (CC BY 4.0; via OpenStax).

The Mitotic Index (MI) is a measure of the proportion of dividing cells. An elevated mitotic index (higher cellular proliferation rate) indicates more cells are dividing and is an important prognostic factor predicting both overall survival and response to chemotherapy in most cancer types. This happens due to the self-sufficiency of growth signals, insensitivity to anti-growth signals, and limitless replicative potential. The mitotic index may be elevated during processes that promote division, such as normal growth or cellular repair.

MI can be determined by analyzing micrographs and counting the relative number of dividing versus non-dividing cells.

- Percentage of cells in mitosis = $\frac{\text{total number of cells in all phases of mitosis}}{\text{total number of cells}} \times 100$
- Mitotic index = $\frac{\text{total number of cells in all phases of mitosis}}{\text{total number of cells}}$

If you were to compare the mitotic indices of healthy tissue and tumor tissue, what differences would you expect to observe? Write proposed hypothesis.

Table 4.6.1: Hypothetical data for calculating percentage of cells in mitosis and mitotic index

Tissue Type	Percent cells in each phase					Calculate	
	Interphase	Prophase	Metaphase	Anaphase	Telophase	Percent of cells in mitosis	Mitotic Index
Normal lung	19	0	0	1	0		
Cancerous lung	15	1	3	1	0		
Normal stomach	18	0	0	1	1		
Cancerous stomach	15	2	1	1	1		
Normal ovary	17	0	1	2	0		
Cancerous ovary	11	2	2	3	2		

Analysis

1. Why is the mitotic index an important parameter in cell biology? Discuss its relevance in understanding cell proliferation and tissue growth.
2. What are some limitations of using the mitotic index as a sole indicator of tumor behavior? Discuss other factors that should be considered in conjunction with the mitotic index for a comprehensive assessment of cancer.
3. What does the data show about the rate of cell division in cancerous tissue compared to normal tissue?
4. Which type of cancer is the fastest growing? Explain your answer, using relevant data to support your claim.

Key Terms and Definitions

- **Active Transport:** Movement across the cell membrane that requires cellular energy (ATP), often via transport proteins (e.g., pumps).
- **Amphipathic:** Describes a molecule with two ends that differ in polarity, resulting in different water solubility.
- **Cell Cycle:** The series of phases a cell goes through as it grows and divides, from cell formation to division into two daughter cells (includes interphase and the mitotic phase).
- **Cell Membrane:** Membrane surrounding animal cells; a lipid bilayer with embedded molecules; also called the plasma membrane.
- **Centriole:** Small, self-replicating organelle that helps organize microtubules and supports chromosome movement during cell division.
- **Centromere:** Region where two sister chromatids are attached.
- **Centrosome:** Cellular structure that organizes microtubules during cell division.
- **Channel Protein:** Membrane-spanning protein with a pore that allows specific substances to pass through.
- **Checkpoint:** A control point in the cell cycle where specific conditions must be met before the cell proceeds.
- **Chromatin:** DNA plus associated proteins.
- **Chromosome:** The condensed form of chromatin.
- **Cilium:** A short, hair-like projection (plural: cilia) that moves a cell or moves substances along the cell surface.
- **Concentration Gradient:** A difference in the concentration of a substance between two regions.
- **Cytoplasm:** Region between the plasma membrane and nuclear envelope; includes organelles, cytosol, cytoskeleton, and dissolved chemicals.
- **Cytoskeleton:** Network of protein fibers that maintains cell shape, anchors organelles, enables internal movement, and supports cell movement.
- **Cytosol:** Gel-like fluid portion of the cytoplasm where cell structures are suspended.
- **Diffusion:** Movement of a substance from higher concentration to lower concentration.
- **Endocytosis:** Cell process that brings substances in by engulfing them in a vesicle formed from the plasma membrane.
- **Endomembrane System:** Group of eukaryotic membranes and organelles that modify, package, and transport lipids and proteins.
- **Endoplasmic Reticulum (ER):** Interconnected membrane network that modifies proteins and synthesizes lipids.
- **Exocytosis:** Process of expelling materials when vesicles fuse with the plasma membrane and release contents outside the cell.
- **Extracellular Fluid (ECF):** Fluid outside cells, including interstitial fluid, blood plasma, and fluid in other body reservoirs.
- **Flagellum:** A long, hair-like projection (plural: flagella) used to move a cell.
- **G₀ Phase:** Cell cycle phase (often entered from G₁) where the cell does not proceed to DNA synthesis; may be long-term or permanent.
- **G₁ Phase:** Cell growth and protein synthesis phase.
- **G₂ Phase:** Further growth and preparation for mitosis.
- **Glycoprotein:** A protein with one or more carbohydrates attached.
- **Golgi Apparatus:** Stacked membranes that modify, sort, tag, and package proteins and lipids for transport.
- **Hydrophilic:** Attracted to water.
- **Hydrophobic:** Repelled by water.
- **Hypertonic:** A solution with a higher solute concentration than a reference solution.
- **Hypotonic:** A solution with a lower solute concentration than a reference solution.
- **Integral Protein:** Membrane-associated protein that spans the lipid bilayer.
- **Intermediate Filament:** Cytoskeletal filament (often keratin-based) that resists tension and provides structural support.
- **Interphase:** Cell cycle phase when the cell grows and prepares for division.
- **Isotonic:** A solution with the same solute concentration as a reference solution.
- **Lysosome:** Digestive organelle that breaks down macromolecules and worn-out organelles.
- **Metaphase:** Mitosis stage when sister chromatids align at the cell's center.
- **Mitochondria:** Organelles (singular: mitochondrion) that perform cellular respiration and produce ATP.
- **Mitotic Phase:** Cell cycle phase when the cell undergoes mitosis.
- **Mitotic Spindle:** Microtubule network that organizes and separates chromosomes during mitosis.
- **Nuclear Envelope:** Double membrane surrounding the nucleus.
- **Nucleolus:** Structure inside the nucleus that assembles ribosomal subunits.
- **Nucleus:** Organelle that houses DNA and directs ribosome and protein synthesis.

- **Passive Transport:** Movement across the membrane without energy use, typically down a concentration gradient (e.g., diffusion, osmosis).
- **Peroxisome:** Organelle that breaks down fatty acids and amino acids and detoxifies harmful compounds (contains hydrogen peroxide).
- **Phagocytosis:** A type of endocytosis (“cell eating”) in which large particles are engulfed.
- **Pinocytosis:** A type of endocytosis (“cell drinking”) in which small particles or fluids are taken into the cell.
- **Plasma Membrane:** Phospholipid-and-protein membrane that separates the inside of the cell from its environment.
- **Ribosome:** Cell structure that carries out protein synthesis.
- **Rough Endoplasmic Reticulum (RER):** ER region with ribosomes attached; modifies proteins.
- **S Phase:** Phase when DNA replication occurs and the centrosome duplicates.
- **Smooth Endoplasmic Reticulum (SER):** ER region with few/no ribosomes; synthesizes lipids and carbohydrates, detoxifies chemicals, and stores calcium ions.
- **Vesicle:** Small membrane-bound sac for storage and transport; can fuse with the plasma membrane, ER, and Golgi.

5: HISTOLOGY

Introduction

In this lab, we will explore the microscopic structure of tissues through histological examination. Histology is the science that provides the adequate learning of the tissue organization of the body, and is a fundamental part of medical/health education. Tissues are made from large groups of cells that cluster together to complete a shared function. From tissues arise organs, and organs keep the body operating.

“One must understand the normal to be able to recognize the abnormal” is a common phrase in healthcare. Many diseases occur at the cell/tissue level. Cytology is the examination of a single cell type. It is mainly used to diagnose or screen for cancer (pap smear for cancer of cervix). Histology bridges anatomy and physiology, helping us understand how microscopic structures support bodily functions. Histopathology is the examination of tissues in order to observe the appearance of diseased cells in microscopic detail. Histopathology typically involves a biopsy, which is a procedure involving taking a small sample of tissue, usually undertaken by a pathologist, who are experts in diagnoses of diseases. Hospital laboratories prepare microscope sections which are stained to show key features of the cells and anatomical structures within the tissues. Understanding the changes that are characteristic of a disease requires a detailed knowledge of the normal appearance of cells and tissues, and the range of normality. By using light microscopes and prepared histological slides, we will analyze the structural characteristics of the four primary tissue types:

- Epithelial Tissue – Covers body surfaces, lines cavities, and forms glands.
- Connective Tissue – Provides structural support, protection, and transport of substances.
- Muscle Tissue – Facilitates movement through contraction.
- Nervous Tissue – Enables communication and coordination within the body.

Learning Objectives

- Identify diverse types of epithelial tissue from an image or histology slide and relate location and function.
- Explain the structural modifications such as cilia, microvilli, or keratinization that contribute to the specific function of each epithelial tissue sub-type, if applicable.
- Identify several types of connective tissue from an image or histology slide and relate location and function.
- Identify the ground substance and the diverse types of protein fibers that create the extracellular matrix on an image or histology slide of connective tissue.
- Identify the most common type(s) of cells present in a picture or histology slide of connective tissue.
- Differentiate the three types of cartilage.
- Locate and Identify the three distinct types of muscle tissue from an image or histology slide and relate location and function.
- Describe the function and common locations of the three diverse types of muscle tissue.
- Identify nervous tissue in an image or histology slide.

5.1: Terminology Checklist

5.2: Warm-Up Activity

5.3: Background Information

5.4: Lab 5 - Procedure

5.5: Activity 1

5.6: Activity 2

5.7: Activity 3

5.8: Activity 4

5.9: Glossary

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5.1: Terminology Checklist

Terminology Checklist for tissue lab

To enhance your understanding of different tissue types and their structures, the following checklist provides essential terminology and classifications related to epithelial, connective, muscle, and nervous tissues. Familiarizing yourself with these terms will help you identify and describe the unique characteristics and functions of each tissue type as you progress through the lab activities.

Epithelial Tissue

Key Terms

- Apical surface
- Basal surface
- Basement membrane
- Cell projections
 - Cilia
 - Microvilli

Types of Epithelial Tissue

- Simple epithelia
 - Simple squamous epithelium
 - Simple cuboidal epithelium
 - Simple columnar epithelium
 - Pseudostratified columnar epithelium
- Stratified epithelia
 - Stratified squamous epithelium
 - Non-keratinized
 - Keratinized
 - Transitional epithelium

Connective Tissue

Key Terms

- Extracellular matrix
- Fibers
 - Collagen
 - Elastic
 - Reticular
- Ground substance
- Cells
 - Fibroblasts
 - Chondrocytes
 - Osteocytes
 - Red blood cells
 - White blood cells

Types of Connective Tissue

- Areolar tissue
- Adipose tissue
- Dense regular collagenous
- Dense irregular collagenous
- Cartilaginous connective tissue
 - Hyaline cartilage
 - Fibrocartilage
 - Elastic cartilage
- Compact bone
- Blood

Muscle Tissue

- Skeletal muscle
 - Striations
 - Nucleus
- Cardiac muscle
 - Striations
 - Intercalated discs
 - Nucleus
- Smooth muscle
 - Nucleus

Nervous Tissue

Key Terms

- Neuron
- Neuroglial cell

5.2: Warm-Up Activity

Warm up Activity to a scenario: "Case of the Persistent Cough"

You are assisting a pulmonologist. A pulmonologist is a healthcare provider that specializes in conditions that affect respiratory system, including your airways and lungs. Emergent coronaviruses such as severe acute respiratory syndrome (SARS-CoV) caused significant impacts on human health, especially during pandemic during 2020 - 2021. People infected with these coronaviruses often had significant lung disease that contributed to clinical morbidity and mortality. Histopathologic examination of lung tissues are essential to better understand disease pathogenesis and evaluate novel treatments of these current (and future) virus outbreaks.

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5.3: Background Information

Overview: Epithelial Tissue

There are a total of eight types of epithelial tissue, marked by differences in shape and arrangement. The focus of the lab will be the following six tissue types: simple squamous, simple cuboidal, simple columnar, ciliated pseudostratified columnar, stratified squamous (keratinized and non-keratinized), and transitional epithelium.

Epi- means above and -thelium means tissue, so epithelium is a group of tissues that are located above (covering or lining) all other tissues of the body. All epithelial tissue is composed of tightly packed cells. Cells are linked together by special intercellular junctions creating an effective barrier. Epithelial tissue is typically avascular, meaning that nutrients must diffuse from underlying connective tissue. Since epithelial tissue lines body surfaces, membranes, tubes, and ducts, it also exhibits polarity, meaning it has a top and a bottom. The apical surface faces the external environment or the inner surface of a body cavity (lumen). The basal surface is bound to the basement membrane and is continuous with underlying connective tissue. Often, epithelial tissue may also have cellular projections. These tiny projections may make the tissue appear fuzzy under the microscope. There are two main types of projections are cilia and microvilli. Cilia are thin, long projections that can move, while microvilli are short, dense extensions of the cell membrane for increasing surface area. Pseudostratified columnar epithelium of the trachea has cilia for moving debris out of the respiratory tract. Simple columnar epithelium of the digestive tract has microvilli for increasing absorption.

Epithelial tissue must be an effective barrier and allow for varying amounts of diffusion across its surface. Epithelial tissue can form a single layer (simple), multiple layers (stratified), or be “falsely stratified” (pseudostratified), where the cells seem to form multiple layers, but are, in fact, all part of one layer. The cells of epithelial tissue can vary in shape, from flat (squamous), to square (or as tall as they are wide) (cuboidal), to much taller than they are wide (columnar). Stratified epithelium can be tricky to identify as the cells of stratified epithelial tissue may have slightly different shapes in the deeper layers of the tissue than at the apical edge. As a rule of thumb, always look at the apical (top) layer to determine shape. Transitional epithelium is a special type of stratified epithelial tissue found only in the urinary bladder and ureter. It has apical cells which vary in shape depending on forces applied to the tissue. The apical cells appear cuboidal when no force is applied (as when the bladder is empty) and transition to a more squamous shape when the tissue is stretched (as when the bladder is full).

When trying to find and identify epithelial tissue on a slide it will help to use a flowchart or decision tree. Use the Figure 5.3.1 flowchart and the following questions try to identify the diverse types of epithelial tissue.

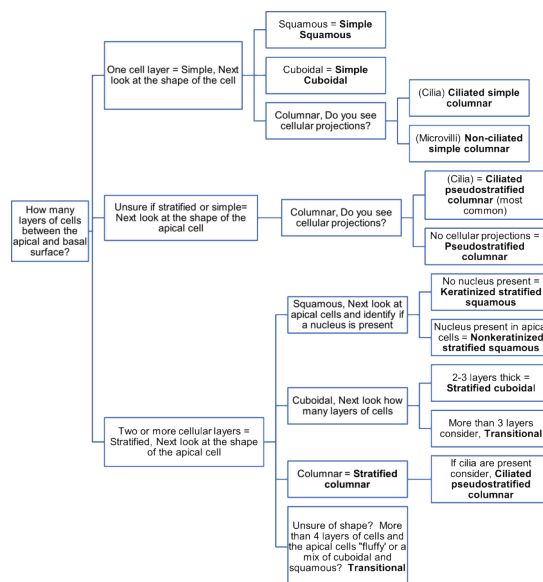


Figure 5.3.1: Identifying epithelial tissue types using a friendly flowchart approach. Understanding these tissues involves examining three main aspects: the number of cell layers, the shapes of the cells, and whether there are any cellular projections. (CC BY-NC-SA 4.0; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via [Histology Lab](#)).

Figure 5.3.1 is a decision tree diagram for identifying epithelial tissue types, guiding through characteristics such as cell shape, layer arrangement, and specific features to classify tissues like squamous, cuboidal, columnar, simple, and stratified epithelia. It helps determine the classification of epithelial cells by following these steps:

1. Determine the number of cell layers:
 - One layer is classified as simple epithelium.
 - Two or more layers are classified as stratified epithelium.
2. For Simple Epithelium, identify the cell shapes.
 - Squamous is simple squamous
 - Cuboidal is simple cuboidal columnar:
 - If cells have cilia: ciliated Simple Columnar
 - If cells have microvilli: non-ciliated Simple Columnar
3. If unsure whether it's simple or stratified, examine the apical cell shape.
4. For Stratified Epithelium, identify the apical cell shape:
 - Squamous:
 - If apical cells lack nuclei: Keratinized Stratified Squamous
 - If apical cells have nuclei: Nonkeratinized Stratified Squamous
 - Cuboidal:
 - If 2–3 layers thick: Stratified Cuboidal
 - Columnar: Stratified Columnar
5. If the shape is unclear, and there are more than 4 layers with apical cells appearing “fluffy” or mixed in shape is likely Transitional Epithelium
6. If cilia are present, and the layering appears complex:
 - Consider Ciliated Pseudostratified Columnar Epithelium

Steps to find epithelial tissue on a slide

1. Look for a collection of cells that appear to line or surround a lumen or on the edge of the tissue. The cells will be in contact with the free surface creating a continuous line of cells.
2. Find the cells on the apical or free surface of the tissue.
 - a. Next, look for the basal surface of the tissue. Typically, you will see a darkly stained line or a change in cell type to indicate the basement membrane.
 - b. Determine if all the epithelial cells are in contact with the basement membrane and if most are in contact with the apical surface.
 - c. If they are, the epithelium is one cell layer thick and is called simple epithelial.
 - d. If you see more than one cell layer between the apical and basement membrane, then it is stratified epithelial.
3. Use Figure 5.3.1 and follow the features listed below to distinguish among the tissue types. Note that we will be identifying only seven types of epithelial tissue, based on the slides available.

Tips for identifying the different epithelial tissues on a slide

- Simple epithelial (one thick cell layer. Most cells are in contact with both the apical and the basement membrane).
- Next examine the epithelial cell and determine its shape.
 - Squamous (scale-like, flattened cells that resemble the scales on a fish with a flat disc nucleus), the tissue is classified as simple squamous epithelium. This type of epithelium is commonly found in many locations in the body (lining of blood vessels, lining the alveoli/air sacs of our lungs). This allows for gas exchange between lungs and blood vessels.
 - Cuboidal (square looking), the tissue is classified as simple cuboidal epithelium. Single layer of cube-shaped cells with round nuclei, can look a little different depending on the direction the tissue has been sectioned. This type of epithelium is commonly found in the tubules of kidney, follicles of the thyroid gland, salivary gland, surface of ovaries, facilitates absorption and secretions.
 - Columnar (long, slender, or rectangular looking) with oval nuclei toward the basement membrane, the tissue is classified as simple columnar epithelium. Single layer of column (rectangular)-shaped cells with oval nuclei usually located near the basal side of the cell. This type of epithelium is commonly found in the lining of intestines, stomach, and gallbladder, facilitates absorption and secretions. These cells may contain goblet cells to secrete mucus, often cells have microvilli which appear as a fuzzy apical edge (called the brush border in the small intestines).

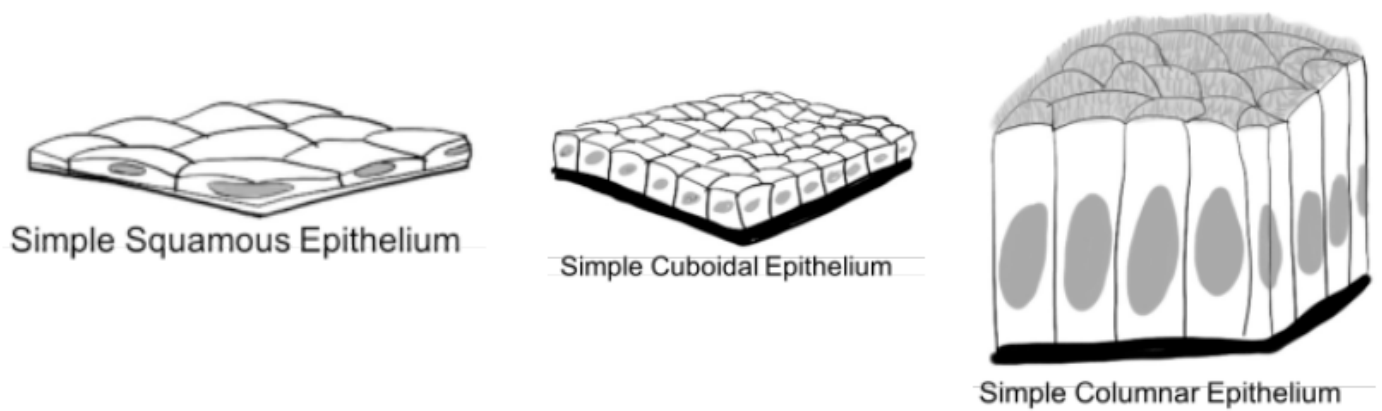


Figure 5.3.2: Simplified diagram showing three types of simple epithelial tissue organization: simple squamous, simple cuboidal, and simple columnar epithelium, each characterized by a single layer of cells with distinct shapes. (CC BY-NC-SA 4.0; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via [Histology Lab](#)).

Figure 5.3.2 displays three types of epithelial tissues, each labeled and illustrated:

1. Simple Squamous Epithelium:
 - Composed of a single layer of flat cells.
 - These cells are thin and allow for easy diffusion and filtration.
 - Commonly found in areas like the lungs and blood vessels.
 2. Simple Cuboidal Epithelium:
 - Made up of a single layer of cube-shaped cells.
 - These cells are involved in secretion and absorption.
 - Typically found in kidney tubules and glandular ducts.
 3. Simple Columnar Epithelium:
 - Consists of a single layer of tall, column-like cells.
 - These cells often have microvilli or cilia and are specialized for absorption and secretion.
 - Found in the digestive tract lining and uterine tubes.
- Do you see surface projections from the apical membrane?
 - Are the projections long and distinct? If yes, then they are cilia, which indicates the presence of ciliated simple columnar epithelium.
 - These are microscopic extensions of the apical cell membrane that are supported by microtubules. They beat in unison and move fluids as well as trapped particles.
 - Do you see a “haze” or lots of small projections packed together (brush border/ (Microvilli)? Then this indicated the presence of non-ciliated simple columnar epithelium.
 - You may also notice goblet cells which are a mucus-secreting unicellular “gland” interspersed between the columnar epithelial cells of mucous membrane.

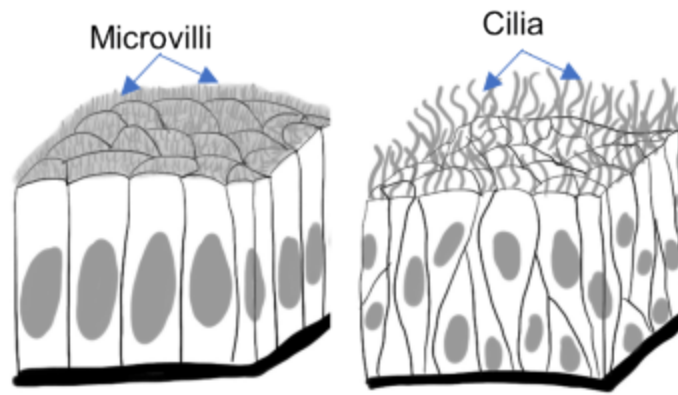


Figure 5.3.3: Two detailed illustrations, side-by-side, comparing the structure and function of microvilli (left) and cilia (right) on epithelial cells, emphasizing their structural and functional differences (CC BY-NC-SA 4.0; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via Histology Lab).

Figure 5.3.3 contains two labeled diagrams comparing microvilli and cilia, which are surface structures found on certain cells:

1. Left Diagram – Microvilli:
 - Shows a group of cells with short, dense projections on their surface.
 - These projections increase the surface area of the cell, aiding in absorption.
 - Commonly found in the lining of the small intestine.
2. Right Diagram – Cilia:
 - Displays cells with longer, hair-like projections.
 - These structures help with movement, either moving the cell itself or substances across the cell surface.
 - Found in areas like the respiratory tract, where they help move mucus.

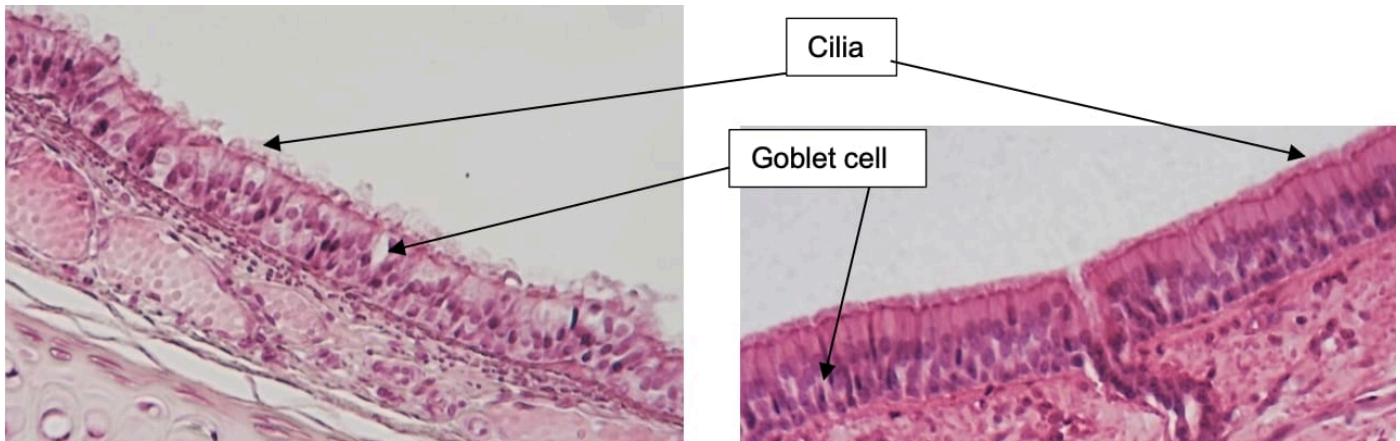


Figure 5.3.4: Microscopic view of special features of epithelial tissue in the tracheal lining, showing hair-like cilia and mucus-secreting goblet cells TM-400 times. (CC BY 4.0; Julie Robinson via LibreTexts).

Figure 5.3.4 highlights special features of tracheal epithelia, showing two examples of cilia and goblet cells, which work together to move mucus and trap particles. It presents a microscopic view of epithelial tissue, commonly found lining the respiratory tract. It highlights two key structures:

- **Cilia:** Located on the left side of the image, these are fine, hair-like projections extending from the surface of epithelial cells. Arrows point to these structures, which play a crucial role in moving mucus and trapped particles out of the airway.
- **Goblet Cell:** Found on the right side of the image, this cell is larger and more rounded than the surrounding epithelial cells. It is marked by an arrow and is responsible for secreting mucus, which helps trap dust, microbes, and other particles.

This type of tissue is commonly found lining the respiratory tract, where cilia and goblet cells work together to trap and move particles out of the airways.

- Are you unsure if the epithelium is stratified or simple?

- Are most of the cells columnar, but some cells are of different heights?
- Do all the cells touch the basement membrane and not all reach the apical surface?

When examining a tissue sample, if you notice that the nuclei are not aligned in a straight line but appear scattered instead, you are likely observing pseudostratified columnar epithelium. The prefix "pseudo-" indicates that this tissue gives the illusion of being stratified, although it is not.

In stratified epithelium, cells are stacked in layers, while in pseudostratified columnar epithelium, the cells vary in height, causing the nuclei to appear at different levels. Despite this appearance, all cells in this type of epithelium contact the basement membrane on their basal side; however, not all cells extend to the apical surface.

The pseudostratified ciliated columnar epithelium are found in trachea, bronchi, nasal cavity, and sperm-carrying ducts. They are important for absorption and/or secretion.

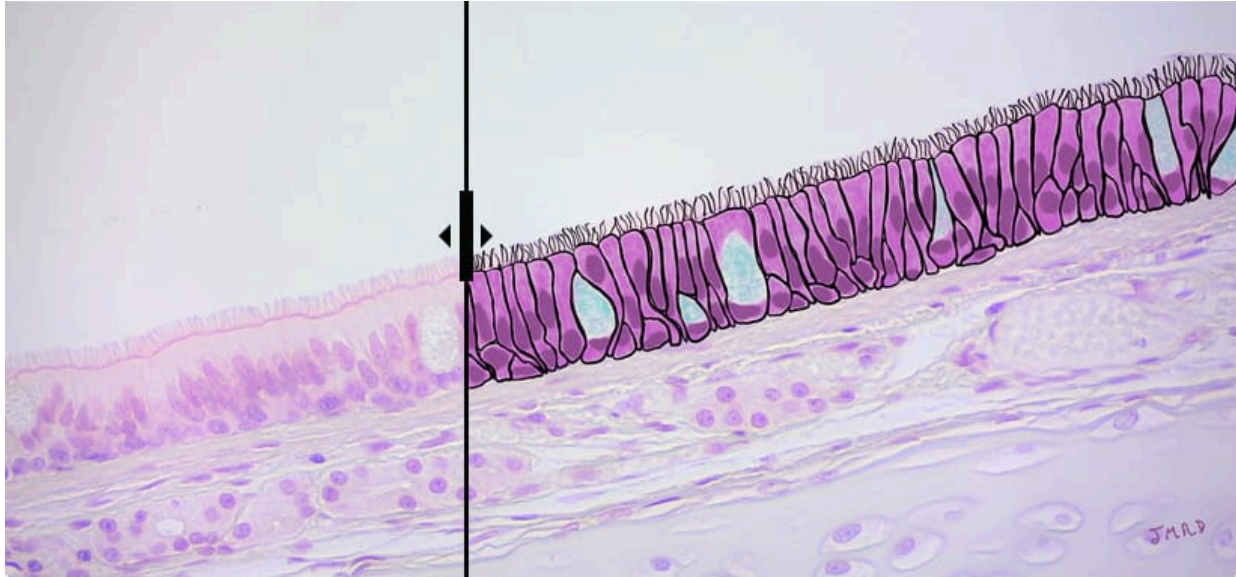


Figure 5.3.5: A cross-section of the trachea revealing ciliated pseudostratified columnar epithelium. Cilia are visible, along with goblet cells that produce mucus. (CC BY-NC-SA 4.0; Juan Manuel Ramiro-Diaz, Ph.D. via PressBooks).

Figure 5.3.5 is an illustration of ciliated pseudostratified columnar epithelium from the trachea, showing visible goblet cells and cilia on the apical surface, aiding in mucus secretion and movement. It is divided into two parts. Left side is a microscope image which shows the actual tissue as seen under a microscope. The cells appear layered, but all touch the basement membrane, which is why it's called pseudostratified. Right side is an illustration overlay which is superimposed on the tissue to highlight key structures. It helps visualize the ciliated cells (with hair-like projections) and other components more clearly. This type of epithelium helps trap and move particles out of the respiratory tract using cilia and mucus-secreting goblet cells.

- Stratified epithelial tissues are composed of two or more cells in between the apical and basal surface. Look at the apical epithelial cell and determine its shape. The most superficial cell layer is exposed on the apical side and the deepest cell layer is anchored to a basement membrane on the basal side. These tissues are named for the shape of the cell at the apical side. This lab will focus on stratified squamous epithelium, which forms our major protective barriers. Stratified squamous epithelium is part of two important protective membranes (protects against physical and chemical wear and tear), where it exists in different forms:
 - Non-keratinized – found in the mouth/esophagus, vagina, rectum/anus. It doesn't need keratin to protect itself from drying out, facilitates absorption and secretion.
 - Keratinized – found in the skin and oral epithelia. The most superficial cells are dead and contain keratin, a protein that makes them waterproof. Provides a protective barrier against abrasion and water loss.

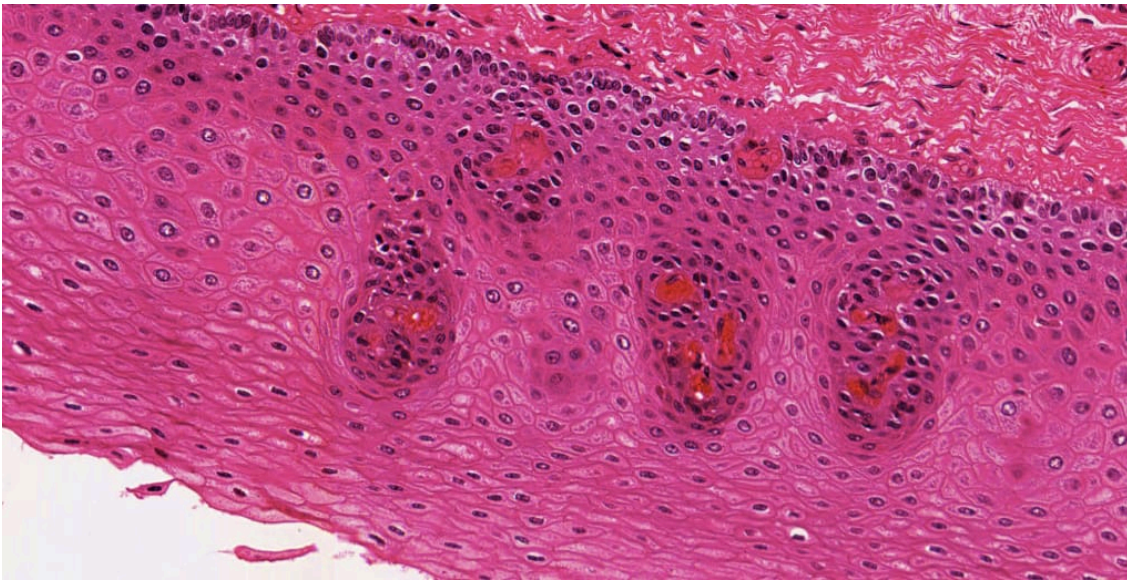


Figure 5.3.6: Microscopic view of non-keratinized stratified squamous epithelium showing multiple layers of flattened cells with visible nuclei in the superficial layers. This type of epithelium is typically found in moist environments like the lining of the oral cavity and esophagus. (CC BY-NC SA 4.0; Michael Hortsch via University of Michigan Histology Lab Manual).

Figure 5.3.6 is a histological section of human skin tissue, stained with hematoxylin and eosin (H&E), which highlights cellular structures in shades of pink and purple.

- The epidermis (top layer) consists of multiple layers of cells, with the outermost layer appearing compact and densely packed.
- Beneath it is the dermis, which has a fibrous texture and fewer cells.
- Within the dermal layer, hair follicles are visible. These appear as circular structures surrounded by dense clusters of cells.

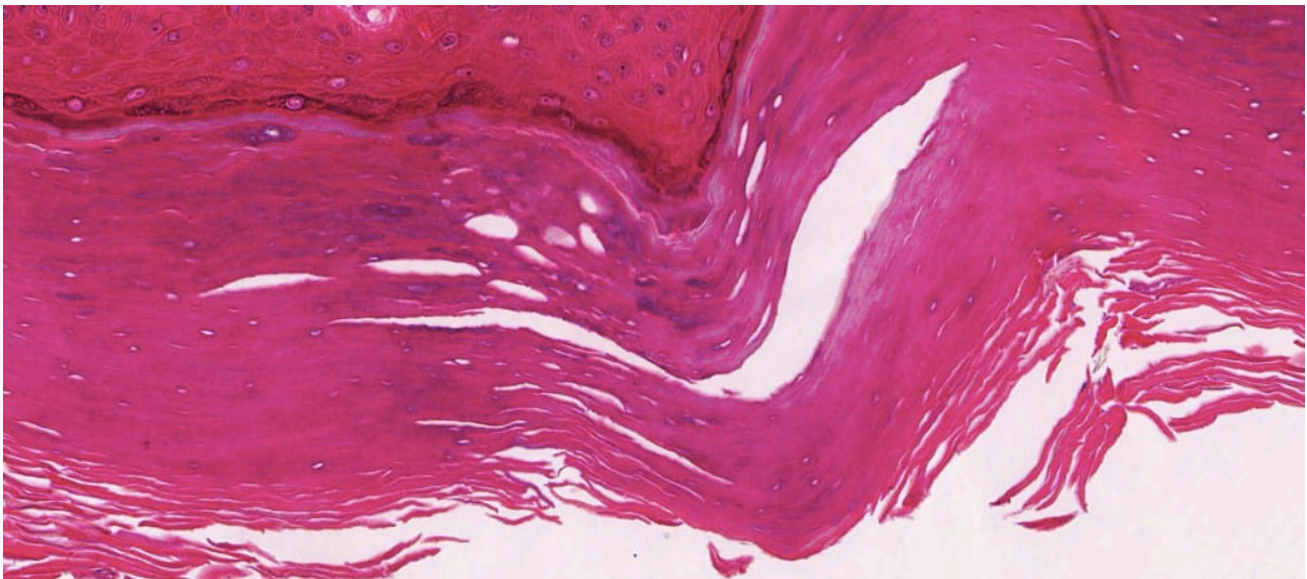


Figure 5.3.7: Keratinized stratified squamous epithelium, with multiple layers of flattened cells forming a protective outer layer lacking nuclei, indicating the presence of dead cells filled with keratin (bottom part of the image). (CC BY-NC-SA 4.0; Michael Hortsch via University of Michigan Histology Lab Manual).

Figure 5.3.7 illustrates keratinized stratified squamous epithelium in skin, showing outermost dead cell layer filled with keratin and lacking nuclei, providing protection against desiccation through cornification. It displays a histological section of skin tissue, stained using hematoxylin and eosin (H&E), a common method in microscopy for highlighting cellular and structural features.

- The epidermis, located at the top of the image, is stained a darker pink to red, indicating a high density of cells. This layer

consists primarily of keratinocytes and is responsible for the protective barrier function of the skin.

- Beneath the epidermis lies the dermis, which appears lighter pink due to its fibrous composition. This layer contains collagen fibers, blood vessels, and connective tissue, providing structural support and nourishment to the epidermis.

The contrast in staining helps distinguish between the cell-rich epidermis and the fibrous dermis, making it easier to study skin architecture and identify any abnormalities.

- Transitional epithelium. Transitional epithelium generally has more than four layers and appears “bubbly” on its surface. Students often confuse transitional epithelium with stratified epithelium. Transitional epithelium is made of cells that can transition or change their shape depending on whether the tissue is relaxed (big round balloon cells or umbrella-shaped) or stretched (cells are pulled flat). Transitional epithelium is found in organs that must stretch a lot (urinary bladder and ureters). Think about how small your urinary bladder is when it is empty (holds about 20 mL) and when it is full (typically holds 500 to 700 mL but can hold more!).

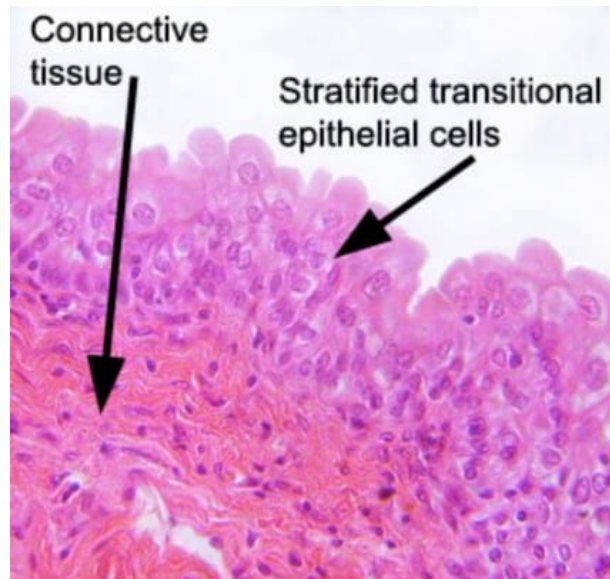


Figure 5.3.8: Transitional epithelium. Microscopic view of a urinary bladder tissue slice at 10 times magnification, revealing layers of stratified transitional epithelial tissue overlying connective tissue. (CC BY-NC-SA 4.0; Michael Hortsch via University of Michigan Histology Lab Manual and LibreTexts).

Figure 5.3.8 is a transitional epithelium in the urinary bladder, illustrating the stratified epithelial layer above the underlying connective tissue, designed to stretch as the bladder fills. The labels use arrows to point directly to these regions, helping to distinguish between the supportive connective tissue and the flexible epithelial layer. The microscopic view of tissue shows two labeled components:

1. Connective Tissue:
 - Appears as a pinkish area with a dense, fibrous texture. This tissue provides structural support and connects other tissues and organs.
2. Stratified Transitional Epithelial Cells:
 - These cells are purple in color and stacked in multiple layers.
 - This type of epithelium is specialized to stretch and is typically found in the urinary bladder and ureters.

5.4: Lab 5 - Procedure

Microscopic Procedure and Slide Analysis

Part 1: Set up your microscope

1. Prepare the microscope
 - a. Plug in the microscope and turn it on.
 - b. Rotate the nosepiece so the scanning objective (4 times) is in position.
 - c. If the stage is not already lowered, use the coarse adjustment knob to lower the stage until it stops.
2. Place and position the slide.
 - a. Place the “sample” slide on the stage.
 - b. Use the stage clips to secure the slide in position.
 - c. While watching the specimen from the side use the stage adjustment knobs, move the slide around until the specimen comes into the field of view.
3. Locate the specimen
 - a. Look into the ocular lens and move the area of focus into the center of view.
 - b. Bring the specimen into focus using the coarse adjustment knob.
 - c. Use the fine adjustment knob to bring it into sharp focus.
4. Focus at scanning power(4 times).
 - a. Make sure the slide is in perfect focus at scanning power (4 times, red) before moving to low power (10 times, yellow).
 - b. Turn your objective without moving the slide or stage.
 - c. Use only the fine adjustment knob to bring the specimen into sharp focus.
 - d. At high power use only the fine focus knob and do not turn it more than half a turn.

Part 2: Observing Epithelial Tissue

1. Identify epithelial tissues
 - a. Using the prepared slides provided, find examples of each of the types of epithelial tissue.
 - b. Adjust focus and magnification as needed following the procedures above.
2. Document observations
 - a. Observe, draw, and label the six types of epithelial tissues.
 - b. Label the important cellular components where present:
 - Apical surface
 - Basal surface
 - Nucleus
 - Cell membrane
 - Cilia or microvilli (if applicable)

Important Observation Note

Since you are looking at slides from an organ or area of the body, you will often see multiple types of tissue present and even multiple types of epithelial tissue. Try to look for a pattern in the tissue and not just one or two cells. Survey the entire slide to find a section that best represents the tissue you are trying to identify.

5.5: Activity 1

Epithelial Tissues

Directions: Microscopic observations of prepared slides for identification of epithelial tissues and drawings. Drawings should be done in pencil and may be colored. The field of view should be filled.

5.5.1 Simple Squamous Epithelium

1. Obtain a prepared slide named simple squamous/ lung section, focus using the scanning lens (4 times). Look for flat cells arranged around an empty space.
2. Position area at the center of microscopic field of view, and switch to the low power lens (10 times) and then switch to high power lens (40 times). Notice that the cells are flattened and irregular in shape with a prominent nucleus.
3. Make a drawing of the tissue on high power (total magnification 400 times) in the space.
4. Draw and label: apical surface, cells with nucleus, cell membrane, basement membrane.

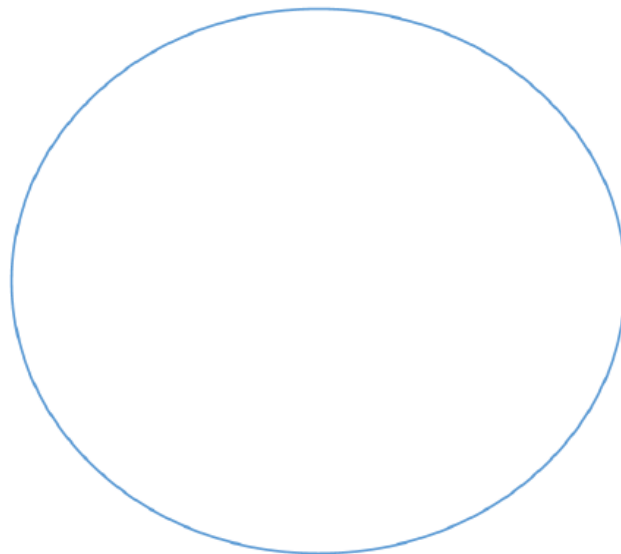


Figure 5.5.1: Draw or attach photograph of microscopic observations of Simple Squamous Epithelium in the space above and label/indicate: apical surface, cells with nucleus, cell membrane, basement membrane.

Fill in the table with information to establish structure-location -function relationships:

Table 5.5.1: Key Identification Features, Locations, and Functions of Simple Squamous Epithelial Tissue

Category	Details
Total Magnification	
Distinctive histological features for Identification of Simple Squamous Epithelial Tissue	
Locations	
Functions	

5.5.2 Simple Cuboidal Epithelium

1. Obtain a simple cuboidal (kidney) slide and bring into focus using the scanning lens (4 times). Look for squarish cells with dark nuclei, arranged in a circle.

2. Position them to the center of microscopic field of view, and switch to the low power lens (10 times) and then switch to the high power lens (40 times). Notice that the cells are flattened and irregular in shape with a prominent nucleus.
3. Make a drawing of the tissue on high power (total magnification 400 times) in the space.
4. Draw and label: apical surface, cells with nucleus, basement membrane.

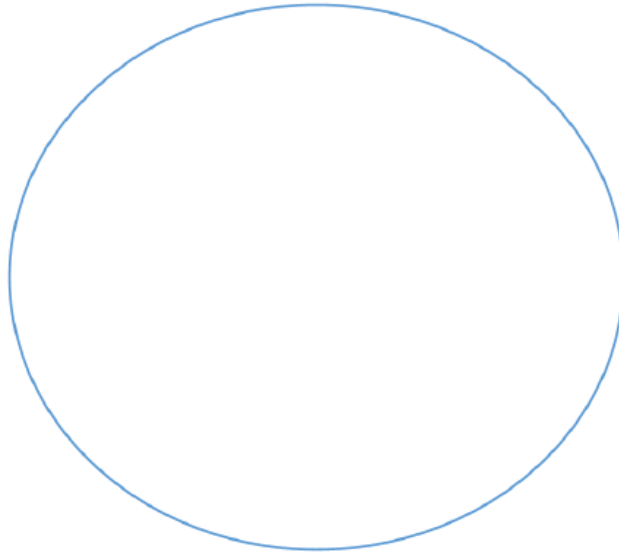


Figure 5.5.2: Draw or attach photograph of microscopic observations of Simple Cuboidal Epithelium in the space above and label/indicate: apical surface, cells with nucleus, cell membrane, basement membrane.

Fill in the table with information to establish structure-location -function relationships:

Table 5.5.2: Key Identification Features, Locations, and Functions of Simple Cuboidal Epithelium

Category	Details
Total Magnification	
Distinctive histological features for Identification of Simple Cuboidal Epithelium	
Locations	
Functions	

5.5.3 Simple Columnar Epithelium

1. Obtain a simple columnar (jejunum) slide and bring into focus using the scanning lens (4 times). Look for column - like cells with large, dark nuclei arranged in a neat row.
2. Position them to the center of microscopic field of view, and switch to the low power lens (10 times) and and then switch to the high power lens (40 times).
3. Make a drawing of the tissue on high power (total magnification 400 times) in the space.
4. Draw and label: apical surface, cells with nucleus, basement membrane.

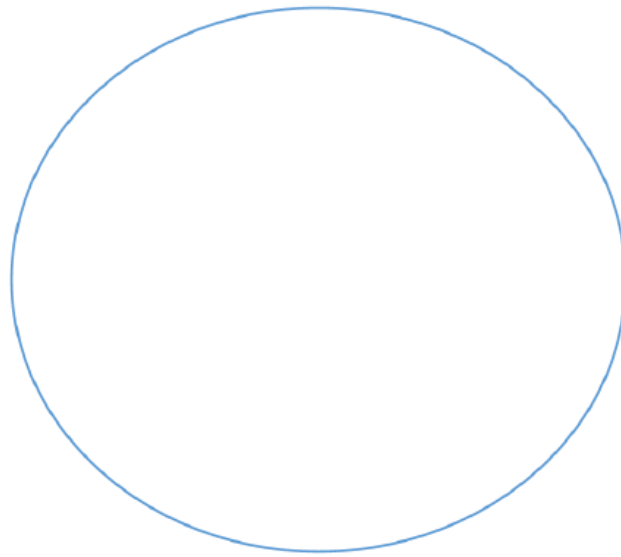


Figure 5.5.3: Draw or attach photograph of microscopic observations of Simple Columnar Epithelium in the space above and label/indicate: apical surface, cells with nucleus, cell membrane, basement membrane.

Fill in the table with information to establish structure-location -function relationships:

Table 5.5.3: Key Identification Features, Locations, and Functions of Simple Columnar Epithelium

Category	Details
Total Magnification	
Distinctive histological features for Identification of Simple Columnar Epithelium	
Locations	
Functions	

5.5.4 Ciliated Pseudostratified Columnar Epithelium

1. Obtain a pseudostratified columnar (trachea) slide and bring into focus using the scanning lens (4 times). Look for many dark nuclei toward the outer edge of the tissue.
2. Focus on the cells, position them to the center of your field of view, and switch to the low power lens (10 times) and then switch to the high power lens (40 times).
3. Draw and label: cilia, goblet cells, and nuclei (at different level).

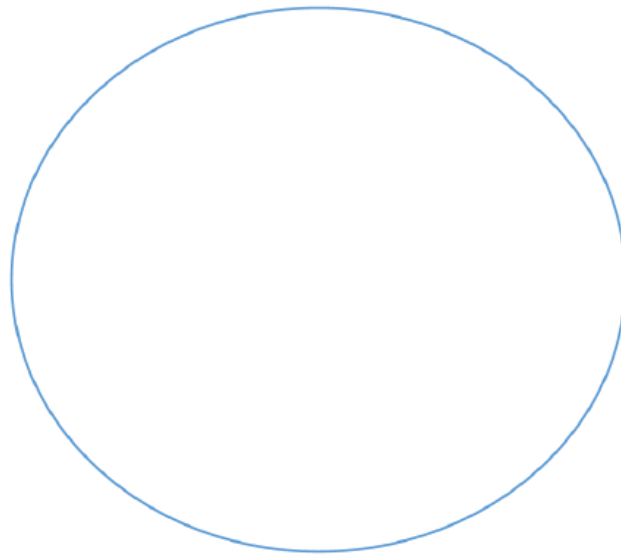


Figure 5.5.4: Draw or attach photograph of microscopic observations of Ciliated Pseudostratified Columnar Epithelium in the space above and label indicate: cilia, goblet cells, and nuclei (at different level).

Fill in the table with information to establish structure-location -function relationships:

Table 5.5.4: Key Identification Features, Locations, and Functions of Ciliated Pseudostratified Columnar Epithelium

Category	Details
Total Magnification	
Distinctive histological features for Identification of Ciliated Pseudostratified Columnar Epithelium	
Locations	
Functions	

5.5.5 Stratified Squamous Non-keratinized Epithelium

1. Obtain a prepared slide labeled Stratified Squamous Non-keratinized Epithelium or a slide representing vagina or esophagus and bring into focus using the scanning lens (4 times). Look for multiple cell layers in thickness, most superficial layer are squamous in shape and look like honeycomb with prominent nucleus, and it lacks keratinization at its free surface.
2. Position them to the center of microscopic field of view, and switch to the low power lens (10 times) and then switch to the high power lens (40 times).
3. Make a drawing of the tissue on high power (total magnification 400 times) in the space.
4. Draw and label: apical surface, cells with nucleus, basement membrane.

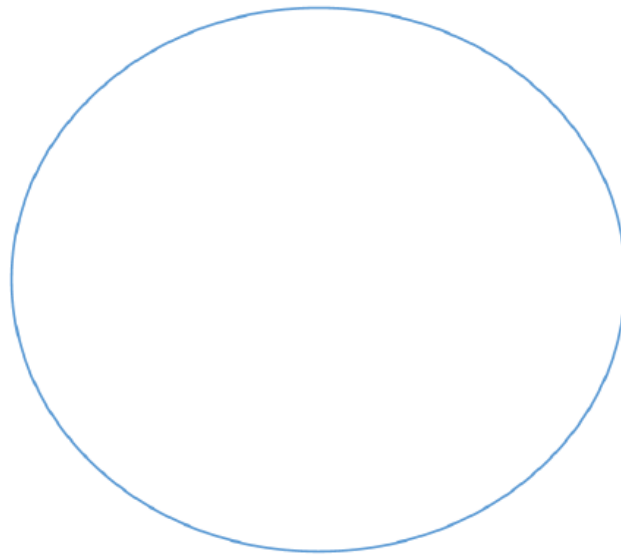


Figure 5.5.5: Draw or attach photograph of microscopic observations of Stratified Squamous Non-keratinized Epithelium in the space above and label/indicate: apical surface, cells with nucleus, basement membrane.

Fill in the table with information to establish structure-location -function relationships:

Table 5.5.5: Key Identification Features, Locations, and Functions of Stratified Squamous Non-keratinized Epithelium

Category	Details
Total Magnification	
Distinctive histological features for Identification of Stratified Squamous Non-keratinized Epithelium	
Locations	
Functions	

5.5.6 Stratified Squamous Keratinized Epithelium

1. Obtain a prepared slide labeled Stratified Squamous keratinized Epithelium or a slide representing skin and bring into focus using the scanning lens (4 times). Look for multiple cell layers in thickness, most superficial layer are squamous in shape with keratin proteins represented by irregular layers.
2. Position them to the center of microscopic field of view, and switch to the low power lens (10 times) and then switch to the high power lens (40 times).
3. Make a drawing of the tissue on low power (10 times) and high power (40 times) in the space.
4. Draw and label: apical surface with dead cell, cells with nucleus, basement membrane.

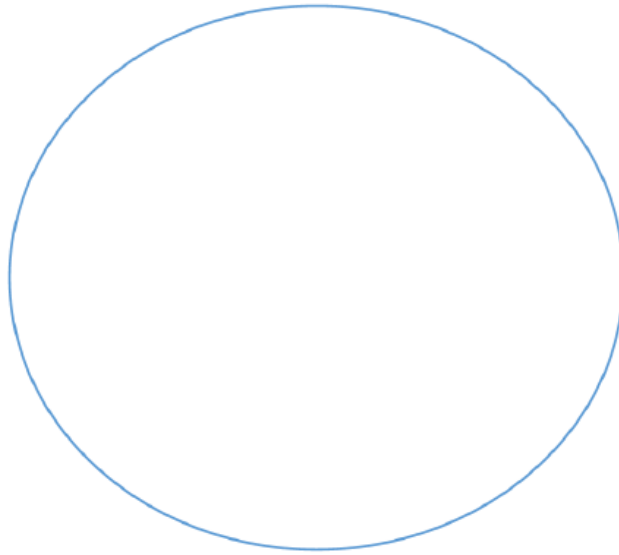


Figure 5.5.6: Draw or attach photograph of microscopic observations of Stratified Squamous keratinized Epithelium in the space above and label/indicate: apical surface with dead cell, cells with nucleus, basement membrane.

Fill in the table with information to establish structure-location -function relationships:

Table 5.5.6: Key Identification Features, Locations, and Functions of Stratified Squamous Keratinized Epithelium

Category	Details
Total Magnification	
Distinctive histological features for Identification of Stratified Squamous keratinized Epithelium	
Locations	
Functions	

5.5.7 Transitional Epithelium

1. Obtain a transitional (urinary bladder) slide and bring into focus using the scanning lens (4 times). Look for many layers of cells surrounding the central space (lumen).
2. Focus on the cells, position them to the center of your field of view, and then switch to the low power lens (10 times) and then switch to the high power lens (40 times).
3. Draw and label: apical surface, cells with nucleus, cell membrane, basement membrane.

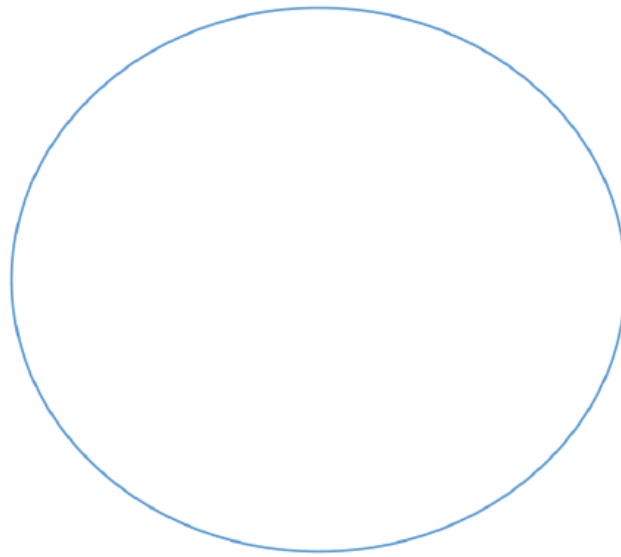


Figure 5.5.7: Draw or attach photograph of microscopic observations of Transitional Epithelium in the space above and label/indicate: apical surface, cells with nucleus, cell membrane, basement membrane.

Fill in the table with information to establish structure-location -function relationships:

Table 5.5.7: Key Identification Features, Locations, and Functions of Transitional Epithelium

Category	Details
Total Magnification	
Distinctive histological features for Identification of Transitional Epithelium	
Locations	
Functions	

5.6: Activity 2

Connective Tissue

In this lab, we will explore the classification of connective tissues, identifying key structural and functional differences. Connective tissue provides support, protection, and integration within the body, and is characterized by specialized cells, extracellular matrix (ECM), fibers, and ground substance.

Background

Connective tissue is the most diverse group of tissues. It can be a fluid (blood) or solid (bone). It includes tissues with high tensile strength like tendons (dense regular connective tissue), and flexible tissue like elastic cartilage or elastic tissue. Moreover, unlike epithelial tissue that consists of highly organized, tightly packed cells, connective tissue often appears disorganized. Given its structural diversity, what is common to all these tissues? All connective tissue consists of cells surrounded by extracellular matrix. The most common cell is the fibroblast. Fibroblasts are responsible for producing the extracellular matrix and collagen fibers. Other cell types exist like chondrocytes in cartilage, osteocytes in bone, and the blood cells common in blood. The extracellular matrix, in turn, is made up of different fibers and a gel-like material, called “ground substance.” The most common fibers are collagen, elastic, and reticular. All of these protein fibers give the connective tissue its tensile strength. However, each type of fiber has different properties that contribute to the different connective tissue functions. Collagen is the most common fiber and can be described as long cables. Collagen fibers are flexible and provide a lot of tensile strength. Elastic fibers typically appear wavy and have the ability of being able to stretch and recoil. Reticular fibers are short and branched. Reticular fibers form a mesh to anchor and support the embedded cells.

Different ground substances allow some connective tissue to be fluid like blood, gel-like like cartilage, or hard, like bone. Here you will investigate eleven of the thirteen different types of connective tissue. Each has its own unique combination of cells and extracellular matrix, and its own combination of fiber and ground substance types.

Categories of Connective Tissues: Structure, Function, and Location

Connective tissues exhibit a remarkable diversity in their structure and function, enabling them to perform a wide array of vital roles throughout the body, from providing structural support to facilitating nutrient exchange and defending against pathogens. Their unique extracellular matrix, which can vary significantly in composition and organization, is key to these diverse functions and relationships with their locations in the body.

I. Connective Tissue Proper

1. Loose Connective Tissue - Provides support and flexibility, with a high proportion of ground substance and fewer fibers.
 - a. Areolar Tissue
 - Loose arrangement of collagen and elastic fibers; fibroblasts are the primary cells.
 - Binds skin to underlying tissues, supports blood vessels, fills spaces.
 - Location: Under epithelial layers, surrounding organs and blood vessels.
 - b. Adipose Tissue
 - Large, fat-storing adipocytes with minimal ECM.
 - Energy storage, insulation, and cushioning.
 - Location: Under skin (subcutaneous fat), around organs (visceral fat).
 - c. Reticular Tissue
 - Reticular fibers forming a mesh-like framework.
 - Structural support for lymphatic and hematopoietic organs.
 - Location: Lymph nodes, spleen, bone marrow.
2. Dense Connective Tissue – Contains abundant fibers, making it stronger and more resistant to stretching.
 - A. Dense Regular Connective Tissue
 - Collagen fibers aligned in parallel, with fibroblasts.
 - Provides tensile strength in one direction.
 - Location: Tendons (muscle to bone), ligaments (bone to bone).
 - B. Dense Irregular Connective Tissue

- Collagen fibers arranged in multiple directions.
 - Resists multi-directional stress.
 - Location: Dermis of skin, joint capsules, organ coverings.
 - C. Elastic Connective Tissue
 - elastic fibers, allowing stretch and recoil.
 - Maintains shape with flexibility.
 - Location: Large arteries (aorta), lungs, vocal cords.
- II. Supportive Connective Tissue
- A. Hyaline Cartilage
 - Glassy matrix, chondrocytes in lacunae.
 - Provides smooth surfaces for joints, flexibility, and support.
 - Location: Nose, trachea, fetal skeleton, articular cartilage.
 - B. Elastic Cartilage
 - Elastic fibers in matrix.
 - Allows repeated bending while maintaining shape.
 - Location: External ear, epiglottis.
 - C. Fibrocartilage
 - Dense collagen fibers in matrix.
 - Absorbs shock, resists compression.
 - Location: Intervertebral discs, pubic symphysis, knee menisci.
 - D. Bone (Osseous Tissue)
 - Hard calcified ECM, arranged in osteons.
 - Supports body, protects organs, stores calcium.
 - Location: Skeleton (compact and spongy bone).
- II. Fluid Connective Tissue
- A. Blood
 - Fluid plasma matrix with red blood cells, white blood cells, and platelets.
 - Transport oxygen, nutrients, immune defense.
 - Location: Blood vessels, heart.
 - B. Lymph
 - Clear fluid, fewer cells than blood.
 - Returns interstitial fluid to circulation, immune function.
 - Location: Lymphatic vessels, lymph nodes.

Hints to identify connective tissue proper on a slide

- First determine that you are observing connective tissue, not epithelial tissue. Cells of connective tissue are not tightly packed like epithelial tissue; cells will appear scattered. Connective tissue will lack a free edge, as it lies under other tissues.
- Determine if you have fluid, supportive, loose, or dense connective tissue type. To distinguish among the loose and dense connective tissue subtypes Figure 5.6.1 and Figure 5.6.2, pay close attention to the density of the fibers and the appearance of the cells. Use the decision tree Figure 5.6.3 to help you.

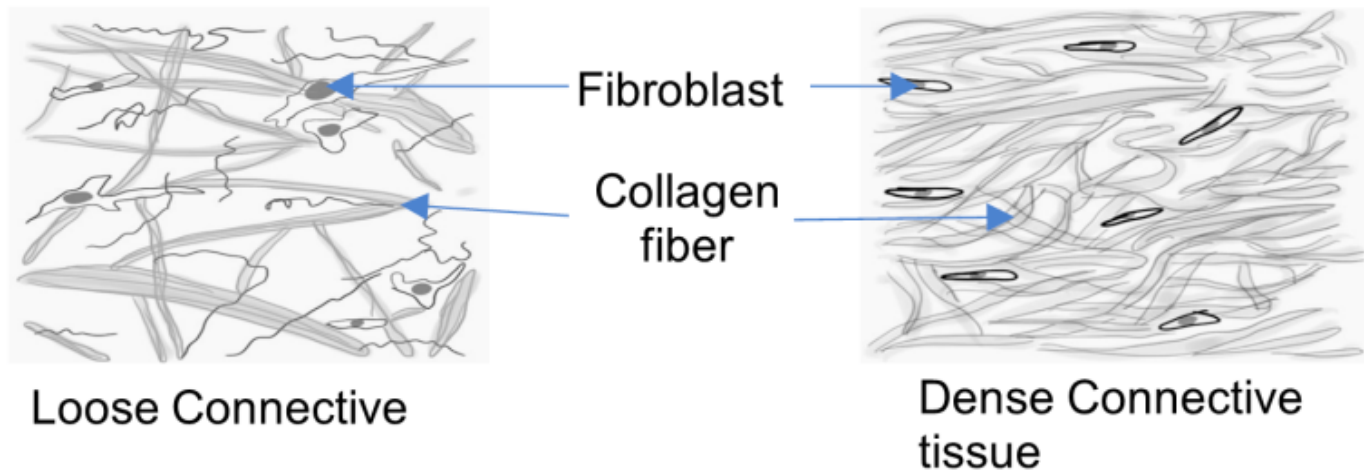


Figure 5.6.1: Diagram comparing loose connective tissue, with a sparse extracellular matrix and more cells, to dense connective tissue, characterized by a tightly packed extracellular matrix and fewer cells. (CC BY-NC-SA 4.0; via PressBooks).

Figure 5.6.1 compares two types of connective tissue: loose connective tissue and dense connective tissue.

- Left Side – Loose Connective Tissue:
 - Labeled as "Loose Connective." Contains fibroblasts (cells that produce fibers) and collagen fibers.
 - The fibers are loosely arranged, allowing flexibility and space for blood vessels and other structures.
- Right Side – Dense Connective Tissue:
 - Labeled as "Dense Connective Tissue."
 - Also contains fibroblasts and collagen fibers.
 - The fibers are densely packed, providing strength and resistance to stretching.

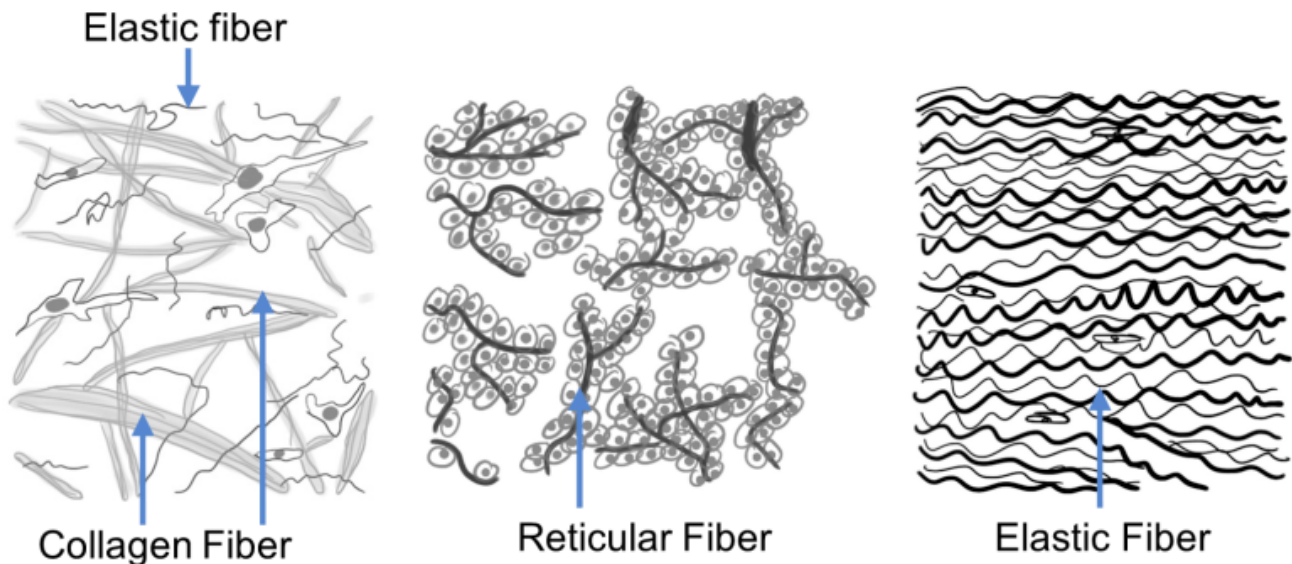


Figure 5.6.2: Diagram showing diverse protein fibers in connective tissue proper's extracellular matrix, including collagen, elastic, and reticular fibers, each providing distinct structural support and flexibility. (CC BY-NC-SA 4.0; via PressBooks).

Figure 5.6.2 illustrates three types of connective tissue fibers, each shown with a labeled diagram

1. Collagen Fiber (left side): Depicted as thick, wavy lines.
 - Provides strength and structure to tissues.
 - Includes thinner lines labeled "Elastic fiber" interspersed among the collagen.
2. Reticular Fiber (center):

- Shown as a network of interconnected circular structures.
 - Forms a supportive mesh in soft tissues like lymph nodes and bone marrow.
3. Elastic Fiber (right side):
- Illustrated as parallel wavy lines.
 - Allows tissues to stretch and return to their original shape, found in skin, lungs, and blood vessels.
 - Blue arrows in the image point to each fiber type, helping to visually distinguish their structure and function.

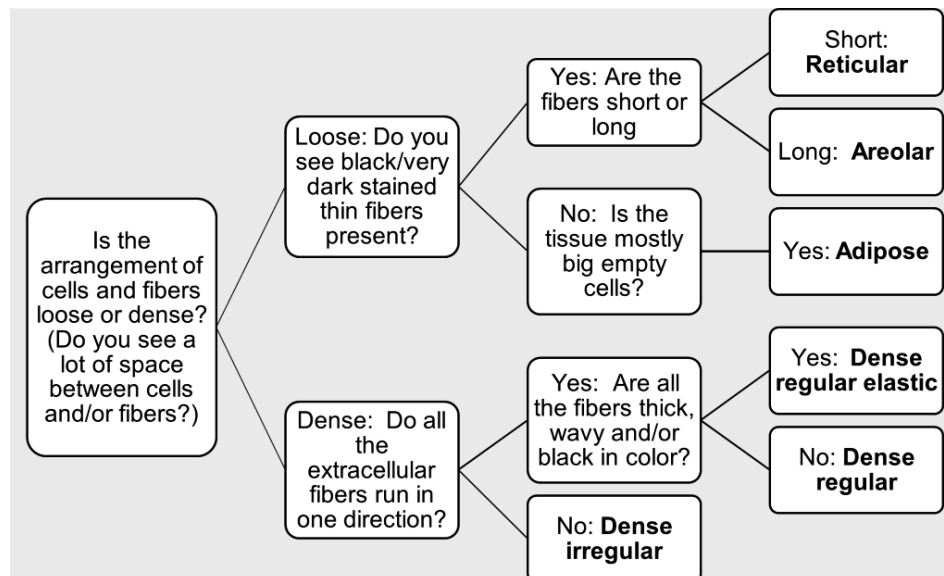


Figure 5.6.3: Decision tree diagram for identifying loose and dense connective tissue subtypes, outlining characteristics distinguishing between areolar, adipose, reticular, regular, irregular, and elastic tissues. (CC BY-NC-SA 4.0; via PressBooks).

Figure 5.6.3 presents a microscopic view of connective tissue, accompanied by a decision tree-style guide to help identify the tissue type based on visual characteristics. The guide prompts the viewer to assess:

- Cell and fiber arrangement:
 - Is the tissue loose (with visible space between cells and fibers)?
 - Or is it dense (with tightly packed fibers and cells)?
- Fiber characteristics in loose tissue:
 - If thin, dark-stained fibers are present:
 - Short fibers suggest reticular tissue.
 - Long fibers suggest areolar tissue.
 - If the tissue consists mostly of large, empty-looking cells, it is likely adipose tissue.
- Fiber orientation in dense tissue:
 - If fibers run in one direction:
 - Thick, wavy, dark fibers indicate dense regular elastic tissue. Otherwise, it is dense regular tissue.
 - If fibers run in multiple directions, the tissue is dense irregular.

Procedure:

Observe, draw, and label the connective tissue proper and label the important cell and fiber types typical of that tissue. Some examples include: type of cell (ex: fibroblast), fiber type (elastic, collagen, and/or reticular), and ground substance.

5.6.1 Areolar tissue

1. Obtain a prepared slide labeled areolar connective tissue and bring into focus using the scanning lens (4 times). Look for the density and types of fibers and cells multiple.
2. Position them to the center of microscopic field of view, and switch to the low power lens (10 times) and then switch to the high power lens (40 times), if needed (optional).
3. Draw and label, all fiber types of present:
 - Elastic

- Reticular
- Collagen

4. Record detail observations based on total magnification in the Table 5.6.1.

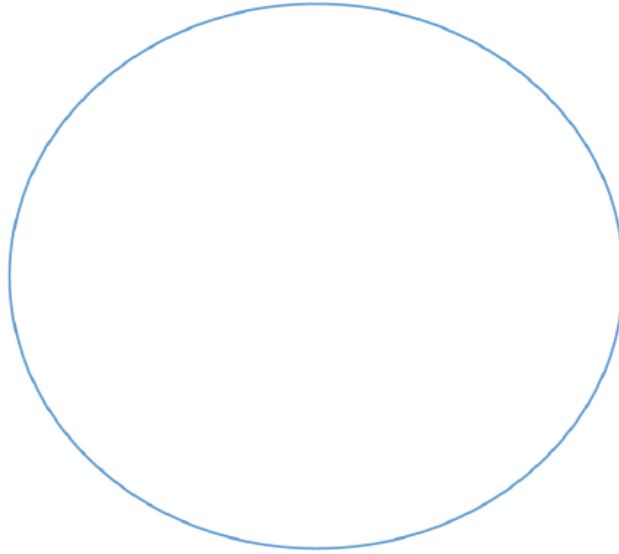


Figure 5.6.4: Document microscopic observations of Areolar Connective Tissue by drawing or attaching photograph in the space above.

Table 5.6.1: Key Identification Features, Locations, and Functions of Areolar tissue

Category	Details of Observation
Total Magnification	

5.6.2 Adipose tissue

1. Obtain a prepared slide labeled adipose tissue or skin and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to the high power lens (40 times), if needed (optional).
2. Cells of adipose tissue are filled with fat and triglycerides, which do not stain well, thus the cells appear mostly empty. The nuclei are pushed to the side of the cell and the cell edges have a dark margin. Nuclei are visibly stained along the cell margins and there is no extracellular spaces visible within the tissue.
3. Draw and label the cell membrane, nucleus and the space.
4. Record detail observations based on total magnification in the Table 5.6.2.

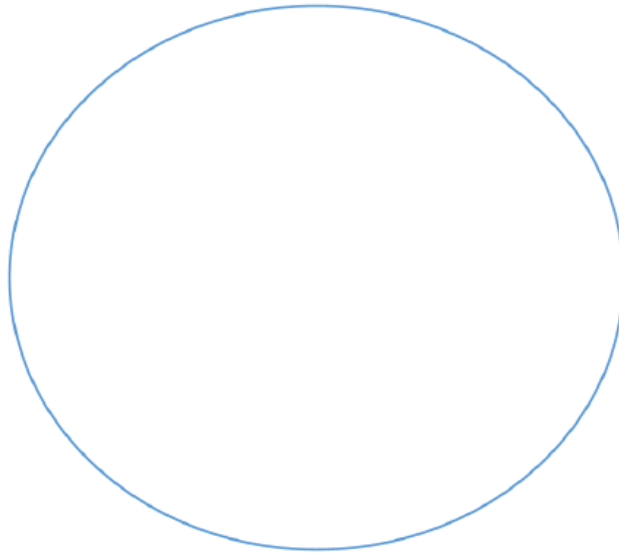


Figure 5.6.5: Document microscopic observations of Adipose Tissue by drawing or attaching photograph in the space above.

Table 5.6.2: Key Identification Features, Locations, and Functions of Adipose tissue

Category	Details of Observation
Total Magnification	

5.6.3 Dense Regular Collagenous

1. Obtain a prepared slide labeled dense regular connective tissue or tendon or ligament and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to the high power lens (40 times), if needed (optional).
2. You will be looking to the thick, collagenous bundles of the tendon run parallel to each other, slight waviness of the tissue is due to fixation. Rows of fibroblasts with heterochromatic nuclei are aligned between the collagenous bundles.
3. Draw and label the collagen fibers as they appear and the fibroblasts.
4. Record detail observations based on total magnification in the Table 5.6.3.

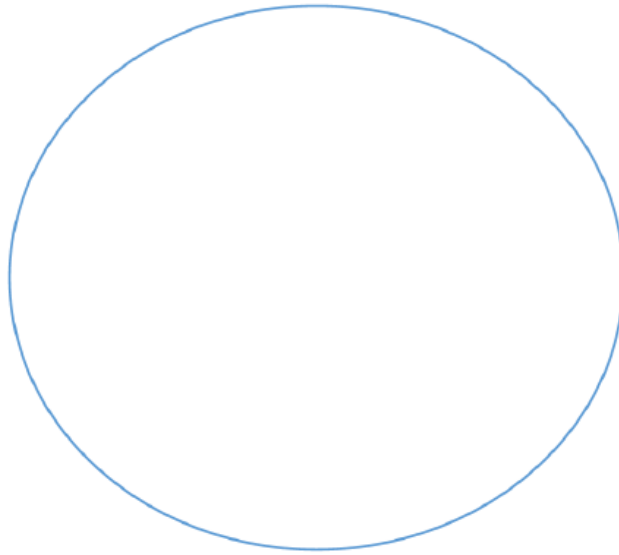


Figure 5.6.6: Document microscopic observations of Dense Regular Collagenous Tissue by drawing or attaching photograph in the space above.

Table 5.6.3: Key Identification Features, Locations, and Functions of Dense Regular Collagenous

Category	Details of Observation
Total Magnification	

5.6.4 Dense irregular collagenous

1. Obtain a prepared slide labeled dense irregular connective tissue or skin (focus on dermis) and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to the high power lens (40 times), if needed (optional).
2. You will be looking under the stratified squamous epithelium examined earlier is the dense irregular connective tissue of the dermis. Its thick collagenous (type I) bundles stain intensely with eosin and can be seen to course in various directions.
3. Draw and label the collagen fibers as they appear and the fibroblasts.
4. Record detail observations based on total magnification in the Table 5.6.4.

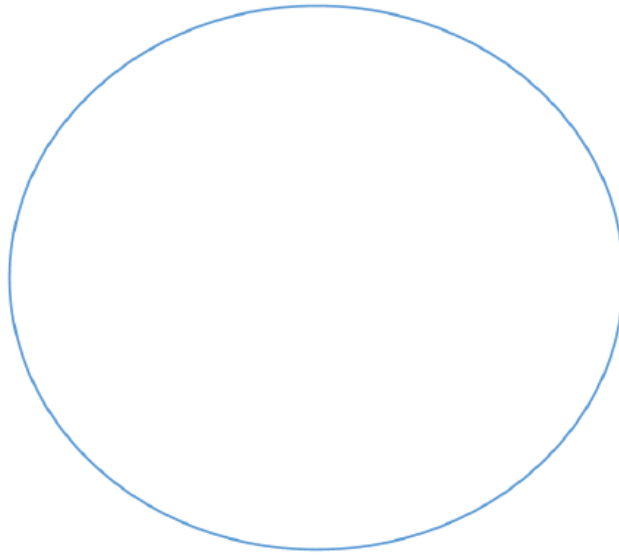


Figure 5.6.7: Document microscopic observations of Dense Irregular Connective Tissue by drawing or attaching photograph in the space above.

Table 5.6.4: Key Identification Features, Locations, and Functions of Dense Irregular Collagenous

Category	Details of Observation
Total Magnification	

5.7: Activity 3

Supportive Connective tissue

Background

In this activity, we investigate the cells, fibers, and ground substance typical of supportive and fluid connective tissue. Supportive connective tissue consists of compact bone, spongy bone and three types of cartilage (hyaline cartilage, elastic cartilage, and fibrocartilage). We will investigate all of these except spongy bone in this activity.

Bone connective tissue has cells called osteocytes. They live within cavities called lacunae. The cells of cartilage are called chondrocytes. They, too, live within lacunae. Collagen is the most common fiber type found in compact bone, spongy bone and fibrocartilage; elastic fibers are embedded in elastic cartilage. The ground substance of the supportive tissues sets these tissues apart from other connective tissues.

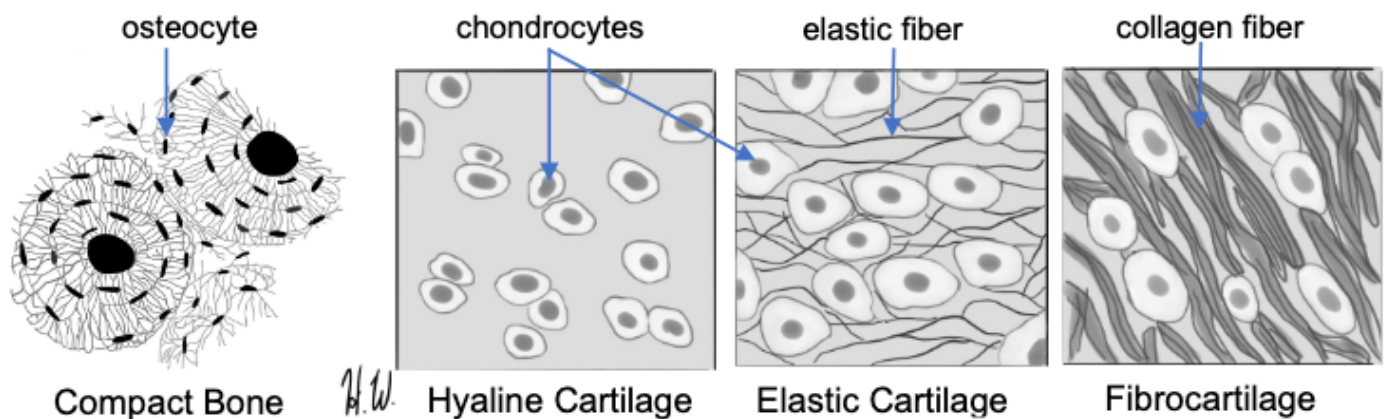


Figure 5.7.1: Examples of four types of supportive connective tissue - compact bone, hyaline cartilage, elastic cartilage and fibrocartilage. (CC BY-NC-SA 4.0; via PressBooks).

Figure 5.7.1 displays four types of connective tissues, each labeled with key structural components:

1. Compact Bone:
 - Contains osteocytes, which are bone cells embedded in a hard matrix.
 - An arrow points to an osteocyte within the circular bone structure.
2. Hyaline Cartilage:
 - Contains chondrocytes, the cells responsible for producing cartilage.
 - These cells are located in small spaces called lacunae within a smooth, glassy matrix.
 - An arrow points to the chondrocytes.
3. Elastic Cartilage:
 - Contains elastic fibers, which provide flexibility.
 - These fibers are visible within the cartilage matrix and are labeled with an arrow.
4. Fibrocartilage:
 - Contains collagen fibers, which provide strength and support.
 - An arrow points to the dense, wavy collagen fibers within the matrix.
 - There is also a small signature labeled "H.W." beneath the Hyaline Cartilage section, likely indicating the creator of the diagram.

Bone and cartilage each have a unique matrix, made of different ground substances. Compact bone contains a hardened calcified matrix. The ground substance is rigid due to the inorganic calcium salts deposited amongst the collagen fibers. Another unique characteristic of compact bone is its arrangement in concentric rings called osteons. All three cartilage types (hyaline cartilage, elastic cartilage and fibrocartilage) have a gel like, squishy ground substance made of glycosaminoglycans such as hyaluronic acid and chondroitin sulfate. This slippery, putty-like ground substance makes cartilage flexible and a good cushion. The fiber content varies from few collagen fibers (hyaline cartilage) to many collagen fibers (fibrocartilage) or perhaps elastic fibers instead

(elastic cartilage).

Fluid connective tissue, blood, has a ground substance composed mainly of water, called plasma. The watery plasma contains dissolved proteins and electrolytes. The blood cells (red blood cells, white blood cells, and platelets) are suspended in the plasma. There are no fibers to speak of in normal blood. Red blood cells are anucleate (no nucleus), white blood cells have uniquely shaped nucleus, and platelets are small, cell fragments.

Hints to Identify Supportive Connective Tissue Types

- Cartilage
 - Look closely at the size of the cells. If the cells have prominent nuclei and are larger you have cartilage. To determine which of the three types of cartilage it is, determine the differences in the density and appearance of their fibers. Cartilage without prominent fibers visible is hyaline cartilage. Prominent collagen fibers are embedded in fibrocartilage, and prominent embedded elastic fibers make up elastic cartilage.
- Compact Bone
 - If the cells are small, it is likely compact bone. Compact bone has the distinctive characteristic that the cells are arranged in concentric rings, a structure called an osteon. Use the decision tree to distinguish among the supportive connective tissue types.

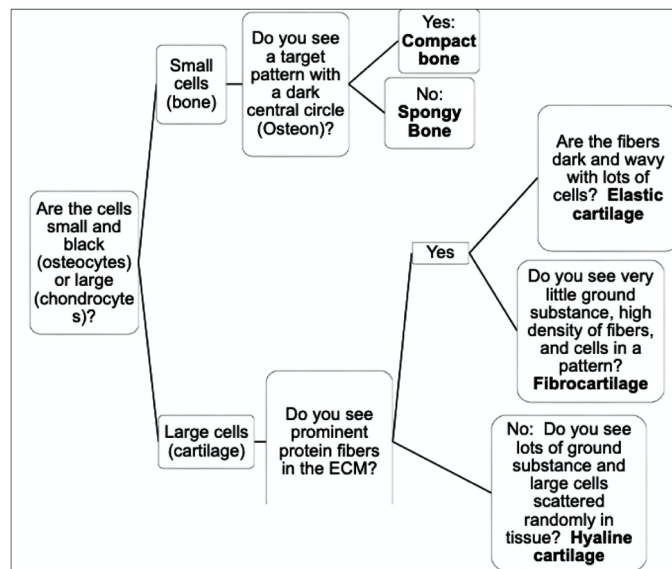


Figure 5.7.2: Flowchart for classifying bone and cartilage tissues based on cell type, structural patterns, and fiber content. (CC BY-NC-SA 4.0; via PressBooks).

Figure 5.7.2 presents a microscopic view of connective tissue, accompanied by a decision tree-style guide to help identify the tissue type based on visual characteristics.

The guide prompts the viewer to assess:

- Cell and fiber arrangement:
 - Is the tissue loose (with visible space between cells and fibers)?
 - Is it dense (with tightly packed fibers and cells)?
- Fiber characteristics in loose tissue:
 - If thin, dark-stained fibers are present:
 - Short fibers suggest reticular tissue.
 - Long fibers suggest areolar tissue.
- If the tissue consists mostly of large, empty-looking cells, it is likely adipose tissue. Fiber orientation in dense tissue:
 - If fibers run in one direction then it is thick, wavy, dark fibers indicate dense regular elastic tissue.
 - Otherwise, it is dense regular tissue.
 - If fibers run in multiple directions, the tissue is dense irregular.

5.7.1 Hyaline cartilage

1. Obtain a prepared slide labeled hyaline cartilage or trachea and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to the high power lens (40 times), if needed (optional).
2. Draw and describe observation by answering the following questions.

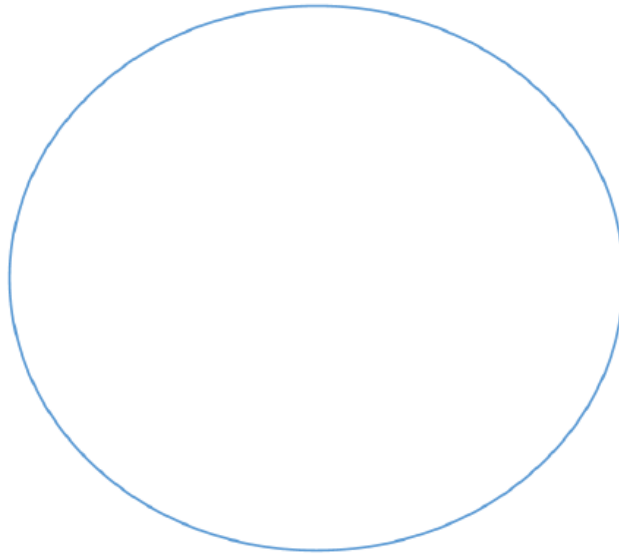


Figure 5.7.3: Document microscopic observations of Hyaline cartilage by drawing or attaching photograph in the space above.

Table 5.7.1: Table for recording microscopic observations of hyaline cartilage tissue.

Observation Criteria	Your Observation
Cell type(s) common	
Type of fiber present (if any)	
Are they clearly visible?	
Total Magnification	

5.7.2 Elastic Cartilage

1. Obtain a prepared slide labeled Elastic cartilage or trachea and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to high power lens (40 times), if needed (optional).
2. Draw and describe observation by answering the following questions.

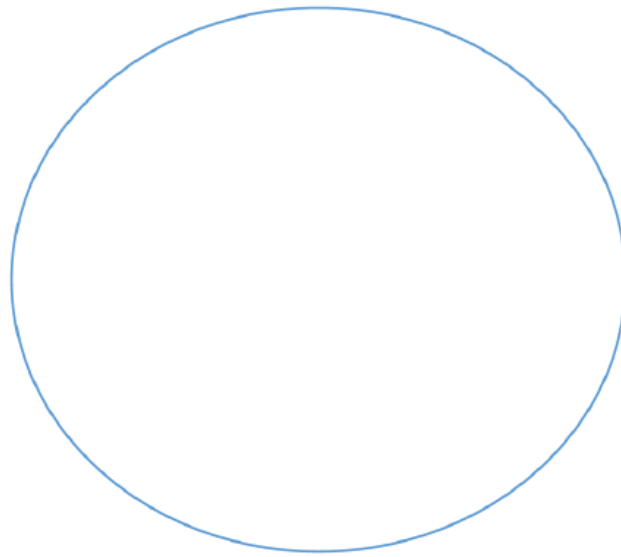


Figure 5.7.4: Document microscopic observations of Elastic cartilage by drawing or attaching photograph in the space above.

Table 5.7.2: Table for recording microscopic observations of Elastic cartilage tissue.

Observation Criteria	Your Observation
Cell type(s) common	
Type of fiber present (if any)	
Are they clearly visible?	
Total Magnification	

5.7.3 Fibrocartilage

Fibrocartilage can be considered as a transitional type of tissue, between hyaline cartilage and dense collagenous connective tissue, and it occurs in regions where support and great tensile strength are desirable like intervertebral disc.

1. Obtain a prepared slide labeled Fibrocartilage and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to high power lens (40 times), if needed (optional).
2. Draw and describe observation by answering the following questions.

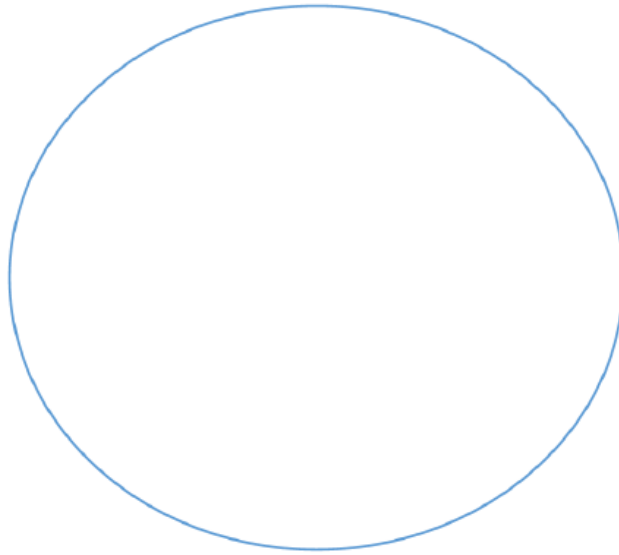


Figure 5.7.5: Document microscopic observations of Fibrocartilage Elastic cartilage by drawing or attaching photograph in the space above.

Table 5.7.3: Table for recording microscopic observations of Fibrocartilage tissue.

Observation Criteria	Your Observation
Cell type(s) common	
Type of fiber present (if any)	
Are they clearly visible?	
Total Magnification	

5.7.4 Compact bone

1. Obtain a prepared slide labeled ground bone tissue or and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to high power lens (40 times), if needed (optional).
2. Observe the slide carefully to relate to the following description.
 - Haversian Systems (osteons) are distinctive structural units of compact bone that reflect the developmental and nutritive pattern of its lamellar configuration. Haversian systems consist of Haversian canals containing blood vessels and nerves surrounded by concentric lamellae of bone. Lacunae lie between or within the lamellae. In life these lacunae are occupied by osteocytes. Lacunae are connected with each other, and ultimately with the perivascular spaces of the Haversian canal, by canaliculi. This communicating system of canaliculi is essential for exchange of gases and metabolites between the osteocytes and the perivascular spaces of the Haversian canal. Volkmann's canals, which also contain vessels and nerves, are larger in diameter than Haversian canals and run perpendicularly to them.
3. Draw and label osteon, Haversian canal, osteocytes in lacunae, concentric lamella.

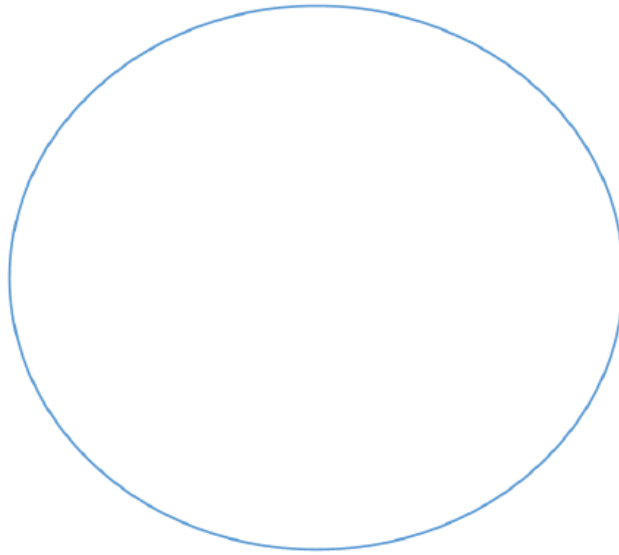


Figure 5.7.6: Document microscopic observations of Ground Bone Tissue by drawing or attaching photograph in the space above. Label/indicate osteon, Haversian canal, osteocytes in lacunae, concentric lamella.

5.7.5 Blood

1. Obtain a prepared slide labeled blood smear and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to high power lens (40 times), if needed (optional).
2. Draw and describe observation by answering the following questions.

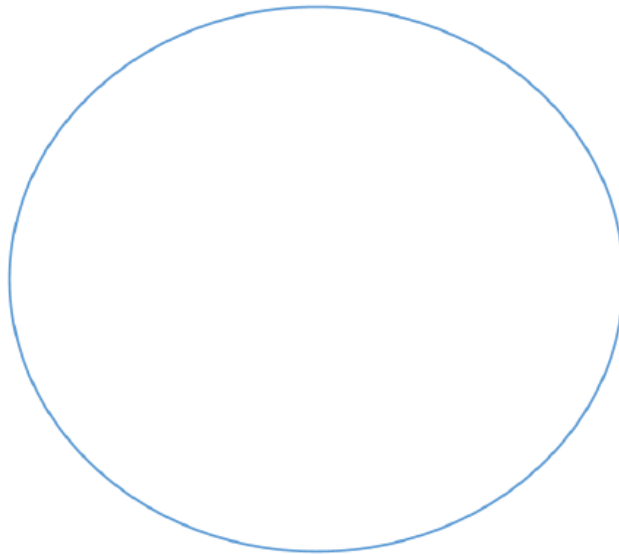


Figure 5.7.7: Document microscopic observations of formed elements of blood by drawing or attaching photograph in the space above.

Table 5.7.4: Table for recording microscopic observations of Fibrocartilage tissue.

Observation Criteria	Your Observation
Type of fiber present (if any)	
What is the ground substance of this tissue called?	
Name three specific cell/formed element types you observe	
Total Magnification	

5.8: Activity 4

Muscle Tissue

Background

Muscle tissue is a collection of cells that can contract (shorten), and thus generate a force. The cells in muscle tissue are excitable and require a stimulus. Muscle tissue can be characterized based on the presence of striations, cell shape, number of nuclei, location in body, and innervation type. The three types of muscle tissue are skeletal, cardiac, and smooth Figure 5.8.1. Muscle tissue contains protein fibers which help the cells contract. When the protein fibers are densely packed and arranged in an organized fashion, striations, or a striped appearance, this type of tissue is defined as striated muscle tissue. Both skeletal and cardiac muscle have striations. Smooth muscle tissue has protein fibers, but they are dispersed through the cell and are not clearly visible. Cardiac muscle has a distinct branching pattern and darkly stained bodies called intercalated discs at the cell junctions.

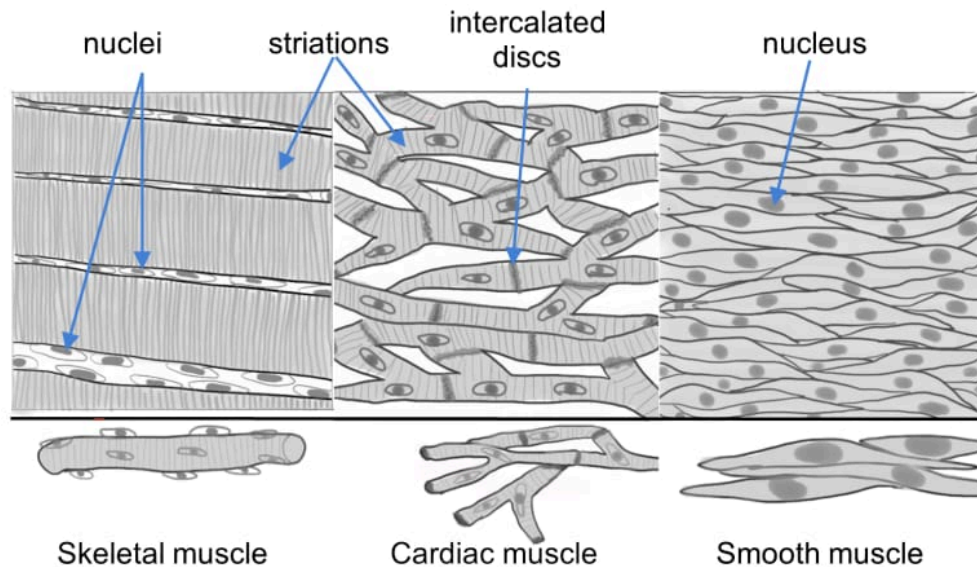


Figure 5.8.1: Microscopic images of skeletal, cardiac, and smooth muscle, highlighting their structural differences. Skeletal muscle shows multiple nuclei and striations; cardiac muscle features striations and intercalated discs; smooth muscle has a single nucleus and lacks striations (CC BY-NC-SA 4.0; via PressBooks).

Figure 5.8.1 presents three types of muscle tissue, each labeled with key structural features and accompanied by simplified illustrations:

1. **Skeletal Muscle:**
 - Shows multiple nuclei per cell.
 - Contains striations, which are alternating light and dark bands.
 - Typically found in muscles attached to bones and responsible for voluntary movement.
2. **Cardiac Muscle:**
 - Displays intercalated discs, which are specialized connections between cells that help coordinate contractions.
 - Cardiac muscle also contains striations.
 - Found only in the heart and responsible for pumping blood.
3. **Smooth Muscle:**
 - Contains a single, centrally located nucleus per cell.
 - Lacks striations, giving it a smooth appearance.
 - Found in walls of internal organs like the stomach, intestines, and blood vessels, and responsible for involuntary movements.

- Each tissue type is paired with a simplified illustration to visually reinforce its structure and function

Hints to identify muscle tissue

1. Smooth Muscle: Look closely for the presence of striations (striped appearance). If the tissue lacks striations, it is smooth muscle.
2. Skeletal Muscle: If the tissue is striated and has long parallel cells, it is skeletal muscle.
3. Cardiac Muscle: If it has striations and short, branched cells and darkly stained borders between cells (called intercalated disks), it is cardiac muscle tissue.
4. Use the decision tree to help you distinguish among these tissue types Figure 5.8.2.

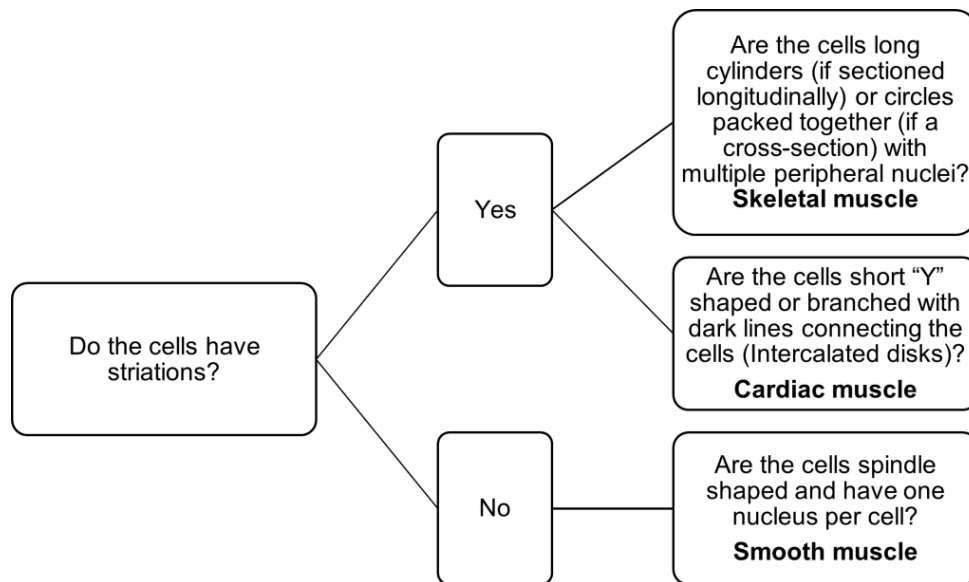


Figure 5.8.2: Decision tree diagram for identifying muscle tissue types, distinguishing between skeletal, cardiac, and smooth muscle based on characteristics like striations, nuclei, and cell shape. (CC BY-NC-SA 4.0; via PressBooks).

Figure 5.8.2 presents a microscopic view of connective tissue, accompanied by a diagnostic decision guide for identifying bone and cartilage types based on cellular and structural features. The guide prompts the viewer to assess:

- Cell size and type:
 - Small, dark cells suggest osteocytes, indicating bone tissue.
 - Large cells suggest chondrocytes, indicating cartilage tissue.
- Bone tissue identification:
 - If a target-like pattern with a dark central circle is visible, the tissue is compact bone.
 - If no such pattern is present, the tissue is spongy bone.
- Cartilage tissue identification:
 - If prominent protein fibers are visible in the extracellular matrix (ECM):
 - Dark, wavy fibers with many cells suggest elastic cartilage.
 - Dense fibers with minimal ground substance and patterned cells suggest fibrocartilage.
 - If the ECM has abundant ground substance and randomly scattered large cells, the tissue is hyaline cartilage.

Instructions

1. Obtain a prepared slide labeled either composite muscle tissue (has all three muscle types) or individually labeled muscle slides and bring into focus using the scanning lens (4 times) and switch to the low power lens (10 times) and then switch to the high power lens (40 times).
2. Draw each type and describe observation by complete the table 5.8.3 using the background information and images.

Skeletal muscle tissue

Cardiac muscle tissue

Smooth muscle tissue

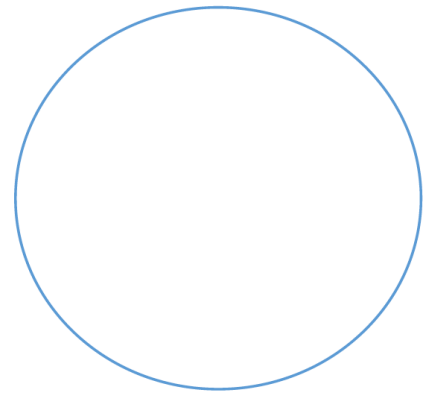
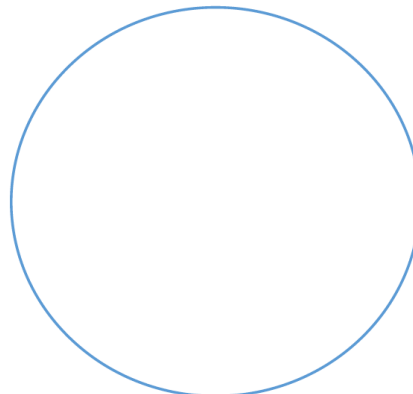
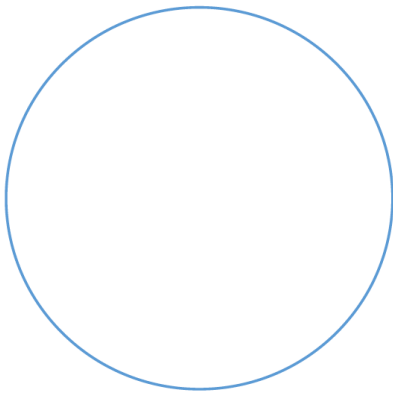


Figure 5.8.3: Create clear and accurate drawings/photographs of what you see under the microscope for each muscle tissue type in the spaces (representing microscopic fields) above. Drawings should reflect the relative sizes, shapes, and arrangements of cells and other structures within the tissue. Focus on Key Features.

Observations

Table 5.8.1 : Three Muscle Types

	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Are striations present?			
Number of nuclei			
Intercalated disc present?			
Cell shape			

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Key Terms and Definitions

- **Adipocytes** - mature cells found in adipose (fat) tissue - filled with a large storage sac of lipid. The lipid in these cells does not stain well with H&E staining, so the cells appear empty.
- **Agranulocytes** - without prominent-staining cytoplasmic granules.
- **Anucleate** - without a nucleus.
- **Apical** - the exposed side of epithelial tissue.
- **Aponeuroses** - connective tissue connections between to muscle groups.
- **Articular cartilage** - cartilage that surrounds the articular surface of bones (surfaces where bone meets bone to form a joint). This cartilage decreases friction in movement and provides cushioning.
- **Avascular** - without blood vessels.
- **Axon** - axon hillock of the cell body narrows to become the axon, which transmits electrical signals to the axon terminus to communicate with other cells.
- **Basal** - the anchored side of epithelial tissue.
- **Basement membrane** - a thin layer of connective tissue that anchors the cells of epithelial tissues to the deeper structures of our body.
- **Biconcave** - narrow in the center and thicker on the edges, RBC's are biconcave or shaped like a donut (if the icing touched in the center).
- **Bone matrix** - extracellular matrix containing collagen, calcium-binding proteins, calcium and phosphate depositions.
- **Branched** - branched cells will resemble the letter Y. A branched cell may connect to one cell on one end, but two cells on the other end.
- **Canaliculi** - meaning "tiny canal".
- **Cell body** - contains nucleus and organelles and serves as the biosynthetic center of the cell (synthesizes biological molecules)
- **Central canal** - running the length of the osteon, containing blood vessels and nerves.
- **Chondrocytes** - mature cells found in cartilage that monitor and maintain the cartilage extracellular matrix.
- **Cilia** - surface appendages found in some epithelial cells that move in a rhythmic manner to move mucous across the apical surface of the tissue.
- **Collagen** - a fibrous protein that has many structural types.
- **Columnar** - a tall, rectangular cell with an egg-shaped nucleus.
- **Cross section** - a transverse section, cutting perpendicular to the length of a structure. If cutting a tubular structure, a cross section would produce a ring of tissue.
- **Cuboidal** - a cube-shaped cell with a round nucleus.
- **Dendrites** - receive stimuli (signals/information) from environment or other neurons, which are conducted to the axon.
- **Dermis** - the deepest region of the skin (underlying the epidermis), consisting of two layers: the papillary layer is areolar connective tissue and the reticular layer is dense irregular connective tissue.
- **Elastic fibers** - provide elasticity to tissues - the ability to be pulled and recoil like a rubber band.
- **Erythrocytes** - red blood cells, biconcave cells lacking a nucleus and organelles that contain approximately 250 million molecules of hemoglobin.
- **Extracellular matrix (ECM)** - structural proteins and surrounding ground substance, and minerals that surround cells in our tissues, specifically connective tissues.
- **Fibroblasts** - cell type found in connective tissue that actively produces the proteins in the extracellular matrix.
- **Glial cells/Neuroglia** - cells that play an important role in supporting neurons and the nervous system.
- **Goblet cells** - uni-cellular mucous-producing gland found in epithelium.
- **Granulocytes** - contain prominent-staining cytoplasmic granules.
- **Ground substance** - consists of soluble proteins, nutrients, ions, waste products, dissolved gasses.
- **Hypodermis** - layer of connective tissue, primarily adipose tissue, located deep to the dermis.
- **Innervated** - having nerve endings for sensory or motor function.
- **Intercalated discs** - specialized cell-to-cell connections in cardiac muscle tissue containing gap junctions and desmosomes.
- **Involuntary** - under sub-conscious control, occurs without you thinking about it.
- **Keratinized** - containing keratin, a structural protein found in skin, hair, and nails.
- **Lacunae** - A gap, cavity, or depression. Osteocytes (bone) and chondrocytes (cartilage) are found within lacunae.
- **Lamellae** - sheets or layers.
- **Leukocytes** - white blood cells, function in immune response.

- **Longitudinal section** - cut along the long axis of a tissue.
- **Lumen** - the interior of a tube-shaped organ, like a blood vessel, kidney tubule, or intestines.
- **Lymphocytes** - a type of lymphocyte (white blood cell) that is part of our adaptive immune system (i.e., B-cells and T-cells).
- **Mesenchyme** - loosely arranged connective tissue in the embryo that originates from the mesoderm.
- **Multinucleated** - cell that contains many nuclei.
- **Neurons** - excitable cells that can receive and send electrical signals.
- **Nissl bodies** - granular substance in neuron cell body caused by the staining pattern of the rough ER.
- **Nucleated** - containing a nucleus.
- **Osteoblasts** - immature bone cells that deposit new bone matrix.
- **Osteocytes** - mature cells in bone tissue that monitor and maintain the osseous tissue matrix.
- **Osteogenic cells** - stem cells in bone that can form osteoblasts and osteocytes.
- **Osteons** - the functional unit in compact bone, consisting of a central (Haversian) canal surrounded by concentric rings/ layers of bone matrix called lamellae.
- **Perpendicular canals** - running at right angles to the central canal, containing blood vessels and nerves.
- **Plasma** - the fluid in blood, containing dissolved solutes such as: proteins, blood gasses (CO₂ and O₂), hormones, nutrients, waste products.
- **Platelets** - fragments of a cell precursor (megakaryocytes) that function to stop bleeding of a damaged blood vessel.
- **Polarity** - having two sides with different structural or functional characteristics.
- **Regeneration** - the ability of a tissue to repair itself or to replace old cells with new cells.
- **Regeneration capacity** - the ability of a tissue to repair or replenish itself.
- **Reticular fibers** - a specialized type of collagen that forms branching networks (branches on a tree) instead of long, linear strands.
- **Simple** - in epithelial tissues, a single layer of cells anchored to a basement membrane.
- **Soma** - means "body".
- **Squamous** - a scale-like, flattened cell with a disc-shaped nucleus.
- **Stratified** - in epithelial tissues, a layer of two or more cells with the basal layer anchored to a basement membrane.
- **Striated** - perpendicular "striped" appearance of skeletal and cardiac muscle cells.
- **Superficial** - closer to the surface.
- **Trabeculae** - plates/spikes of bone matrix found in spongy bone.
- **Uninucleated** - containing a single (1) nucleus.
- **Vascularized** - containing blood vessels.
- **Voluntary** - under conscious control - you can actively choose to move your skeletal muscles.

6: EXPLORING THE INTEGUMENTARY SYSTEM

Introduction

In this Lab, we will delve into the fascinating world of the integumentary system, examining its structure, functions, and role as the body's protective shield. This lab provides a hands-on opportunity to explore skin anatomy, identify various layers, and understand how this complex system helps regulate temperature, protect against pathogens, and facilitate sensation. We will also distinguish between and identify first, second and third degree burns in figures and calculate percentage (%) of burns following rule of nine.

The integumentary system is our body's first line of defense. Get ready to explore the epidermis, dermis, and subcutaneous layers, each playing a unique role. The epidermis, for instance, is our waterproof barrier, while the dermis supports it with a rich supply of blood vessels and nerves.

Learning Objectives

- Identify the layers of the skin (epidermis, dermis, hypodermis) and describe their structure and function.
- Differentiate between thick and thin skin based on appearance, structure, and function.
- Identify the tissue types within the layers of the skin and explain their specific functions.
- Locate and label the layers of the epidermis and dermis using a microscope slide.
- Analyze the protective, sensory, and regulatory roles of integumentary structures from a model or image.
- Examine skin appendages (hair, nails, glands) and describe their functions.
- Discuss common integumentary disorders, including burns, and explain their impact on overall health.

6.1: Background Information

6.2: Pre-Lab Activity

6.3: Activity 1

6.4: Activity 2

6.5: Activity 3

6.6: Activity 4

6.7: Activity 5

6.8: Activity 6

6.9: Activity 7

6.10: Activity 8

6.11: Activity 9

6.12: Activity 10

6.13: Activity 11

6.14: Glossary

6.1: Background Information

Overview

Inspection of the skin, hair, and nails is a significant part of a physical examination. Dermatology is the scientific study and medical treatment of the integumentary system. Skin is a complex organ. An average square inch of skin contains 650 sweat glands, 20 blood vessels, and more than 1,000 nerve endings. Despite being just a few millimeters thick, the skin makes up around one-seventh of a person's body weight.

Curiosity Spark

Did you know your skin sheds about 40,000 cells every hour? Imagine the renewal process happening without you even noticing! Would you like to explore more about how this renewal helps in healing wounds?

Motivation

Human skin is the first anatomical site a medical professional examines when seeing a patient, using it as an indicator of general health such as oxygenation, nutritional status, and injury. Skin color is mostly based on the pigmentation or melanin found in the keratinocytes in the epidermis of skin. In addition, the blood supply to the surface (redness), injury (bruising), and jaundice (yellowing) can affect skin color.

Ready to peel back the layers of your body's protective shield? Want me to unpack that step-by-step? Although you may not typically think of the skin as an organ, it is in fact made of tissues that work together as a single structure to perform unique and critical functions. The skin is made of multiple layers of cells and tissues, which are held to underlying structures by connective tissue. The deeper layer of skin is well vascularized (has numerous blood vessels). It also has numerous sensory, autonomic and sympathetic nerve fibers ensuring communication to and from the brain. The skin and its accessory structures make up the integumentary system, let's explore its key functions:

- Physical protection - the integumentary system is the covering of the human body and its most apparent function is physical protection: skin - a tightly knit network of cells, with each layer contributing to its strength. The epidermis has an outermost layer created by layers of dead keratin that can withstand wear and tear of the outer environment, the dermis provides the epidermis with blood supply and has nerves that bring danger to attention amongst other functions. Hypodermis (subcutaneous layer) provides physical cushioning to any mechanical trauma through adipose storage; cutaneous glands secrete protective films; nails protect the digits; hairs throughout the body filter harmful particles from entering the eyes, ears, nose, etc.
- Immunity - the skin is the body's first line of defense, acting as a physical barrier preventing direct entry of pathogens. Resident immune cells are present in the skin, and some, Langerhans cells or dermal dendritic cells, can travel to the periphery and activate the greater immune system.
- Wound healing - when our body undergoes trauma with a resulting injury, the integumentary system orchestrates the wound healing process through hemostasis, inflammation, proliferation, and remodeling.
- Thermoregulation - the skin has a large surface area that is highly vascularized, which allows it to conserve and release heat through vasoconstriction and vasodilation, respectively.
- Vitamin D synthesis - the primary sources of vitamin D are sun exposure and oral intake (crucial for bone health).
- Sensation - skin innervation is by various types of sensory nerve endings that discriminate pain, temperature, touch, and vibration. Each type of receptor and nerve fiber varies in its adaptive and conductive speeds, leading to a wide range of signals that can be integrated to create an understanding of the external environment and help the body to react appropriately.

Layers of the Integument

The skin consists of the epidermis and the dermis. The epidermis is composed of keratinized, stratified squamous epithelium. It

is made of four or five layers of epithelial cells, depending on its location in the body. It does not have any blood vessels within it (i.e., it is avascular). The layers of epidermis tissue are described below from deep to superficial:

- **Stratum basale** - This deepest layer of the epidermis is composed mainly of one layer of proliferating and non-proliferating keratinocytes (keratin-containing cells), attached to the basement membrane by hemidesmosomes. Melanocytes are present in this layer (melanin containing cells also known as pigment cells), connected to numerous keratinocytes through dendrites. Merkel cells are also found in the stratum basale (large numbers of touch-sensitive receptors are found in fingertips and lips).
- **Stratum spinosum** - Keratinocytes become connected through desmosomes and start to produce lamellar bodies, from within the Golgi, enriched in polar lipids, glycosphingolipids, free sterols, phospholipids, and catabolic enzymes. Langerhans cells (immunologically active cells) and melanin are found in the middle of this layer.
- **Stratum granulosum** - A layer in which keratinocytes lose their nuclei and their cytoplasm appears granular. Lipids, contained in those keratinocytes within lamellar bodies, are released into the extracellular space through exocytosis to form a lipid barrier.
- **Stratum lucidum** - A clear, translucent layer of dead keratinocytes, only present in thick skin.
- **Stratum corneum** - Superficial layer of cells, composed of 10 to 30 layers anucleated keratinocyte, with the palms and soles having the most layers. Most of the barrier functions of the epidermis localize to this layer.

Cross-section of human skin with layers, glands, nerves, and hair structures.

Figure 6.1.1: The skin is composed of two main layers: the epidermis, made of closely packed epithelial cells, and the dermis, made of dense, irregular connective tissue that houses blood vessels, hair follicles, sweat glands, and other structures. Beneath the dermis lies the hypodermis, which is composed mainly of loose connective and fatty tissues. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 6.1.1 cross-section illustration of skin, highlighting the epidermis (stratified squamous epithelium), dermis (dense irregular connective tissue containing hair follicles, sweat glands, and blood vessels), and hypodermis (adipose tissue). Each part is labeled to help identify its function and location:

Layers of the Skin:

- **Epidermis:** The outermost layer, providing a protective barrier.
- **Dermis:** The middle layer, containing blood vessels, nerves, and glands.
- **Hypodermis:** The deepest layer, made up of adipose tissue (fat) for insulation and cushioning.

Structures Within the Skin:

- **Hair Shaft:** The visible part of the hair above the skin surface.
- **Hair Root:** The part of the hair embedded in the skin.
- **Hair Follicle:** The structure surrounding the hair root.
- **Hair Follicle Receptor:** Detects movement of the hair.
- **Arrector Pili Muscle:** A small muscle attached to the hair follicle that causes hair to stand up (goosebumps).
- **Sebaceous (Oil) Gland:** Produces oil to lubricate the skin and hair.
- **Eccrine Sweat Gland:** Produces sweat for temperature regulation.
- **Pore of Sweat Gland Duct:** The opening on the skin surface where sweat is released.
- **Sensory Nerve Fiber:** Transmits sensory information like touch and pain.
- **Pacinian Corpuscle:** A deep pressure receptor.
- **Cutaneous Vascular Plexus:** A network of blood vessels that supplies the skin.

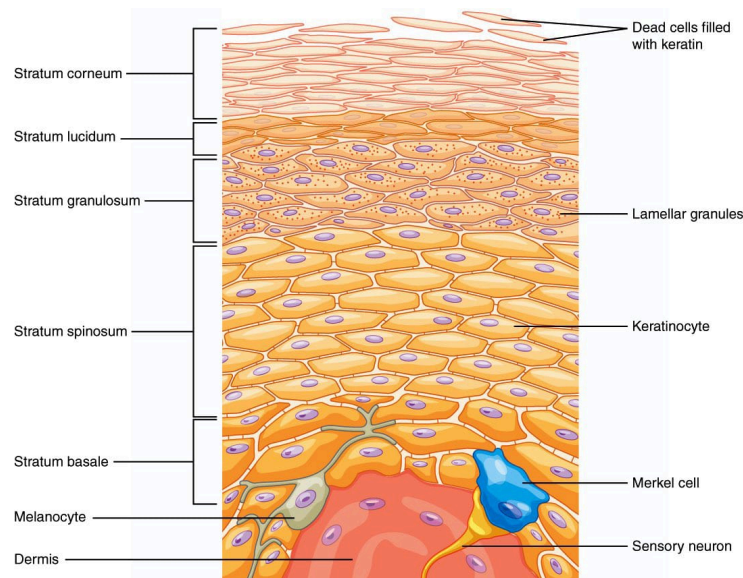


Figure 6.1.2: Layers of the Epidermis: The epidermis of thick skin has five layers (deep to superficial): stratum basale (showing Merkel cell, melanocyte and sensory neuron), stratum spinosum (keratinocytes), stratum granulosum (with lamellar granules), stratum lucidum, and stratum corneum (with dead cells filled with keratin). (CC BY-SA 4.0; via [Anatomy & Physiology](#)).

Figure 6.1.2 is a microscopic view of thick skin epidermis, illustrating the strata basale (with Merkel cell, melanocyte, and sensory neuron), spinosum, granulosum (lamellar granules), lucidum, and corneum (keratinized cells). It shows the layers of the epidermis from top to bottom, along with key cell types and structures.

- Layers of the Epidermis (top to bottom):
 - Stratum Corneum - Outermost layer contains dead cells filled with keratin, providing a tough, protective barrier.
 - Stratum Lucidum - A thin, clear layer found only in thick skin (like palms and soles).
 - Stratum Granulosum - Contains lamellar granules, which help form a waterproof barrier.
 - Stratum Spinosum - Contains keratinocytes, which produce keratin for skin strength and resilience.
 - Stratum Basale - Deepest layer of the epidermis. Contains: Merkel cells, which are connected to sensory neurons and help detect touch.
 - Melanocytes - Produce melanin, the pigment responsible for skin color.
- Dermis:
 - Located beneath the epidermis.
 - Supports the epidermis and contains blood vessels, nerves, and connective tissue.

The dermis contains blood and lymphatic vessels, nerves, and other structures, such as hair follicles and sweat glands. The epidermis is avascular and the cells of this layer must get their oxygen and nutrients from capillaries in the dermis. The dermis is made of two layers of connective tissue that compose an interconnected mesh of elastin and collagenous fibers, produced by fibroblasts. The more superficial papillary layer (made of loose, areolar connective tissue) serves as an anchor point for the epidermis above and is intimately connected to the deeper reticular layer (composed of dense, irregular connective tissue, is well vascularized and has a rich sensory and sympathetic nerve supply).

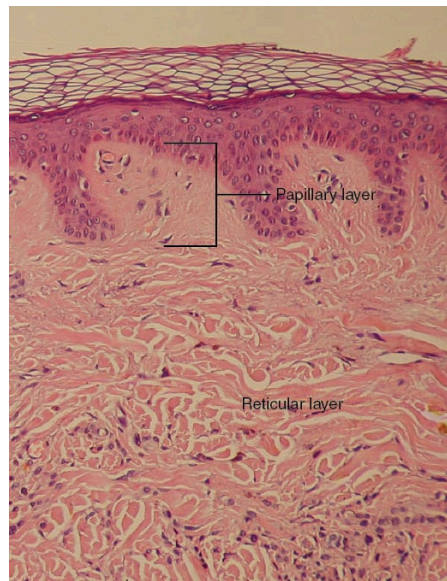


Figure 6.1.3: Layers of the Dermis: This stained slide shows the two components of the dermis—the papillary layer and the reticular layer. Both are made of connective tissue with fibers of collagen extending from one to the other, making the border between the two somewhat indistinct. The dermal papillae extending into the epidermis belong to the papillary layer, whereas the dense collagen fiber bundles below belong to the reticular layer. (CC BY-SA 4.0; via [Anatomy & Physiology](#)).

Figure 6.1.3 shows a histological section of human skin, focusing on the dermis, which is divided into two layers:

Papillary Layer

- Located just beneath the epidermis.
- Composed of loose connective tissue with fine collagen fibers and capillaries.
- Supports the epidermis and aids in nutrient exchange and sensory function.

Reticular Layer

- Found below the papillary layer.
- Made of dense connective tissue with thicker collagen fibers.
- Provides structural strength and elasticity.
- Contains sweat glands, hair follicles, and other deep dermal structures.

The hypodermis (also called the subcutaneous layer or superficial fascia) is a layer directly below the dermis and serves to connect the skin to the underlying fascia (fibrous tissue) surrounding the muscles. It is not strictly a part of the skin, although the border between the hypodermis and dermis can be difficult to distinguish. The hypodermis consists of well-vascularized, loose areolar connective tissue and abundant adipose tissue, which functions as a mode of fat storage and provides insulation and cushioning for the integument. Fascia is a thick connective tissue wrapping that surrounds skeletal muscles, anchoring them to surrounding tissues and investing groups of muscles.

Pigmentation

The color of skin is influenced by a number of pigments, including melanin, carotene, and hemoglobin. Recall that melanin is produced by cells called melanocytes, which are found scattered throughout the stratum basale of the epidermis. The melanin is transferred into the keratinocytes via a cellular vesicle called a melanosome.

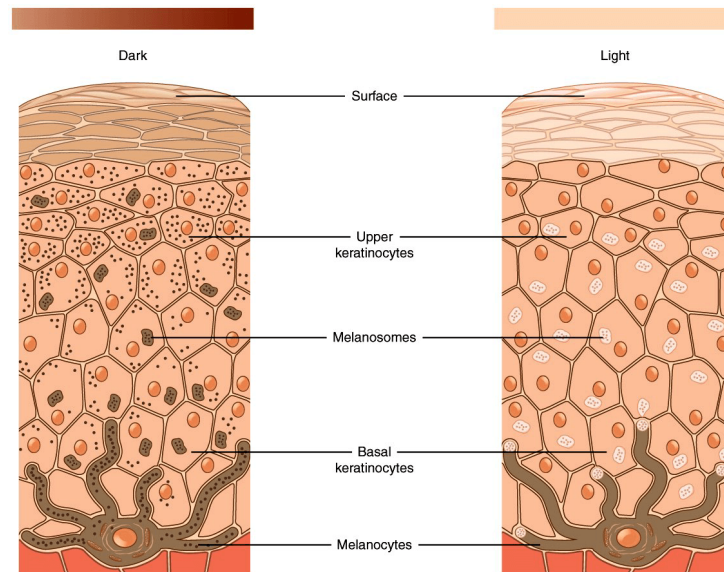


Figure 6.1.4: Skin Pigmentation. The relative coloration of the skin depends of the amount of melanin produced by melanocytes in the stratum basale and taken up by keratinocytes. (CC BY 4.0; via LibreTexts).

Figure 6.1.4 shows a side-by-side cellular comparison of dark and light skin, divided into two labeled sections:

- Left: "Dark"
- Right: "Light"

Skin Layers (Top to Bottom):

- Surface – Outermost skin layer
- Upper Keratinocytes – Contain melanin
- Melanosomes – Pigment organelles within keratinocytes
- Basal Keratinocytes – Base layer skin cells
- Melanocytes – Pigment-producing cells

Key Differences:

- Dark Skin has more melanin in keratinocytes and melanosomes. Melanocytes are more active.
- Light Skin has less melanin and fewer melanosomes. Melanocytes produce less pigment

Dark-skinned individuals produce more melanin than those with pale skin. Exposure to the UV rays of the sun or a tanning salon causes melanin to be manufactured and built up in keratinocytes, as sun exposure stimulates keratinocytes to secrete chemicals that stimulate melanocytes. The accumulation of melanin in keratinocytes results in the darkening of the skin, or a tan. This increased melanin accumulation protects the DNA of epidermal cells from UV ray damage and the breakdown of folic acid, a nutrient necessary for our health and well-being. In contrast, too much melanin can interfere with the production of vitamin D, an important nutrient involved in calcium absorption. Thus, the amount of melanin present in our skin is dependent on a balance between available sunlight and folic acid destruction, and protection from UV radiation and vitamin D production. It requires about 10 days after initial sun exposure for melanin synthesis to peak, which is why pale skinned individuals tend to suffer sunburns of the epidermis initially. Dark-skinned individuals can also get sunburns, but are more protected than pale-skinned individuals. Melanosomes are temporary structures that are eventually destroyed by fusion with lysosomes; this fact, along with melanin-filled keratinocytes in the stratum corneum sloughing off, makes tanning impermanent. Too much sun exposure can eventually lead to wrinkling due to the destruction of the cellular structure of the skin, and in severe cases, can cause sufficient DNA damage to result in skin cancer. When there is an irregular accumulation of melanocytes in the skin, freckles appear. Moles are larger masses of melanocytes, and although most are benign, they should be monitored for changes that might indicate the presence of cancer.

Accessory structures

Accessory structures of the skin include hair, nails, sweat glands, and sebaceous glands. These structures embryologically originate from the epidermis and can extend down through the dermis into the hypodermis.

Hair

Hair is a keratinous filament growing out of the epidermis. It is primarily made of dead, keratinized cells. Strands of hair originate in an epidermal penetration of the dermis called the hair follicle. The hair shaft is the part of the hair not anchored to the follicle, and much of this is exposed at the skin's surface. The rest of the hair, which is anchored in the follicle, lies below the surface of the skin and is referred to as the hair root. The hair root ends deep in the dermis at the hair bulb, and includes a layer of mitotically active basal cells called the hair matrix. The hair bulb surrounds the hair papilla, which is made of connective tissue and contains blood capillaries and nerve endings from the dermis.

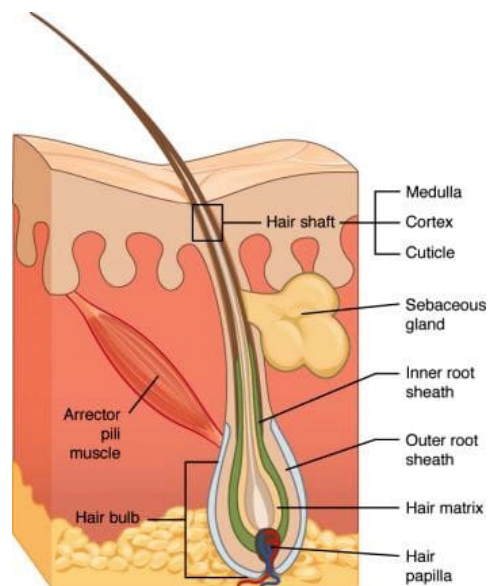
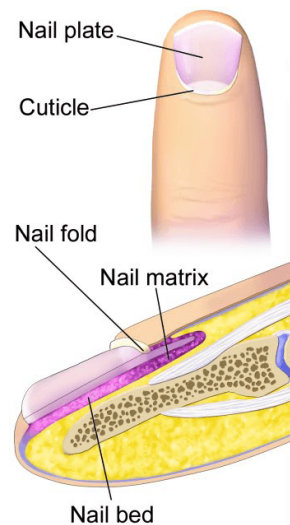


Figure 6.1.5: Detailed diagram of a hair follicle showing internal structures such as the medulla, cortex, cuticle, and associated glands and muscles involved in hair growth and skin function. (CC BY 4.0; via LibreTexts).

Figure 6.1.5 illustrates sectional view of the thin skin showing hair bulb (located at the base of the root, contains active cells that produce new hair), hair papilla (containing blood vessels), hair matrix (region within the bulb where new hair cells divide and differentiate), outer root sheath (a multilayered tissue that surrounds the hair follicle and extends from the hair bulb to the skin surface; plays a role in hair growth, sensory perception, and immune functions within the skin), inner root sheath (a specialized structure that surrounds the hair shaft within the follicle, providing support and protection, sebaceous gland (connected to the follicle, producing sebum to lubricate the hair and skin), hair shaft (the visible portion of hair, composed of three layers: the cuticle, cortex, and, in some cases, the medulla) and the Arrector pili muscle (attached to the follicle, responsible for making hair stand on end - goosebumps).

Nails

Nail has three main parts, the root, plate, and free margin. Other structures around or under the nail include the nail bed, cuticle, and nail fold. Nails grow from a deep layer of living epidermal tissue, known as the nail matrix, at the proximal end of the nail. The nail root is the portion of the nail found under the surface of the skin at the near (or proximal) end of the nail. It is where the nail begins. The free margin is the portion of the nail that protrudes beyond the distal end of the finger or toe. This is the part that is cut or filed to keep the nail trimmed.



Nail Anatomy

Figure 6.1.6: Labeled diagram of fingernail anatomy highlighting key structures involved in nail growth and protection. (CC BY-NA 4.0; Christine Miller via Human Biology).

Figure 6.1.6 illustrates the top diagram in this diagram shows the external, visible part of the nail plate (or the body) and the cuticle (layer of dead epithelial cells that overlaps and covers the edge of the nail plate, it helps to seal the edges of the nail to prevent infection of the underlying tissues). The bottom diagram shows nail fold (a groove in the skin in which the side edges of the nail plate are embedded), nail bed (the area of skin under the nail plate; it is pink in color, due to the presence of capillaries in

the dermis) and the nail matrix (the area at the base of the nail, under the cuticle, that is responsible for nail growth; it is a living, growing tissue that produces the nail plate).

Sweat

When the body becomes warm, sweat (sudoriferous) glands produce sweat to cool the body. Sweat glands develop from epidermal projections into the dermis and are classified as merocrine glands; that is, the secretions are excreted by exocytosis through a duct without affecting the cells of the gland. There are two types of sweat glands, each secreting slightly different products. An eccrine sweat gland is type of gland that produces a hypotonic sweat for thermoregulation. These glands are found all over the skin's surface, but are especially abundant on the palms of the hand, the soles of the feet, and the forehead. They are coiled glands lying deep in the dermis, with the duct rising up to a pore on the skin surface, where the sweat is released. Eccrine glands are a primary component of thermoregulation in humans and thus help to maintain homeostasis.

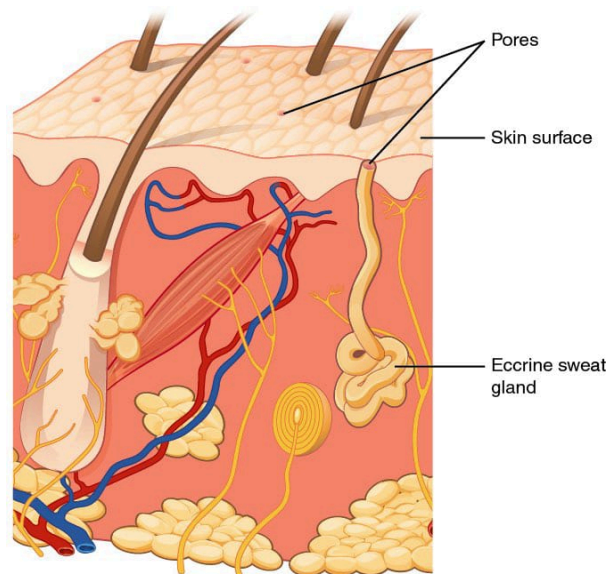


Figure 6.1.7: Eccrine Gland. Eccrine glands are coiled glands in the dermis that release sweat that is mostly water. (CC BY 4.0; via LibreTexts).

Figure 6.1.7 is a cross-sectional anatomical diagram of human skin, showing multiple layers and internal structures.

Labeled Components:

- Skin Surface – Outermost visible layer
- Pores – Openings for sweat and oil release
- Eccrine Sweat Gland – Deep coiled gland that regulates body temperature

Additional Visible Structures (Unlabeled):

- Hair Follicles – Tubes housing hair roots
- Blood Vessels – Arteries and veins supplying nutrients
- Nerves – Sensory pathways for touch, temperature, and pain
- Other Glands – Likely sebaceous glands secreting oil near hair follicles

Apocrine Sweat Glands – An apocrine sweat gland is usually associated with hair follicles in densely hairy areas, such as armpits and genital regions. Apocrine sweat glands are larger than eccrine sweat glands and lie deeper in the dermis, sometimes even reaching the hypodermis, with the duct normally emptying into the hair follicle. In addition to water and salts, apocrine sweat includes organic compounds that make the sweat thicker and subject to bacterial decomposition and subsequent smell.

Sebaceous Glands

A sebaceous gland is a type of oil gland that is found all over the body and helps to lubricate and waterproof the skin and hair. Most sebaceous glands are associated with hair follicles. They generate and excrete sebum, a mixture of lipids, onto the skin surface, thereby naturally lubricating the dry and dead layer of keratinized cells of the stratum corneum, keeping it pliable. The fatty acids of sebum also have antibacterial properties, and prevent water loss from the skin in low-humidity environments. The secretion of sebum is stimulated by hormones, many of which do not become active until puberty. Thus, sebaceous glands are relatively inactive during childhood.

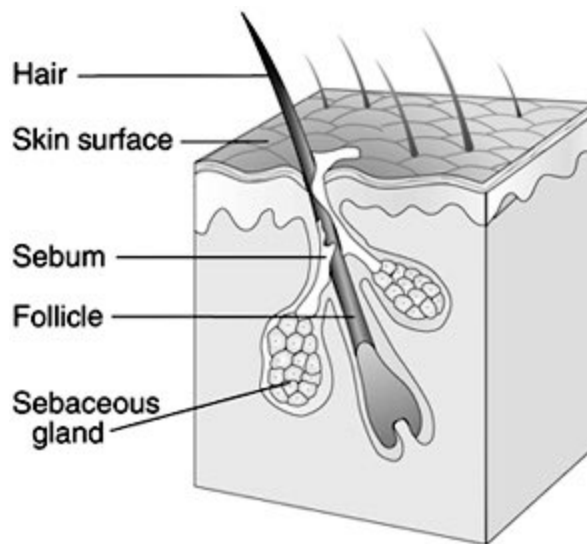


Figure 6.1.8: Sebaceous Gland: Schematic view of a hair follicle with sebaceous gland. (CC BY-SA 4.0; via [Sebaceous \(oil\) Glands](#)).

Figure 6.1.8 is a labeled cross-sectional diagram of human skin, focusing on the structure of a hair follicle.

Labeled Components:

- Hair – Strand extending from the follicle through the skin surface
- Skin Surface – Outermost layer where hair emerges
- Sebum – Oily substance near the follicle
- Follicle – Tubular structure housing the hair root
- Sebaceous Gland – Gland connected to the follicle that secretes sebum

Arrector pili - Each hair root is connected to a smooth muscle called the arrector pili Figure 6.1.5 that contracts in response to nerve signals from the sympathetic nervous system, making the external hair shaft “stand up.” The primary purpose for this is to trap a layer of air to add insulation. This is visible in humans as goose bumps and even more obvious in animals, such as when a frightened cat raises its fur.

Concept and Applications About Skin Conditions

Let's explore integumentary system issues, focusing on albinism, burn classifications (including the Rule of Nines), and the concept of SPF.

- Albinism is a genetic condition resulting from a deficiency or absence of melanin, the pigment responsible for skin, hair, and eye color. This melanin deficiency leads to:
 - Photosensitivity - Extreme sensitivity to sunlight, significantly increasing the risk of sunburn and skin cancer.
 - Vision Problems - Melanin's role in eye development means albinism often causes vision impairments like nystagmus (involuntary eye movements) and photophobia (light sensitivity).
 - Social and Psychological Impacts - The visible differences can unfortunately lead to social stigma and psychological challenges.
- Burns are tissue injuries caused by heat, chemicals, electricity, or radiation. Severity is classified by degree:
 - First-degree (Superficial) - Affects only the epidermis; characterized by redness, pain, and mild swelling.
 - Second-degree (Partial-Thickness) - Involves the epidermis and part of the dermis; blistering, intense pain, and swelling are common. Sub-classified as superficial partial-thickness (upper dermis) or deep partial-thickness (deeper into the dermis).
 - Third-degree (Full-Thickness) - Damages the entire epidermis and dermis, often extending deeper; appears charred, white, or leathery, with potentially less pain (due to nerve damage).
 - Fourth-degree - The most severe; extends through all skin layers and into underlying structures like muscle and bone.
 - The Rule of Nines estimates the total body surface area (TBSA) affected by burns, vital for fluid resuscitation and treatment. The body is divided into regions representing 9% or multiples of 9% TBSA.
- Sun Protection Factor (SPF): SPF indicates a sunscreen's ability to protect against UVB radiation, a major cause of sunburn

and skin cancer. An SPF of 15 means it takes 15 times longer to sunburn with the sunscreen than without. Higher SPF values offer greater protection, but even high SPF doesn't block 100% of UVB rays. While SPF focuses on UVB, UVA rays also contribute to skin aging and cancer risk. Choosing a sunscreen with broad-spectrum protection is crucial

Table 6.1.1: Surface Area Distribution by Anatomic Structure in Adults and Children

Anatomic structure of Adult	Surface area	Anatomic structure of Child (less than 10 years)	Surface area
Anterior head	9%	Anterior head	12%
Posterior head	9%	Posterior head	12%
Anterior torso	18%	Anterior torso	18%
Posterior torso	18%	Posterior torso	18%
Anterior leg, each	6.75%	Anterior leg, each	5.5%
Posterior leg, each	6.75%	Posterior leg, each	5.5%
Anterior arm, each	4.5%	Anterior arm, each	4.5%
Posterior arm, each	4.5%	Posterior arm, each	4.5%
Genitalia/perineum	1%	Genitalia/perineum	1%

6.2: Pre-Lab Activity

Think-Pair-Share about diverse functions of the integumentary system

Phase 1: Think (Individual Reflection - 5 minutes)

- Review: Briefly review the key functions of the integumentary system.
- Focus: Select one specific function you find most fascinating or impactful.
- Elaborate: Write down detailed notes about your chosen function, including specific examples of how it works and its importance to overall health. Consider any conditions that might disrupt this function.

Phase 2: Pair (Collaborative Discussion - 5 minutes)

- Share: Pair up with a classmate. Each person shares detailed notes with their partner.
- Expand: Use this discussion to expand your understanding of the integumentary system's complexity. Explore any unexpected connections or insights that arise.

Phase 3: Share (Group Sharing - 15 minutes)

- Present: Each group briefly presents their chosen function and integrate and key insights about overall importance of the integumentary system.
- Synthesize: Discuss how the various functions contribute to maintaining homeostasis and overall health.

Note: The first cell is pre-filled as an example. Fill in the Table 6.2.1 accordingly.

Table 6.2.1: Functions of the Integumentary System and Their Roles

Functions	Describe the role in details
Protection	• Acts as a physical barrier that protects the entire body from physical injury, trauma, bumps, and scrapes. • Offers protection against harmful chemicals, toxins, microbes, solar radiation and excessive heat or cold.
Thermo-regulation	
Sensory perception	
Add another function	
Immune defense	

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6.3: Activity 1

Connecting history to health issues

During the Industrial Revolution (1760 AD to 1840 AD), as children spent little time outdoors and most of their time working in factories, increasing numbers of them developed a bone disorder called rickets.

Based on your prior knowledge of skin functions, why do you think these children developed rickets? Explain.

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6.4: Activity 2

Skin Deep: Unmasking the Truths and Myths of Skin Color - A Critical Thinking Exercise

This critical thinking exercise invites students to evaluate various statements about skin color, vitamin D, and sunscreen to discern fact from fiction. By engaging in this activity, participants will develop a deeper understanding of the scientific basis behind these topics and challenge common misconceptions.

Table 6.4.1: Evaluating Statements About Skin Color, Vitamin D, and Sunscreen: Fact or Fiction

Statement	Fact (Justify Why do you think so)	Fiction (Justify Why do you think so)
Skin color is determined solely by the amount of melanin present. Select one and justify		
Vitamin D synthesis is affected by skin color; individuals with darker skin may need more sun exposure to produce sufficient Vitamin D. Select one and justify		
Dark-skinned people don't get skin cancer. Select one and justify		
When it comes to sunscreen, the higher the SPF the better! Select one and justify		

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6.5: Activity 3

Identifying Key Structures of the integumentary system

In this activity, you will use the integumentary anatomical model to identify key structures associated with the skin and its appendages. Understanding these components is essential for grasping the functions of the integumentary system.

- Use the laboratory model to visually locate and identify each structure listed.
- Collaborate with classmates to share insights and clarify any questions you may have about the integumentary system.

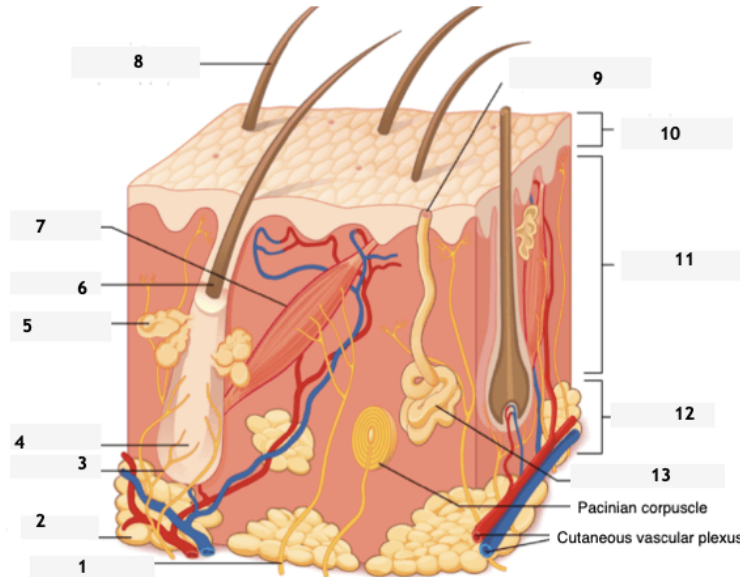


Figure 6.5.1: This image showcases the integumentary model, with key structures indicated by numbers for easy identification. Each number corresponds to a specific component of the integumentary system, such as hair follicles, sebaceous glands, and layers of skin. (CC BY 4.0 ; Kimberlee Carter and Marie Rutherford via [Integumentary System](#))

Table 6.5.1: Identification of Skin Structures Using Labels 1 to 13 with the Key Terms

Key structures for identification	Indicated by the number
Hair follicle	
Adipose tissue	
Hair follicle receptor	
Sebaceous gland	
Hair shaft	
Epidermis	
Sensory nerve fiber	
Dermis	
Hair root	
Hypodermis	
Arrector pili muscle	
Eccrine sweat gland	

Key structures for identification	Indicated by the number
Sweat gland pore	

Instructions:

1. Use a small glass plate for this observation.
2. Firmly press the heel of your hand against the glass plate for several seconds. Ensure you apply enough pressure to cause a noticeable change in your skin color.
3. After releasing the pressure, look through the glass and observe the color of your skin in the compressed area. Record your observations, noting any changes in color.
4. Write down the reason behind the color change you observed. What physiological processes are at play?
5. Discuss what might happen if the pressure were maintained for an extended period in that area. How would the skin and underlying tissues respond?

6.6: Activity 4

Visualizing Changes in Skin Color Due to Continuous External Pressure

In this lab activity, you will explore how continuous external pressure affects skin color. This exercise will help you understand the physiological responses of the skin, including how blood flow and oxygenation can change skin appearance under different conditions. By observing these changes, you will gain insights into the mechanisms behind skin color variations, which can be relevant in various medical and cosmetic contexts.

Instructions

1. Use a small glass plate for this observation.
2. Firmly press the heel of your hand against the glass plate for several seconds. Ensure you apply enough pressure to cause a noticeable change in your skin color.
3. After releasing the pressure, look through the glass and observe the color of your skin in the compressed area. Record your observations, noting any changes in color.
4. Write down the reason behind the color change you observed. What physiological processes are at play?
5. Discuss what might happen if the pressure were maintained for an extended period in that area. How would the skin and underlying tissues respond?

6.7: Activity 5

Unveiling the Integumentary System: Identifying Components and Relating Functions

Examine the model closely, focusing on the different layers: epidermis, dermis, and hypodermis. Identify structures indicated by letters (A to D) and relate each structure with its function.

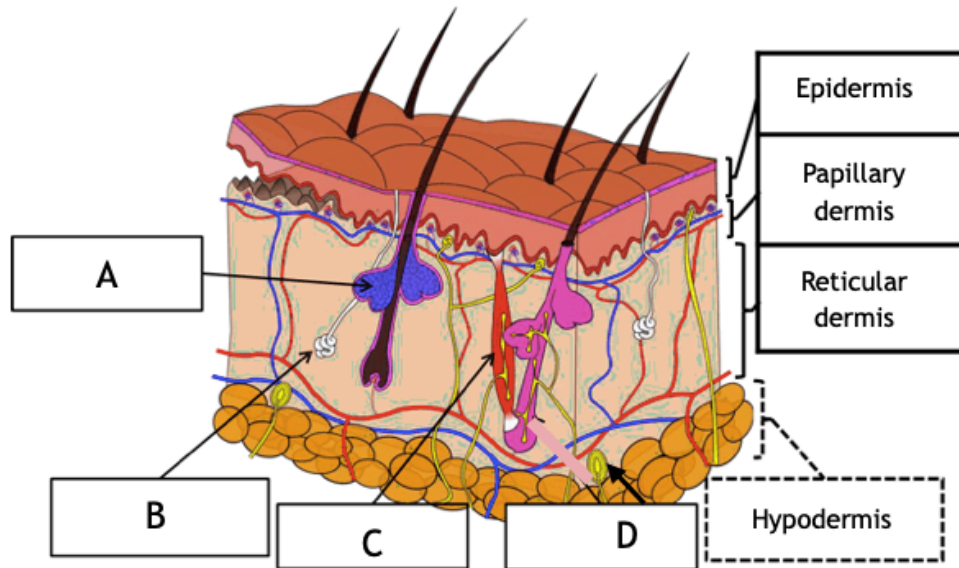


Figure 6.7.1: This anatomical model of integumentary system displays labeled parts including epidermis, papillary dermis and the hypodermis. Four specific structures are indicated with letters (A to D) for identification and the relating their role in human physiology. (CC BY-NC-SA 4.0; Rosanna Hartline via LibreTexts)

Table 6.7.1: Identification and Function of Skin Structures Labeled A to D

Letter	Identify the structure/part indicated by letter, describe their role in human health
A	
B	
C	
D	

6.8: Activity 6

Compare the thick and thin skin based on given parameters

In this activity, you'll delve into the intriguing differences between thick and thin skin by examining their unique features like differences with respect the epidermal layers (hint - what are the four strata present in both and which is present exclusively in the thick skin?); specific locations you will find thick and thin skin and also presence of accessory structures or not.

Table 6.8.1: Comparison of Thick and Thin Skin Based on Histological and Functional Features

Feature	Thick Skin
Epidermal Layers Name all layers	
Location Across the Body Where?	
Stratum Corneum Thickness (relative to each other)	
Eccrine Sweat Glands Present or Absent	
Sebaceous Glands Present or Absent	
Regeneration Capability	

6.9: Activity 7

Comparing the histology of the epidermis, dermis and hypodermis.

Integumentary system represents multiple tissues. Demonstrate mastery of the structure-function location relationships by checking (X) in the table.

Table 6.9.1: Comparison of Thick and Thin Skin Based on Histological and Functional Features

Structure or Tissue	Epidermis	Dermis	Hypodermis
Stratified squamous epithelium			
keratinized			
Adipose tissue			X
Dense irregular connective tissue			
Sensory receptors			
Loose Areolar connective tissue			
Glandular epithelial tissue			
Blood vessel		X	X

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6.10: Activity 8

Histology of the Integumentary System

Instructions

1. Obtain the slides available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the total magnification you make each illustration/photograph in the space provided.
4. Label illustration with the structures listed for each.

Skin (cross section)

Label the tissue with:

- Epidermis
- Dermis
- Papillary layer of the dermis
- Reticular layer of the dermis
- Basement membrane
- Stratum basale, stratum corneum
- Dermal papilla
- Epithelial tissue
- Areolar tissue
- Dense irregular
- Connective tissue
- Skin surface

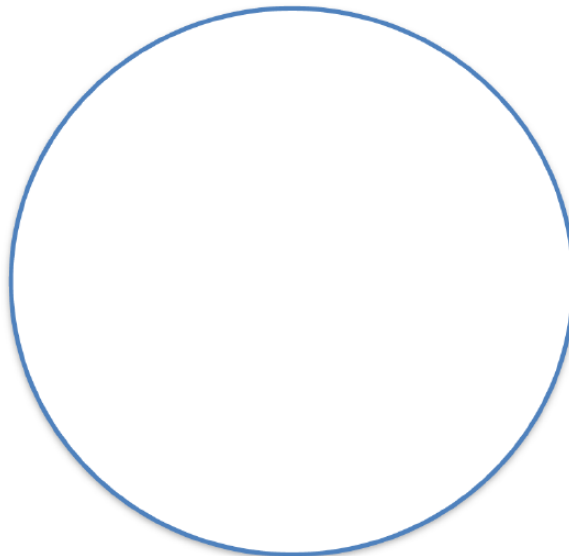


Figure 6.10.1: Skin Total Magnification

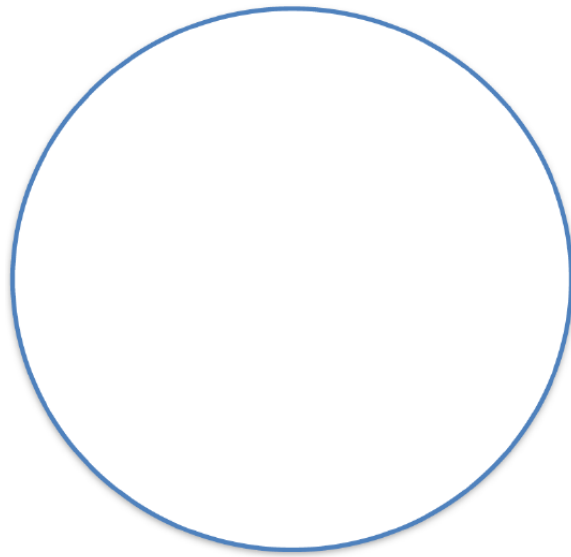


Figure 6.10.2: Scalp Total Magnification

6.11: Activity 9

Plotting the Distribution of Sweat Glands in Thick vs. Thin Skin

Sweat production from eccrine glands is arguably the most important effector mechanism involved in human temperature regulation during heat stress. Sweat is produced by 2 to 4 million eccrine sweat glands dispersed over the non-glabrous skin regions of the human body.

This activity involves use an iodine and starch test to compare the eccrine sweat gland density of a thick skin area (like the palm) and a thin skin area (like the forearm).

Before beginning the experiment, get together with your lab group and formulate a hypothesis based on your previous experience with sweating by forearm and palm.

1. Write hypothesis of your table group.
2. Pick up the following supplies:
 - dropper bottle of Lugol's iodine
 - small squares of white paper that has a dried cornstarch solution on them
 - roll of tape
 - 2 cotton swabs

Instructions

1. Using a cotton swab, each member of the lab group should paint (1 cm^2 area) with iodine on both the palm and on the forearm. Note: use non-writing arm so you can do other parts of the lab while waiting for the experiment to finish. Allow the iodine to dry completely (approximately 3 min).
2. Use the tape to secure a small piece of bond paper over each dried iodine spot.
3. Tape the paper directly to your skin. (Note: the area must have dried).
4. Perform light exercise for 2 to 3 minutes. Wait an additional 5 to 10 minutes. During this time, you can do other parts of the lab.
5. When the 5 to 10 minutes has elapsed, peel the paper off your skin.
6. Small, dark colored dots indicate the location of sweat gland. Blue- black color is positive for sweating; white is negative for sweating. Count the number of sweat glands and record in your data table.

Table 6.11.1: Sweat Gland Count by Location and Group Member

	Member 1	Member 2	Member 3	Member 4
Anterior forearm				
Palm of the hand				

Analysis

1. Which area of the body demonstrated to have greatest concentration of sweat glands?
2. What is the physiological purpose of sweat?

6.12: Activity 10

UV light and SPF (Sun Protection Factor)

Ultraviolet light is invisible to humans, because it has shorter wavelengths than the light we can see. Within the Ultra Violet (UV) spectrum, there are two types of rays that can damage the DNA in skin cells and lead to skin cancer. It's important to protect skin from both types:

- UV-B rays cause sunburn and play a key role in developing skin cancer. A sunscreen's SPF number refers mainly to the amount of UV-B protection it provides.
- UV-A rays cause skin damage that leads to tanning as well as skin aging and wrinkles. The shortest wavelengths of UV-A rays also contribute to sunburn. It's important to look for the words "broad spectrum" on a product's label, which means it has ingredients that can protect you from UV-A as well as UV-B rays.

What protects us from UV light? One strategy would be to avoid exposure to any type of sunlight. Since we cannot avoid sunlight while outdoors, we can physically or chemically block the sun. A wide variety of commercial sunscreens are available with Sun Protection Factors (SPF) ranging from SPF 2 to SPF 100. These lotions contain organic molecules that absorb UV light. Some materials, such as glass and plastic also absorb UV light, while still allowing visible light through.

The SPF number is not a perfect measure of sun protection. The actual time it takes to burn depends on various factors, including the intensity of the sun, skin type, and how much sunscreen is applied. UV Beads are the perfect tool for understanding how solar radiation can be harmful and to recognize measures that can be taken to reduce the risks associated with exposure to sunlight. When we expose bare skin to sunlight, it will either burn or tan. UV radiation wavelengths are short enough to break chemical bonds in your skin tissue and, with prolonged exposure, your skin may wrinkle or skin cancer may occur.

Materials and Equipment

UV-sensitive beads, sunscreen lotions with various SPF ratings, sunblock, sunglasses, clear and opaque yellow/amber color plastic container (generally used in storage of medicines), small plastic bags, laboratory UV light.

Safety Note - Your eyes should not be directly exposed to the indoor lab UV light source. No materials used in this experiment should be ingested.

Personal protective equipment (PPE): lab coat, safety goggles

Part A: Detecting UV light

1. Place 6 to 8 UV-sensitive beads in two small plastic bags. These beads will turn color in the presence of UV light. The higher the intensity of UV light the stronger the color change.
2. Make two bags: one labeled "Control" and one labeled "Experiment".
 - Record the color of the beads when exposed to indoor light (lighting in the lab).
3. The control bag will remain at your bench, and should be used for comparison to color changes in experiment.
4. Take the experiment bag outside, in an area of direct sunlight.
 - Record the color of the beads after 10 seconds of exposure to outside sunlight.
5. Find a shaded area (example: under a tree or in a corridor).
 - Record the color of the beads in shade.

Table 6.12.1: Color Change in UV-Sensitive Beads Under Different Lighting Conditions

Condition	Color of Control Beads	Color of Experiment Beads
Indoor Light		
Sunlight		
Shade		

Part B: Absorption of UV Light by SPF lotions

1. Place 6 to 8 UV-sensitive beads into a small plastic bag; make three bags, label with the SPF numbers. Note the color of the beads under indoor lighting.
2. Add one small drop/dab of each lotion onto each bag. Lightly coat/spread to cover one side of the bag. Allow lotion to dry. Bring the bags to a laboratory UV light setup. Leave bag for 10 seconds. Look into the front of the setup (but not directly at the light) to record the color of the beads under UV light.
3. Empty the beads into beaker at front bench. Discard coated plastic bags.

Table 6.12.2: Effect of SPF Lotions on UV-Sensitive Bead Color Change

Condition	Color of Control Beads Before UV	Color of Beads Under UV
SPF 90		
SPF 70		
SPF 50		
SPF 15		
Yellow Bottle		

Questions

1. What is the difference between UV-A, UV-B, and UV-C light?
2. What is the purpose of an experimental control? Give one specific example of a control used in this experiment.
3. From your data in Part B, do higher SPF ratings provide more protection from UV light?
4. Imagine the Los Angeles Times has reported a UV Index of 6.5 today. Given this level of UV exposure, which is considered high, how might you adjust your plans to take care of your skin and overall health?

6.13: Activity 11

Understanding a Burn Injury - degree and percent of burn estimation (Rule of Nines)

Scenario

You are the trauma team member in the burn unit at the regional hospital. Your team includes a variety of healthcare providers including an ER technician who is interested in the prevention of infection, a paramedic who has lots of experience with patients going into shock, an emergency medicine physician who specializes in burns, and an ER nurse who has years of experience helping in pain management for children.

A visual assessment should be made to determine the severity of the burn injuries. The thickness of the burn – how many layers of skin as well as the amount of other tissue damaged – is used to classify the degree of the burn. Review the classification and description given in the Section 6.1 Background Information.

Case Study: Initial reporting from paramedic following a house fire.

Rule of Nines - The Rule of Nines is a quick and easy tool used for the initial management of resuscitation in burn patients.

“This is Unit 701 reporting. We have a 48 year old male who has suffered from severe third degree burns to anterior and posterior of both his lower extremities, second degree burns in the right arm (anterior) and left arm (anterior) and first degree flash burns to the anterior face is also recorded. Patient is conscious. Medications and allergies are unknown. Vitals are unstable and are as follows:

- Blood pressure is 96/52 mmHg
- Heart rate (HR) is 165 beats per minute
- Temperature is 98.4 degree Fahrenheit or 36.9 degree Celsius
- Respiratory rate (RR) is 35 [breaths/min]

Table 6.13.1: Burn Injury Assessment Using the Rule of Nines

Burn Degree	Affected Body Areas (List regions)	Calculation (Add % from Rule of Nines)	Total Burn Percent
First Degree Burns			
Second Degree Burns			
Third Degree Burns			

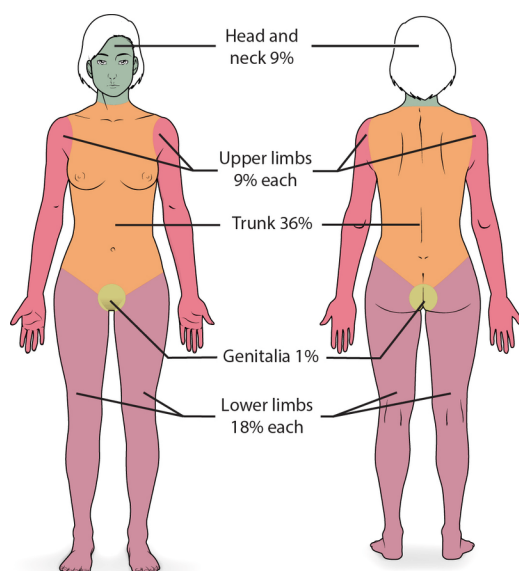


Figure 6.13.1: Anterior and posterior views of a human body with percentages indicating the total body surface area for each section: head/neck 9%, arms 9% each, trunk 36%, legs 18% each, genitalia 1%. (CC BY 4.0; via [Burn Injuries and Management](#)).

Key Terms and Definitions

- **Albinism** - genetic disorder that affects the skin, in which there is no melanin production
- **Basal cell** - type of stem cell found in the stratum basale and in the hair matrix that continually undergoes cell division, producing the keratinocytes of the epidermis
- **Dermal papilla** - (plural = dermal papillae) extension of the papillary layer of the dermis that increases surface contact between the epidermis and dermis
- **Dermis** - layer of skin between the epidermis and hypodermis, composed mainly of connective tissue and containing blood vessels, hair follicles, sweat glands, and other structures
- **Elastin fibers** - fibers made of the protein elastin that increase the elasticity of the dermis
- **Epidermis** - outermost tissue layer of the skin
- **Hypodermis** - connective tissue connecting the integument to the underlying bone and muscle
- **Integumentary system** - skin, hair, nail and its accessory structures
- **Keratin** - type of structural protein that gives skin, hair, and nails its hard, water-resistant properties
- **Keratinocyte** - cell that produces keratin and is the most predominant type of cell found in the epidermis
- **Keratohyalin** - granulated protein found in the stratum granulosum
- **Langerhans cell** - specialized dendritic cell found in the stratum spinosum that functions as a macrophage
- **Melanin** - pigment that determines the color of hair and skin
- **Melanocyte** - cell found in the stratum basale of the epidermis that produces the pigment melanin
- **Melanosome** - intercellular vesicle that transfers melanin from melanocytes into keratinocytes of the epidermis
- **Merkel cell** - receptor cell in the stratum basale of the epidermis that responds to the sense of touch
- **Papillary layer** - superficial layer of the dermis, made of loose, areolar connective tissue
- **Reticular layer** - deeper layer of the dermis; it has a reticulated appearance due to the presence of abundant collagen and elastin fibers
- **Stratum basale** - deepest layer of the epidermis, made of epidermal stem cells
- **Stratum corneum** - most superficial layer of the epidermis
- **Stratum granulosum** - layer of the epidermis superficial to the stratum spinosum
- **Stratum lucidum** - layer of the epidermis between the stratum granulosum and stratum corneum, found only in thick skin covering the palms, soles of the feet, and digits
- **Stratum spinosum** - layer of the epidermis superficial to the stratum basale, characterized by the presence of desmosomes
- **Vitiligo** - skin condition in which melanocytes in certain areas lose the ability to produce melanin, possibly due an autoimmune reaction that leads to loss of color in patches

7: HUMAN SKELETAL SYSTEM - BONE MARKINGS, BONE TISSUES, AND AXIAL SKELETON

Introduction

In this lab, you will explore the fundamental components of the human skeletal system, focusing on bone markings, bone tissues, and the axial skeleton. Through hands-on activities and observation, you will learn to identify various bone markings that serve as sites for muscle attachments, joint formations, and passageways for nerves and blood vessels. The lab will also introduce you to the axial skeleton, which forms the central axis of the body, including the skull, vertebral column, and thoracic cage.

Learning Objectives

- Differentiate among the six types of bones based on the shape.
- Differentiate between axial and appendicular skeleton.
- Identify and describe key bone markings (e.g., foramina, processes, fossae) and their functional significance.
- Identify the bones of the skull and bone markings using axial skeleton study specimens.
- Compare adult and fetal/newborn skull, relate the function of fontanel.
- Identify, compare and contrast vertebral bones based on the bone markings and locations (cervical, thoracic, lumbar, sacral and coccygeal) establishing structure-function relationships.
- Identify the normal and abnormal vertebral curvatures.
- Apply knowledge of the skeletal system to interpret X-ray images and solve clinical case studies.

7.1: Background Information

7.2: Activity 1

7.3: Activity 2

7.4: Activity 3

7.5: Activity 4

7.6: Activity 5

7.7: Activity 6

7.8: Activity 7

7.9: Activity 8

7.10: Activity 9

7.11: Activity 10

7.12: Glossary

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7.1: Background Information

Overview

The skeletal system composed of bones and cartilage forms the structural framework of the human body and is composed of 206 bones in adults. Bones support the weight of the body, allow for body movements, and protect internal organs. Cartilage provides flexible strength and support for body structures such as the thoracic cage, the external ear, and the trachea and larynx. At joints of the body, cartilage can also unite adjacent bones or provide cushioning between them. Ligaments are the strong connective tissue bands that hold the bones at a moveable joint together and serve to prevent excessive movements of the joint that would result in injury.

The skeletal system is organized into two major sections: the axial skeleton and the appendicular skeleton. The axial skeleton, consisting of the 80 bones of the skull, vertebral column, and thoracic cage, forms the vertical, central axis of the body (Figure 7.1.1). It serves to protect the brain, spinal cord, heart, and lungs. It also serves as the attachment site for muscles that move the head, neck, and back, and for muscles that act across the shoulder and hip joints to move their corresponding limbs.

The appendicular skeleton includes all 126 bones of the upper and lower limbs, as well as the bones that connect each limb to the axial skeleton (illustrated in Figure 7.1.1). These bones are divided into two groups, the bones located within the limbs themselves and the girdle bones that attach the limbs to the axial skeleton. The bones of the shoulder region form the pectoral girdle, which anchors the upper limb to the thoracic cage of the axial skeleton. Meanwhile, the lower limb is connected to the vertebral column by the pelvic girdle.

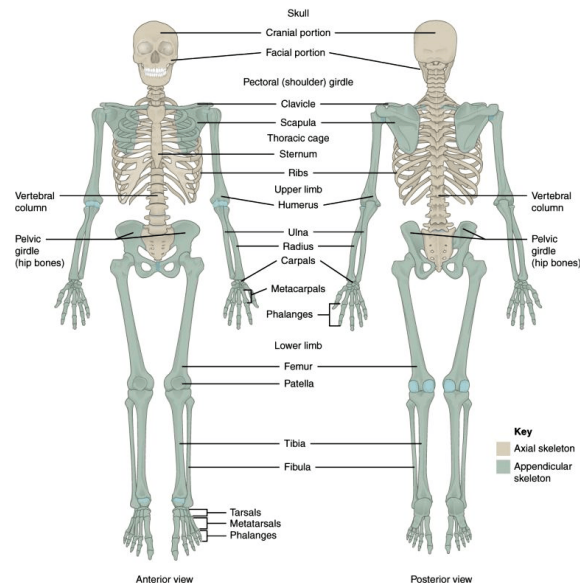


Figure 7.1.1: Axial and Appendicular Skeleton. The axial skeleton forms the body's central axis (skull, vertebrae, ribs, sternum, sacrum, coccyx). The appendicular skeleton includes the limbs and their attachments (shoulder girdle and hip bones). (CC BY 4.0; Carly Manz via Fundamentals of Human Anatomy Laboratory Manual).

Figure 7.1.1 illustrates the human skeleton in two views: an anterior (front) view on the left and a posterior (back) view on the right.

- Axial skeleton: forms the body's central framework and includes the skull, vertebral column, and thoracic cage (ribs and sternum). It primarily supports posture and protects the brain, spinal cord, and organs of the chest.
- Appendicular skeleton: includes the pectoral (shoulder) girdle, upper limbs, pelvic girdle (hip bones), and lower limbs. It primarily supports movement and locomotion.

The skull is labeled in two parts:

- Cranial portion: the part that encloses and protects the brain.

- Facial portion: the bones that form the face.

Trunk (axial skeleton):

- Vertebral column: runs from the base of the skull down through the back; supports the body and protects the spinal cord.
- Thoracic cage: the chest framework, labeled with:
 - Ribs: curved bones forming the cage around the chest.
 - Sternum: the breastbone at the front midline of the chest.

The shoulder region is labeled as the pectoral (shoulder) girdle, which includes:

- Clavicle: collarbone; connects the upper limb region to the trunk.
- Scapula: shoulder blade; provides attachment and movement support for the upper limb.

The upper limb is labeled with:

- Humerus: upper arm bone.
- Radius and ulna: forearm bones.
- Carpals: wrist bones.
- Metacarpals: palm bones.
- Phalanges: finger bones

The hip region is labeled as the pelvic girdle (hip bones), which attaches the lower limbs to the trunk and supports body weight. The lower limb is labeled with:

- Femur: thigh bone.
- Patella: kneecap.
- Tibia and fibula: lower leg bones.
- Tarsals: ankle and rear-foot bones.
- Metatarsals: mid-foot bones.
- Phalanges: toe bones.
- The anterior view helps locate front-facing structures such as the sternum, the arrangement of the ribs, and the limb bones from the front.
- The posterior view helps locate structures best understood from the back, such as the alignment of the vertebral column and the positioning of the scapula.

Classification of Bones by Shape

The 206 bones that compose the adult skeleton are divided into five categories based on their shapes into long bones, short bones, flat bones, irregular bones, and sesamoid bones Figure 7.1.2. Their shapes and their functions are related such that each categorical shape of bone has a distinct function. For example, long bones like the femur provide leverage for movement, while flat bones like the sternum protect internal organs. Each bone contains specific markings such as foramina (holes for blood vessels and nerves), processes (projections for muscle attachment), and fossae (depressions for articulation with other bones).

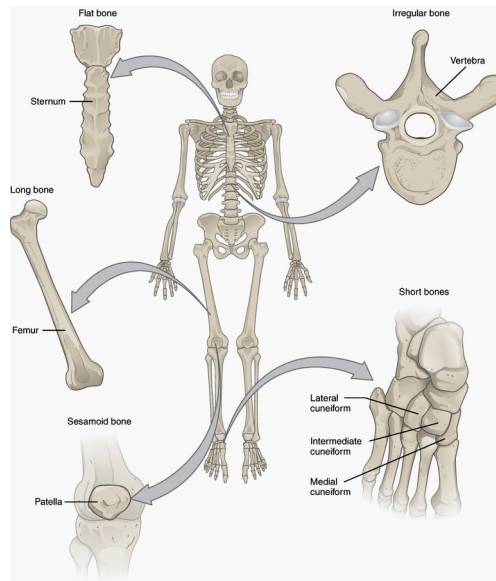


Figure 7.1.2: Classifications of Bones by shape. A diagram illustrating the bones based on their shape, including long bones (like the femur), short bones (like the carpals), flat bones (like the skull), and irregular bones (like the vertebrae). (CC BY 4.0; via [OpenStax Anatomy & Physiology](#)).

Figure 7.1.2 illustrates the five major types of bones in the human skeleton, each labeled with a representative example:

1. Flat Bone – Represented by the sternum (breastbone), which protects internal organs and provides surface area for muscle attachment.
2. Irregular Bone – Shown as a vertebra, which has complex shapes and helps protect the spinal cord.
3. Long Bone – Illustrated by the femur (thigh bone), which supports weight and facilitates movement.
4. Sesamoid Bone – Depicted as the patella (kneecap), which is embedded in tendons and helps reduce friction.
5. Short Bones – Shown as the medial, intermediate, and lateral cuneiform bones in the foot, which provide stability and support with limited motion.

Each bone type is visually distinct and labeled to help learners understand their structure and function.

- Long Bones - A long bone is one that is cylindrical and is longer than it is wide. Long bones are found in the arms (humerus, ulna, radius) and legs (femur, tibia, fibula), as well as in the fingers (metacarpals, phalanges) and toes (metatarsals, phalanges). Long bones function as levers; they move when muscles contract.
- Short Bones - A short bone is one that is cube-like in shape, being approximately equal in length, width, and thickness. The only short bones in the human skeleton are in the carpals of the wrists and the tarsals of the ankles. Short bones provide stability and support as well as some limited motion.
- Flat Bones - Flat bones are thin, flattened, and usually curved. Most of the bones of the cranium are flat bones. Other examples include the scapulae (shoulder blades), the sternum (breastbone), and the ribs. Flat bones serve as points of attachment for muscles and often protect internal organs.
- Irregular Bones - An irregular bone is one that does not have any easily characterized shape and therefore does not fit any other classification. These bones tend to have more complex shapes, like the vertebrae that support the spinal cord and protect it from compressive forces. Many facial bones, particularly the ones containing sinuses, such as the ethmoid, sphenoid, frontal, and maxillary bones, are classified as irregular bones. The zygomatic bone (cheek bone) is also in this category.
- Sesamoid Bones - A sesamoid bone is a small, round bone that, as the name suggests, is shaped like a sesame seed. These bones form in tendons (the sheaths of tissue that connect bones to muscles) where a great deal of pressure is generated in a joint. Sesamoid bones protect tendons by helping them overcome compressive forces. Sesamoid bones vary in number and placement from person to person but are typically found in tendons associated with the feet, hands, and knees. The patellae (singular:patella) are the only sesamoid bones found in common with every person.

Each Bone is an Organ - Bone Organization

As with all organs, bones are made of more than one tissue type. Bones are made of dense fibrous connective tissue, reticular

tissue, blood, as well as bone (osseous) tissue. A leathery, dense fibrous connective tissue called the periosteum makes up the most superficial layer. Under the periosteum is the bulk of the bone's mass, osseous tissue, either compact (cancellous) bone or spongy bone. Because solid bone would be too heavy, the inside of many bones is mostly hollow, the medullary cavity. The outer layer of the medullary cavity, called endosteum, contains a layer of bone forming and bone resorbing cells. The rest of the medullary cavity is filled with reticular tissue called bone marrow. There are two types of bone marrow: yellow marrow, which stores fat, and red marrow, which produces red blood cells, white blood cells, and platelets.

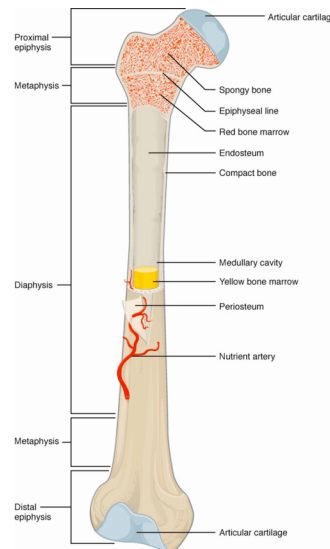


Figure 7.1.3: Long bone anatomy: diaphysis (shaft, compact bone), metaphysis (growth plate), epiphyses (ends, spongy bone), periosteum, and medullary cavity (marrow). (CC BY-NC-SA 4.0; via [Anatomy & Physiology OER Lab Manual](#)).

Figure 7.1.3 illustrates the structure of a long bone, such as the femur or humerus. It is labeled with both external and internal anatomical features:

- Proximal and Distal Epiphysis: The rounded ends of the bone.
- Metaphysis: The region between the epiphysis and diaphysis, where growth occurs.
- Diaphysis: The long, central shaft of the bone.
- Articular Cartilage: Smooth tissue at both ends that reduces friction in joints.
- Spongy Bone: Porous bone tissue found in the epiphysis, containing red bone marrow.
- Epiphyseal Line: A remnant of the growth plate.
- Red Bone Marrow: Found in spongy bone, responsible for blood cell production.
- Endosteum: A thin membrane lining the medullary cavity.
- Compact Bone: Dense outer layer providing strength.
- Medullary Cavity: Central cavity within the diaphysis, containing yellow bone marrow.
- Yellow Bone Marrow: Stores fat.
- Periosteum: Outer fibrous layer covering the bone.
- Nutrient Artery: Supplies blood to the bone.

When we look at bone under a microscope, we notice that there are two types of bones: compact (or cancellous) bone and spongy bone. Compact (cancellous) bone is found at the edges of bone and consists of circular, tree-trunk shaped units called osteons. Each osteon consists of rings of tissue surrounding a central canal that holds blood vessels and nerves. The tiny osteocytes, located in cavities called lacunae, are in the concentric rings called lamellae surrounding the central canal. There are also tiny radiating canals called canaliculi emanating from the central canal that deliver nutrients to the lacunae.

For an osteocyte to receive nutrients and get rid of waste, it must be serviced by a series of blood vessels. Blood vessels enter bone via the nutrient foramen where they wind their way among the bone tissue via horizontal Volkmann's (or perforating) Canals. These horizontal canals intersect with vertical central canals that serve the center of each osteon. From there, the tiny canaliculi distribute blood from the central canal to the lacunae.

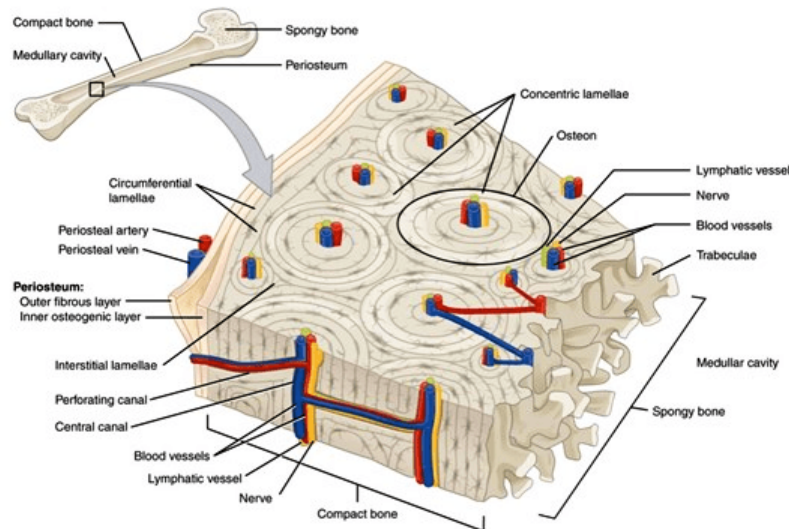


Figure 7.1.4: Cross-section of compact bone showing osteons made of lamellae around a central (Haversian) canal; perforating (Volkmann's) canals connect to the periosteum and endosteum. (CC BY-NC-SA 4.0; via [Blue Structure](#)).

Figure 7.1.4 presents a microscopic cross-sectional view of compact bone tissue, highlighting its complex internal structure. Key components include:

- **Compact Bone:** Dense outer layer providing strength.
- **Spongy Bone:** Porous inner layer with trabeculae, located near the medullary cavity.
- **Medullary Cavity:** Central cavity containing bone marrow.
- **Periosteum:** Outer covering of bone with two layers:
 - **Outer Fibrous Layer:** Protective and structural.
 - **Inner Osteogenic Layer:** Contains cells for bone growth and repair.
- **Osteon:** The functional unit of compact bone, made up of concentric rings.
- **Concentric Lamellae:** Circular layers of bone matrix around the central canal.
- **Interstitial Lamellae:** Fills spaces between osteons.
- **Circumferential Lamellae:** Surrounds the entire bone structure.
- **Central Canal (Haversian Canal):** Contains blood vessels, lymphatic vessels, and nerves.
- **Perforating Canal (Volkmann's Canal):** Connects central canals across osteons.
- **Periosteal Artery and Vein:** Supplies blood to the outer bone layers.

Spongy Bone Tissue Organization

Like compact bone, spongy bone, also known as cancellous bone, contains osteocytes, but they are not arranged in concentric circles. Instead, the osteocytes are found in a lattice like network of matrix spikes called trabeculae (Trabecula is singular form). The spaces in some spongy bones contain red marrow, protected by the trabeculae, where hematopoiesis occurs.

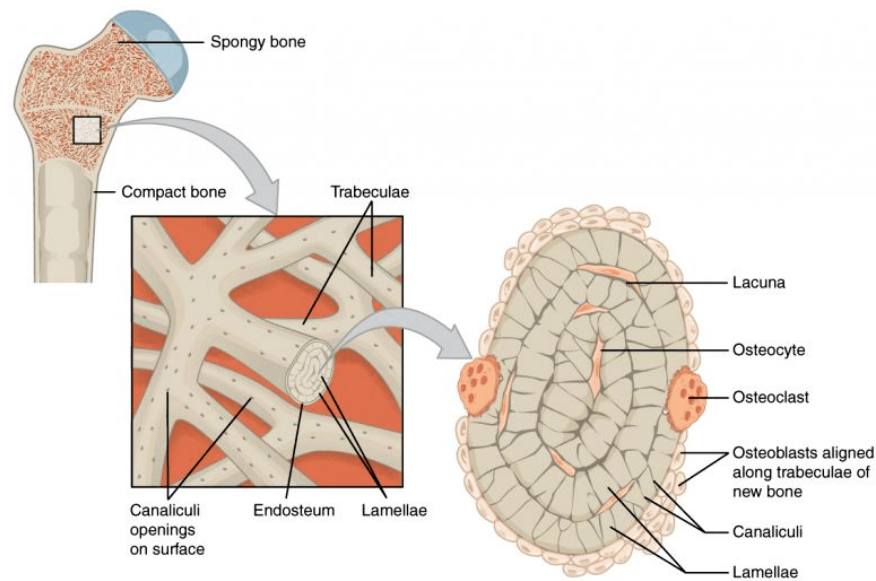


Figure 7.1.5: Diagram of Spongy Bone: Spongy bone is composed of trabeculae that contain the osteocytes. Red marrow fills the spaces in some bones. (CC BY-NC-SA 4.0; via [Bone Structure](#)).

Figure 7.1.5 is a multi-level anatomical diagram of spongy bone structure, showing increasing magnification from whole bone to cellular detail. It is divided into three main sections:

1. **Overview Section:** Displays the location of spongy bone within a larger bone, adjacent to compact bone. Spongy bone appears porous and is typically found at the ends of long bones.
2. **Magnified View of Trabeculae:** Shows the trabeculae, which are the thin, branching structures that form the lattice-like framework of spongy bone. This section also highlights:
 - Canaliculi openings on the surface, which are small channels for nutrient exchange.
 - The endosteum, a thin membrane lining the inner surface of the trabeculae.
3. **Cellular Detail View:** Focuses on the microscopic components embedded in the trabeculae:
 - **Lamellae:** Concentric layers of bone matrix.
 - **Lacuna:** Small cavities housing bone cells.
 - **Osteocyte:** A mature bone cell residing in a lacuna.
 - **Osteoclast:** A large cell responsible for bone resorption.
 - **Osteoblasts:** Bone-forming cells aligned along the surface of new trabeculae.

Bone Markings

Bone markings are the various projections, depressions, and openings found on the surface of bones that serve crucial functions like enabling joint movement, providing attachment points for muscles and tendons, and allowing passage of nerves and blood vessels through the bone; essentially acting as landmarks for muscle and tissue attachment, joint formation, and structural support within the body.

- **Types of markings:**
 - **Projections:** Bony bumps or ridges that serve as attachment points for muscles and tendons, often named based on their shape like "tubercle" or "condyle".
 - **Articulations:** Smooth surfaces where bones meet to form joints, allowing for movement between bones.
 - **Depressions:** Indentations or grooves on the bone surface, often providing space for tendons or nerves to pass through.
 - **Openings (Foramina):** Holes in the bone through which blood vessels and nerves can travel.
- **Functions based on location:**
 - **Joint formation:** Specific bone markings like facets on vertebrae or the head of the femur allow for smooth articulation and joint movement.
 - **Muscle attachment:** Large projections like the greater trochanter on the femur provide ample space for powerful leg muscles to attach.
 - **Nerve and blood vessel pathways:** Grooves and canals within bones guide nerves and blood vessels along specific routes.

Table 7.1.1: Functional Category 1- Projections that help in joint formation (Articulations)

Term	
Condyle	A rounded, knuckle-like knob on a bone, which articulates with another bone. Example(s): femoral lateral and medial condyles; tibial lateral and medial condyles.
Facet	A smooth, flat surface where two bones meet to form a joint. Example(s): articular facets of the vertebrae for flexion and extension.
Head	A rounded end of a bone, it is a prominent extension of bone. Example(s): the head of the radius; the head of the femur.
Ramus (plural Rami)	The curved part of a bone that gives structural support to the bone. Example(s): ramus of the mandible.

Table 7.1.2: Functional Category 2 - Projections for muscle and ligament attachment

Terms	Description
Crest	A raised or prominent part of the edge of a bone, are often found on the iliac crest. Example(s): iliac crest, median sacral crest.
Epicondyle	A prominence that sits atop of a condyle, attaches muscles and ligaments. Example(s): femoral medial and lateral epicondyles; humeral medial and lateral epicondyles.
Line	Ridge along a bone that allows a muscle to attach to the bone. Example(s): arcuate line (of the ilium).
Process	Bony projection, allow for muscle attachment. Example(s): spinous process, acromial process, radial styloid process.
Spine	Sharp, slender, often pointed projection/process. Example(s): anterior superior iliac spine or posterior superior iliac spine.
Trochanter	A large prominence on the side of the bone. Some of the bones have two trochanters. Example(s): greater and lesser trochanters of the femur.
Tubercle	A small, rounded prominence where connective tissues attach. Example(s): greater and lesser tubercle of the humerus.
Tuberosity	A moderate prominence where muscles and connective tissues attach. Example(s): tibial tuberosity; deltoid tuberosity; ischial tuberosity.

Table 7.1.3: Bone Markings – Depressions and Openings for Passage of Blood Vessels and Nerves

Terms	Description and function of Bone Markings with selected examples
Canal	Passageway through a bone. Example(s): optic canal for the passage of optic nerve.
Fissure	An open slit in or between bones. It usually houses nerves and blood vessels. Example(s): superior and inferior orbital fissures.
Foramen (plural foramina)	A hole in a bone through which nerves and blood vessels pass. Example(s): foramen magnum; supraorbital foramen; infraorbital foramen; mental foramen.
Fossa (plural fossae)	A shallow depression in a bone surface. Example(s): mandibular fossa; posterior, middle, and anterior cranial fossae.

Terms	Description and function of Bone Markings with selected examples
Meatus (plural meatuses)	A tube-like channel that extends within the bone, which may provide passage and protection to nerves, vessels, and sound. Example(s): external acoustic meatus; internal auditory meatus.
Sinus	A cavity within a bone. Example(s): frontal sinus, ethmoidal sinus, maxillary sinus, sphenoidal sinus.
Sulcus	Same as groove. Example: inter tubercle sulcus of the humerus.

The Skull (Cranium)

The skull, a critical component of the axial skeleton, is divided into the cranium and facial bones. The cranium protects the brain and houses the structures of the inner ear, while the facial bones support the features of the face and provide attachment points for muscles.

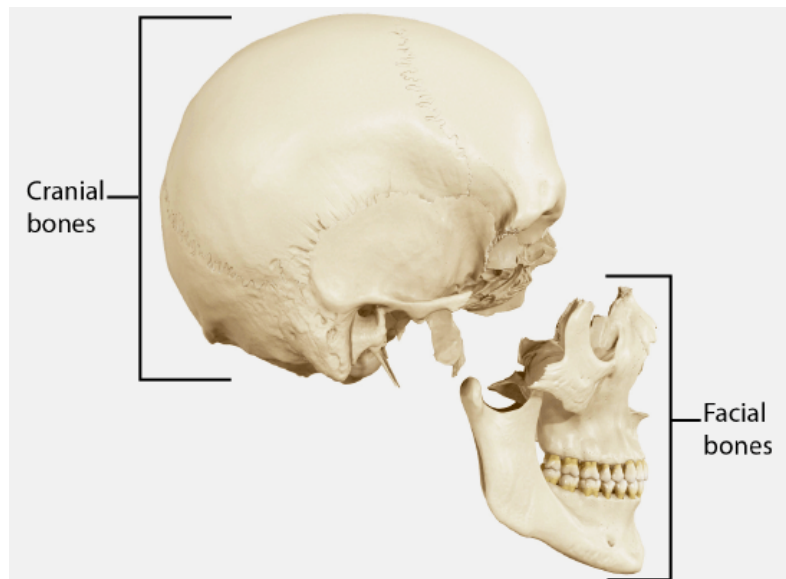


Figure 7.1.6: Parts of the Skull. The skull consists of the rounded cranial bones that protect the brain and the facial bones that form the upper and lower jaws, nose, orbits, and other facial structures. (CC BY-NC-SA 4.0; Jennifer Lange via [Anatomy Standard](#)).

Figure 7.1.6 displays a labeled diagram of a human skull, highlighting two major anatomical regions:

- **Cranial Bones:** These form the upper portion of the skull, enclosing and protecting the brain. They include structures such as the frontal, parietal, temporal, and occipital bones.
- **Facial Bones:** These make up the lower portion of the skull, including the jaw, cheekbones, nasal bones, and teeth. These bones support facial structure and play roles in breathing, eating, and communication

In the adult, the skull consists of a total of 22 individual bones. Sum of 8 cranial and 14 facial bones, 21 of which are immobile. The 22nd bone is the mandible (lower jaw), is the only moveable bone of the skull.

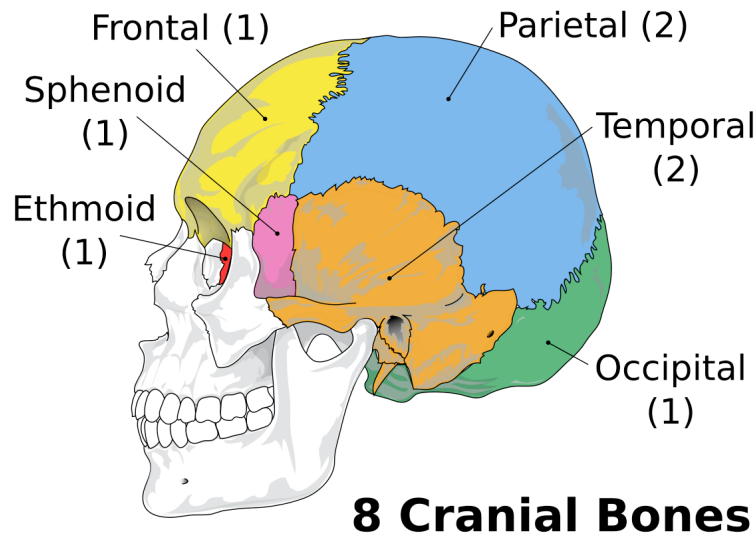


Figure 7.1.7: Human skull scheme highlighting the eight cranial bones in a lateral view showing the paired (parietal and temporal) and unpaired (frontal, sphenoid, ethmoid, occipital) bones. (CC0 1.0; via [Wikimedia Commons](#)).

Figure 7.1.7 is a diagram of the human skull, specifically highlighting the eight cranial bones. Each bone is labeled with its name and the number of bones present in the skull:

- Frontal (1): Located at the front of the skull, forming the forehead.
- Parietal (2): Two bones located on the sides and top of the skull.
- Temporal (2): Two bones located near the ears, forming the lower sides of the skull.
- Occipital (1): Located at the back and base of the skull.
- Sphenoid (1): A butterfly-shaped bone located at the base of the skull, behind the eyes.
- Ethmoid (1): A light, spongy bone located between the eyes, forming part of the nasal cavity.

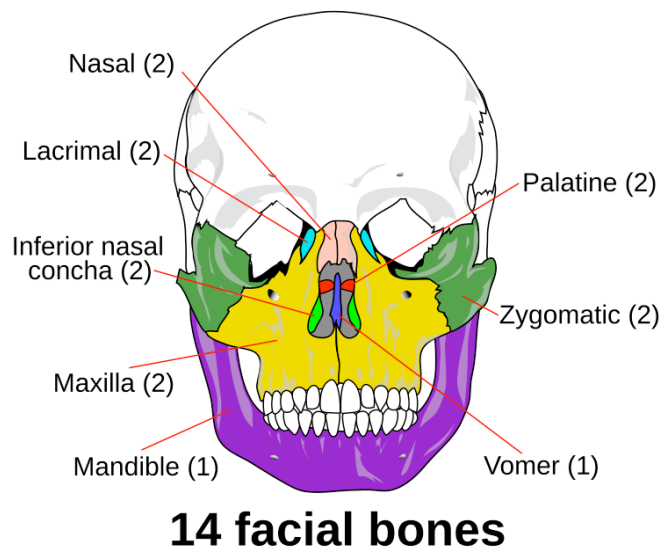


Figure 7.1.8: Color-coded diagram labeling the 14 facial bones, including paired nasal, lacrimal, palatine, zygomatic, maxilla, and inferior nasal concha bones, plus the single mandible and vomer. (CC BY-SA 4.0; via [Wikipedia](#)).

Figure 7.1.8 illustrates human skull scheme highlighting the 14 facial bones in anterior view showing the paired and unpaired bones.

- Maxilla: Forms the upper jaw and floor of the nasal cavity.
- Nasal bones: Two small bones forming the bridge of the nose.

- Palatine bones: Two L-shaped bones forming part of the roof of the mouth and floor of the nasal cavity.
- Zygomatic bones: Two cheekbones that contribute to the shape of the face.
- Vomer: A single, midline bone that separates the nasal cavities.
- Lacrimal bones: Two small bones forming part of the eye socket.
- Inferior nasal conchae: Two curved bones within the nasal cavity.
- Mandible: The lower jawbone.

Sutures of the Skull

A suture is an immobile joint between adjacent bones of the skull. The narrow gap between the bones is filled with dense, fibrous connective tissue that unites the bones adding strength to the skull for brain protection.

- The coronal suture runs from side to side across the skull, within the coronal plane of section. It joins the frontal bone to the right and left parietal bones.
- The sagittal suture extends posteriorly from the coronal suture, running along the midline at the top of the skull in the sagittal plane of section. It unites the right and left parietal bones.
- On the posterior skull, the sagittal suture terminates by joining the lambdoid (lambdoidal) suture that extends downward and laterally to either side away from its junction with the sagittal suture. The lambdoid suture joins the occipital bone to the right and left parietal and temporal bones.
- The squamous suture is located on the lateral skull. It unites the temporal bone with the parietal bone.

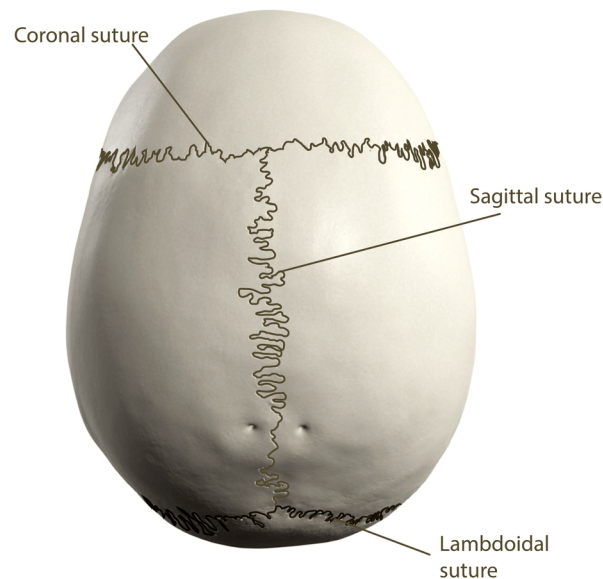


Figure 7.1.9: Superior View. (CC BY NC- SA 4.0, modification of images from [Anatomy Standard](#)).

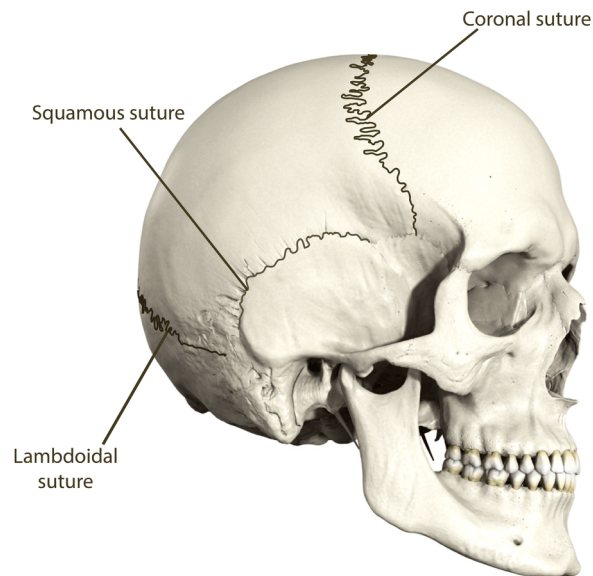


Figure 7.1.10: Lateral View. (CC BY NC- SA 4.0, modification of images from [Anatomy Standard](#)).

Figure 7.1.9 presents a top-down view of a human skull, focusing on the cranial sutures, which are the joints between bones of the skull. Three major sutures are labeled:

- Coronal Suture: Located at the top of the skull, running horizontally from left to right. It separates the frontal bone from the parietal bones.
- Sagittal Suture: Found in the center of the skull, running vertically from front to back. It separates the left and right parietal bones.
- Lambdoidal Suture: Positioned at the bottom of the image, forming an inverted "V" shape. It separates the parietal bones from the occipital bone at the back of the skull.

Figure 7.1.10 presents a diagram of a human skull, highlighting three major cranial sutures, which are immovable joints connecting the bones of the skull:

- Coronal Suture: Runs horizontally across the top of the skull, separating the frontal bone from the parietal bones.
- Squamous Suture: Located on the side of the skull, this suture separates the parietal bone from the temporal bone.
- Lambdoidal Suture: Found at the back of the skull, forming an arch that separates the parietal bones from the occipital bone.

Sutures of the Skull. Sutures represent the immovable joints found between skull bones. In the superior view the coronal, sagittal and lambdoid sutures are visible. A lateral view of the skull shows the coronal, squamous, and lambdoid sutures.

Helpful Hints for Identification of Skull Bones by Touching/Palpating on the Body

- Zygomatic bone and arch - The most prominent part of your cheek is your zygomatic bone. Follow the posterior course of the zygomatic arch to its junction with your temporal bone.
- Mastoid Process - Touch the rough slight projection behind your ears.
- Temporomandibular joint - the articulation of the mandibular condyle with the mandibular fossa of the temporal bone. Palpate directly over the joint while opening and closing your jaws.
- Supraorbital foramen - this landmark lies on a vertical line with the pupil (when the eye is looking directly forward). Apply pressure along the superior orbital margin and locate the indentation.
- Mandibular angle - trace the junction of the lower border of the ramus of the mandible with the posterior border.
- Nasal bones: two small, oblong bones that form the bridge of the nose superior to the nasal cartilage.

Vertebral Column

- The vertebral column is formed by stacking vertebrae together, made of 26 bones namely cervical, thoracic, lumbar, sacral and coccyx vertebrae. The vertebral foramina lining up to create the spinal canal that contains the spinal cord.

- The size and orientation of the articular processes determine the range of motion (ROM) at each vertebral level.

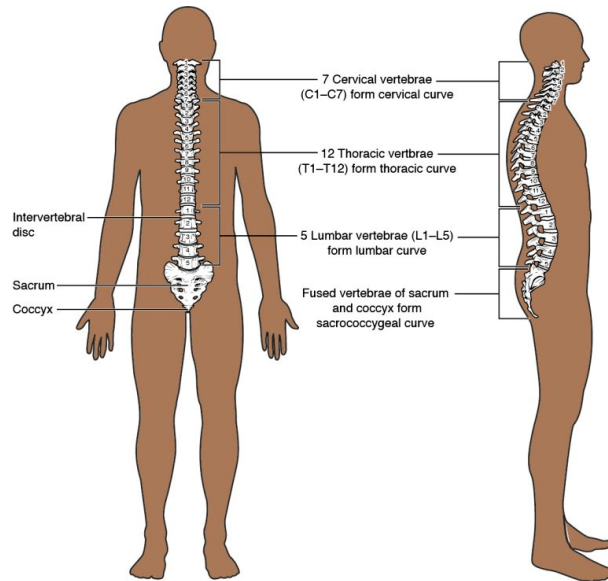


Figure 7.1.11: Posterior and lateral views of the human spine showing cervical, thoracic, lumbar, and sacrococcygeal curves with labeled vertebrae and key structures. (CC BY 4.0; via [Fundamentals of Human Anatomy Laboratory Manual](#)).

Figure 7.1.11 is a labeled diagram of the human vertebral column (spine) shown in two views: a back view on the left and a side view on the right. The labels identify the major spine regions, the number of vertebrae in each region, and the normal spinal curves. Key labeled parts (top to bottom):

- Cervical vertebrae (C1–C7): 7 vertebrae in the neck region; labeled as forming the cervical curve.
- Thoracic vertebrae (T1–T12): 12 vertebrae in the upper and mid-back; labeled as forming the thoracic curve.
- Lumbar vertebrae (L1–L5): 5 vertebrae in the lower back; labeled as forming the lumbar curve.
- Sacrum: shown as fused vertebrae at the base of the spine.
- Coccyx: the small terminal bone below the sacrum; also shown as fused segments.
- The diagram notes that the fused vertebrae of the sacrum and coccyx form the sacrococcygeal curve.
- An intervertebral disc label points to the cushioning discs located between adjacent vertebrae.

The side view emphasizes (spinal curves): The side view highlights the spine's natural alternating curves from the neck through the lower back and into the fused sacrum/coccyx region.

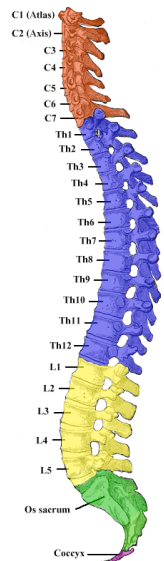


Figure 7.1.12: Spinal column regions and vertebra numbering: cervical, thoracic, lumbar, sacrum, and coccyx. (CC BY 4.0; via [Boundless Anatomy and Physiology](#)).

Figure 7.1.12 is a labeled side view of the human vertebral column (spine). The vertebrae are grouped into regions and labeled from top to bottom: cervical, thoracic, lumbar, sacrum, and coccyx. Labels shown (top to bottom):

- Cervical vertebrae (C1–C7)
 - C1 is labeled Atlas
 - C2 is labeled Axis
 - Then C3, C4, C5, C6, C7
- Thoracic vertebrae (Th1–Th12)
 - Labeled sequentially Th1 through Th12
- Lumbar vertebrae (L1–L5)
 - Labeled sequentially L1 through L5
- Sacrum
 - Labeled Os sacrum (a fused set of vertebrae)
- Coccyx
 - Labeled Coccyx at the bottom tip of the spine

General Anatomical Features of Vertebrae

A vertebra is a single individual bone that makes up the vertebral column (spine), which is a series of connected bones that run from the base of the skull to the tip of the tailbone, primarily functioning to protect the spinal cord and provide structural support for the body; a typical vertebra consists of a body, pedicles, laminae, transverse processes, spinous process, and superior and inferior articular processes, with different regions of the spine (cervical, thoracic, lumbar, sacral, coccygeal) having distinct vertebral shapes adapted to their specific functions.

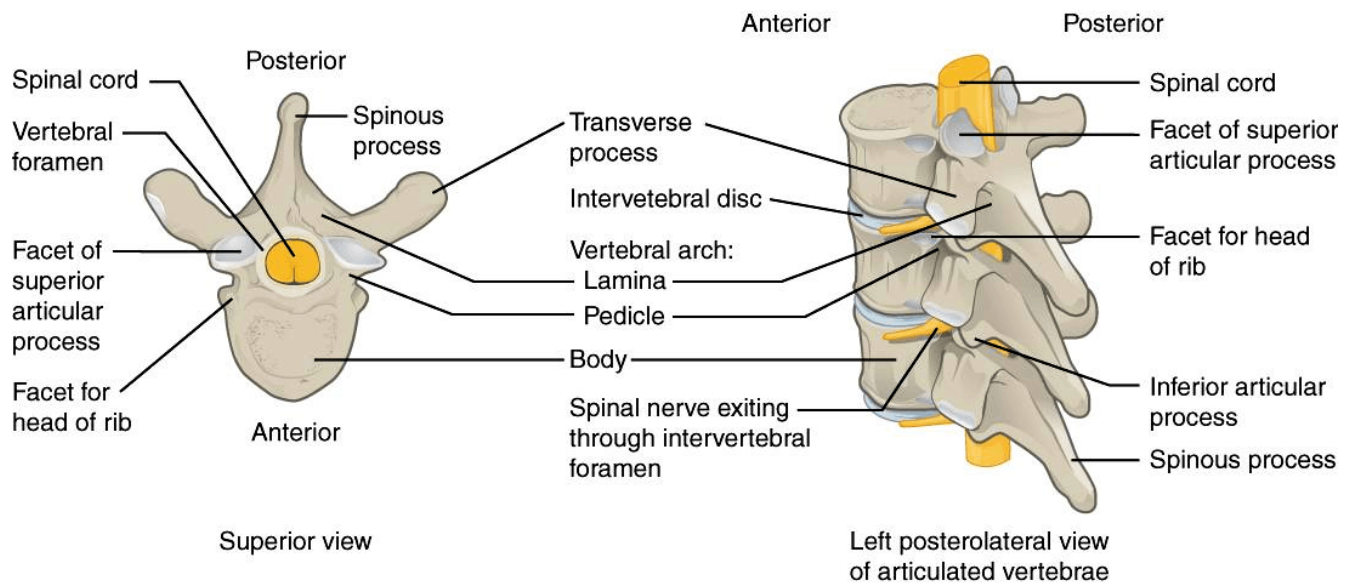


Figure 7.1.13: Two views of vertebrae: left shows a single vertebra from above; right shows connected vertebrae with spinal cord and nerves. (CC BY 4.0; via [Fundamentals of Human Anatomy Laboratory Manual](#)).

Figure 7.1.13 is labeled with orientation terms anterior (front) and posterior (back) to show which side faces the front of the body and which faces the back.

- The body is the large, thick, anterior portion of the vertebra. It is designed for weight-bearing and forms the front of the spinal column.
- Behind the body is the vertebral foramen, an opening that forms part of the canal that houses the spinal cord. The spinal cord is shown passing through this space.
- The vertebral arch surrounds the vertebral foramen and is labeled in parts:
 - Pedicle: the short bony segment connecting the body to the rest of the arch.
 - Lamina: the bony plate forming the posterior portion of the arch.
- Several projections are labeled, which serve as attachment points and joint surfaces:
 - Spinous process: a posterior projection you can think of as the “backward-pointing” spine projection where muscles and ligaments attach.
 - Transverse process: a lateral (side) projection where muscles attach; in some regions it also relates to rib attachment.
- Joint surfaces are labeled as facets (smooth surfaces where bones articulate):
 - Facet of superior articular process: part of the joint surface where one vertebra connects to the vertebra above.
 - Facet for head of rib: a facet indicating this vertebra region is associated with rib articulation (a thoracic feature).

Right panel: left posterolateral view of articulated vertebrae (stacked vertebrae) - this view shows multiple vertebrae connected, emphasizing how the spine is built as a column with cushioning discs and spaces for nerves.

- The intervertebral disc is shown between vertebral bodies. Its role is to cushion and allow limited movement between adjacent vertebrae.
- The spinal cord is shown running vertically through the stacked vertebral foramina, forming the spinal canal.
- The spinal nerve exiting through intervertebral foramen is labeled to show that nerves leave the spinal canal through openings between adjacent vertebrae.
- The vertebral arch is again labeled with lamina and pedicle, reinforcing that these parts form the protective ring around the spinal cord.
- Additional joint and projection labels show how vertebrae connect and stabilize:
 - Facet of superior articular process
 - Inferior articular process
 - Spinous process
 - Transverse process
 - Facet for head of rib

Features for Identification of Regional Vertebra

- Cervical Vertebrae (Neck)
 - Smallest vertebrae
 - Transverse processes with a foramen transversarium to accommodate the vertebral artery
 - Bifid (split) spinous processes
 - Prominent C1 (atlas) and C2 (axis) vertebrae with unique articulation for head movement
- Thoracic Vertebrae (Mid-back)
 - Heart-shaped vertebral body
 - Costal facets on the transverse processes and vertebral body for rib articulation
 - Long, downward-sloping spinous processes
- Lumbar Vertebrae (Lower Back)
 - Largest vertebrae with a large, thick vertebral body
 - Short, thick, and nearly horizontal spinous processes
 - Transverse processes are long and robust

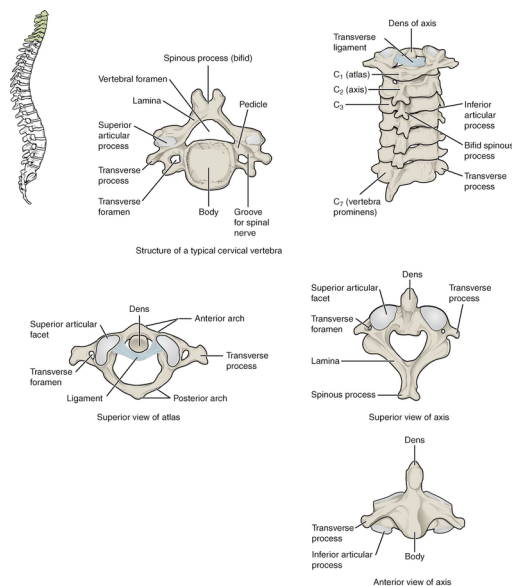


Figure 7.1.14: Views of cervical vertebrae: typical vertebra, atlas (C1), axis (C2), and C1-C7 sequence. (CC BY 4.0; via [Anatomy & Physiology](#)).

Figure 7.1.14 contains multiple diagrams of cervical vertebrae:

1. Leftmost diagram: Lateral view of the entire spine.
2. Top middle diagram: Structure of a typical cervical vertebra, showing labeled parts such as:
 - Spinous process (bifid)
 - Vertebral foramen
 - Lamina and pedicle
 - Superior articular process
 - Transverse process and transverse foramen
 - Body and groove for spinal nerve
3. Top right diagram: Lateral view of cervical vertebrae from C1 (atlas) to C7 (vertebra prominens), highlighting:
 - Dens of axis
 - Transverse ligament
 - Inferior articular process
 - Bifid spinous process
4. Bottom left diagram: Superior view of the atlas (C1), showing:
 - Dens
 - Anterior and posterior arches
 - Superior articular facet
 - Transverse foramen and ligament
5. Bottom middle diagram: Superior view of the axis (C2), showing:

- Dens
- Superior articular facet
- Transverse foramen
- Lamina and spinous process

6. Bottom right diagram: Anterior view of the axis (C2), showing:

- Dens
- Body
- Inferior articular process

Sacrum

A triangle-shaped bone that connects to the hips and forms the posterior pelvic wall. The sacrum is made up of five fused vertebrae (S1 to S5) that weld together during fetal development. The sacrum's main function is to connect the spine to the hip bones.

Coccyx

Also known as the tailbone, the coccyx is made up of four fused vertebrae. The coccyx provides slight support for the pelvic organs and attaches to the pelvic floor muscles and ligaments. During childbirth, the coccyx moves backward to help widen the pelvic passage. The sacrum and coccyx are part of the pelvis, which is a basin-shaped structure that supports the spinal column and protects the abdominal organs. The fusion of the sacral and coccygeal vertebrae doesn't begin until around age 20 and isn't complete until middle age.

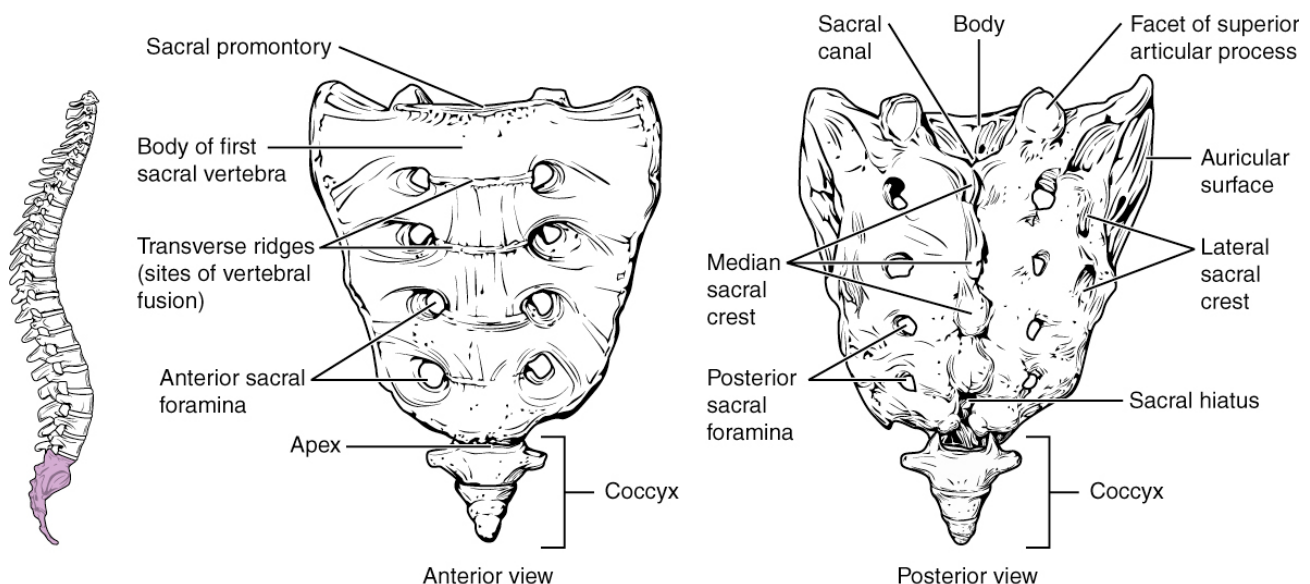


Figure 7.1.15: Anterior and posterior views of the sacrum and coccyx with labeled anatomical features, including foramina, crests, sacral canal, and coccyx. (CC BY 3.0; "Sacrum and Coccyx" by OpenStax).

Figure 7.1.15 displays the sacrum and coccyx in three views:

1. Left: Full spine with the sacrum and coccyx highlighted in purple.
2. Center: Anterior view of the sacrum, labeled with:
 - Sacral promontory
 - Body of first sacral vertebra
 - Transverse ridges (sites of vertebral fusion)
 - Anterior sacral foramina
 - Apex
 - Coccyx
3. Right: Posterior view of the sacrum, labeled with:
 - Sacral canal

- Body
- Facet of superior articular process
- Auricular surface
- Lateral sacral crest
- Median sacral crest
- Posterior sacral foramina
- Sacral hiatus

The Thoracic Cage

The thoracic cage (rib cage) forms the thorax (chest) portion of the body. It consists of the 12 pairs of ribs with their costal cartilages and the sternum Figure 7.1.16. The ribs are anchored posteriorly to the 12 thoracic vertebrae (T1 to T12). The thoracic cage protects the heart and lungs.

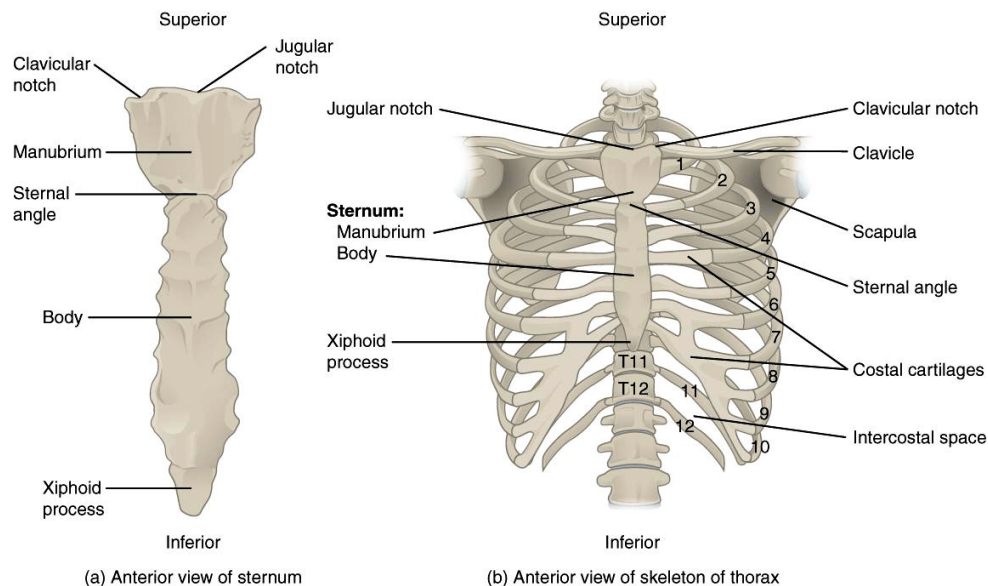


Figure 7.1.16: (a) Anterior view of sternum (b) Anterior view of skeleton of thorax. (CC BY 4.0; via [Fundamentals of Human Anatomy Laboratory Manual](#)).

Figure 7.1.16 represents the thoracic cage which provides protection for vital organs and supports breathing. It consists of:

Main Components

- Sternum: Made up of three parts:
 - Manubrium
 - Body
 - Xiphoid process
- 12 Pairs of Ribs with costal cartilages
- Thoracic Vertebrae: Ribs are anchored posteriorly to 12 thoracic vertebrae.

Rib Classification

- True Ribs (1 to 7): Attach directly to the sternum via costal cartilage.
- False Ribs (8 to 12): Do not attach directly to the sternum.
 - Floating Ribs (11 to 12): A subset of false ribs; no anterior attachment.

Sternum (breastbone)

Located in the middle of the front of the chest, anterior to the mediastinum and medial to the clavicle, made up of three parts: the manubrium (on top), the body (middle), and the xiphoid process. In adults, the sternum is about 15 to 20 cm long. The body is the longest part, about 20 cm long, 3 to 4 cm wide, and 1 cm thick. Several landmarks, including the jugular notch, sternal angle,

and transverse ridges. Protects the organs and muscles of the chest, helps with breathing, and provides structural support.

Hyoid Bone

A horseshoe-shaped bone found in the neck between the chin and the thyroid cartilage. Only distantly articulates to other bones by muscles and ligaments. Important for swallowing and sound production.

7.2: Activity 1

Bone Classification

Bones are classified by shape into six categories and also by their location in the axial or appendicular skeleton - the two divisions of the skeletal system. Fill in the blanks in the table below to demonstrate knowledge. Use articulated skeleton and disarticulated bones.

Table 7.2.1: Bone Names, Shape Classification, and Skeletal Division

Bone Name	Classification by Shape	Belongs to axial or appendicular skeleton
Skull bones of the face		
Scapula ("shoulder" bone)		
Radius (lateral forearm bone)		
Tarsal bones (ankle bones)		
Phalanges ("finger/toe" bones)		
Ribs		
Patella ("knee" bone)		
Hyoid bone		
Vertebra		
Mandible		
Ileum		
Femur		
Carpal bones		
Sacrum		
Ribs		

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7.3: Activity 2

Identification of Components of the Haversian System

In this activity, you will explore and identify the key components of the Haversian system (also known as the osteon), which is essential for understanding the structure and function of compact bone tissue. This system plays a crucial role in bone health and nutrient delivery.

Pick up the Osteon model to identify the parts/structures of compact bone shown in the image below. Each structure is indicated with a letter. Place the corresponding anatomical name in the table below next to the letter highlighting that structure.

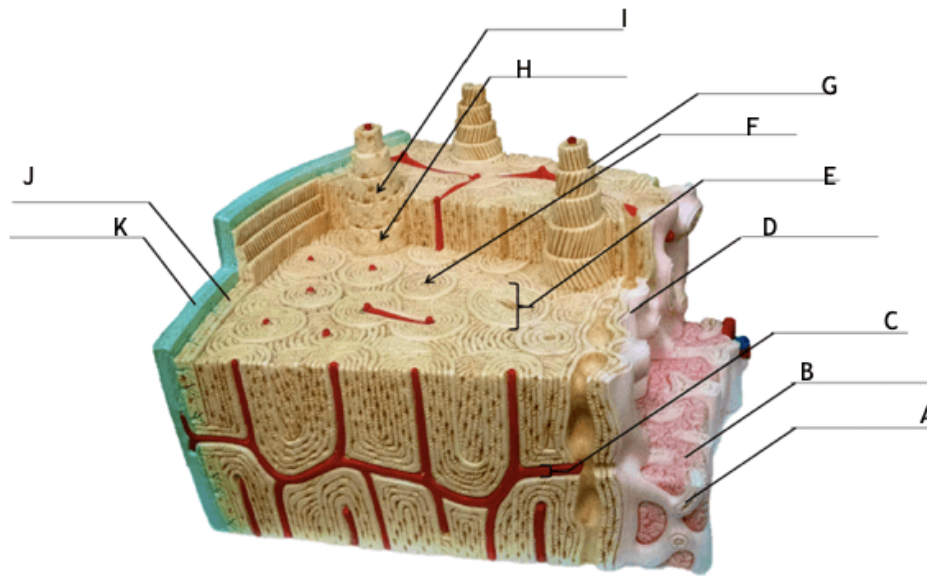


Figure 7.3.1: Detailed anatomical model of bone tissue highlighting the Haversian system, Volkmann's canals, and other microscopic features of compact bone. (CC BY-NC-SA 4.0; Rosanna Hartline via [Laboratory Activities and Assignment](#)).

Figure 7.3.1 presents a detailed anatomical model of compact bone tissue, focusing on its microscopic structure. The model includes several key features:

- **Osteons:** Cylindrical units that form the structural framework of compact bone. Each osteon consists of concentric layers of bone matrix called lamellae.
- **Haversian Canals:** Central channels within each osteon that contain blood vessels and nerves, facilitating nutrient and waste exchange.
- **Other Microscopic Features:** Although the text labels are not visible, arrows point to additional structures likely including:
 - **Lacunae:** Small spaces housing osteocytes (bone cells).
 - **Canaliculi:** Tiny channels connecting lacunae, allowing communication between osteocytes.
 - **Interstitial Lamellae:** Layers of bone matrix found between osteons.

Table 7.3.1: Features and Corresponding Letters in Bone Structure Diagram

Feature/Structure	Corresponding Letter
Canaliculus	
Endosteum	
Circumferential lamellae	
Bone marrow	
Osteocyte in lacuna	

Feature/Structure	Corresponding Letter
Volkman's canal	
Periosteum	
Osteon	
Concentric lamellae	
Trabecula	
Central canal	

7.4: Activity 3

Identifying the Parts of a Long Bone

In this lab activity, you will identify the key parts of a long bone as indicated by letters on the provided diagram. This exercise will enhance your understanding of bone anatomy and the functions of various components.

Instructions

1. Carefully look at the diagram that features letters corresponding to different parts of the long bone.
2. Using the terms listed in the table, match each letter to the correct anatomical part of the long bone.
3. Document your findings by writing down the letter corresponding to each term in the table.
4. Once you have completed the identification, discuss your findings with classmates to clarify any uncertainties and enhance your understanding.

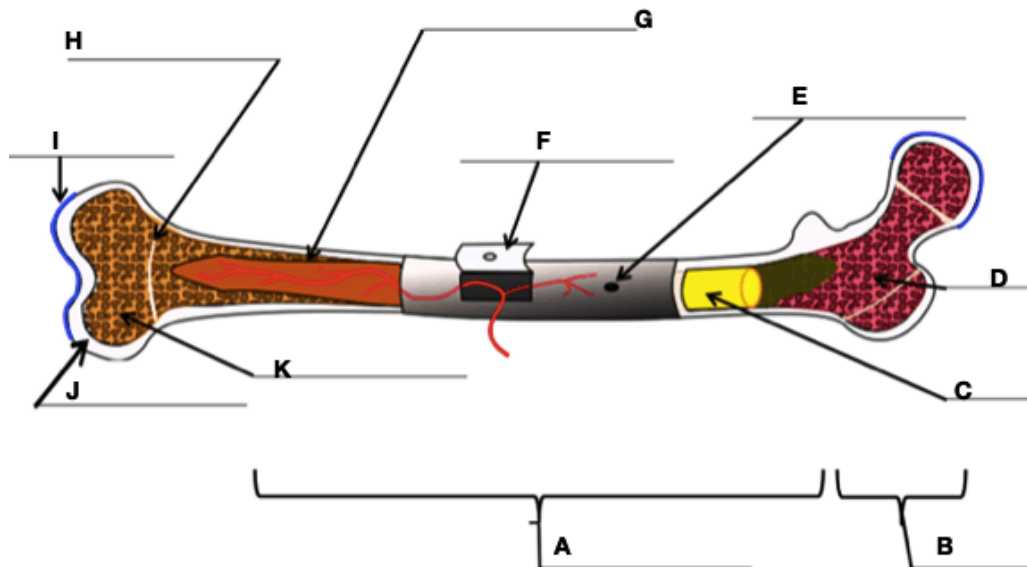


Figure 7.4.1: Diagram of a long bone with labeled internal structures including compact bone, spongy bone, blood vessels, and marrow cavity. (CC BY-NC-SA 4.0; Rosanna Hartline via [Laboratory Activities and Assignment](#)).

Figure 7.4.1 is a labeled anatomical diagram of a long bone, such as the femur or humerus, showing its internal structure and organization. Key components labeled in the diagram include:

- **Outer Layer:** The periosteum, a dense connective tissue membrane covering the bone's surface.
- **Compact Bone:** A dense, solid layer beneath the periosteum that provides strength and structure.
- **Spongy Bone:** Located primarily at the ends of the bone, this porous tissue contains trabeculae and spaces that help reduce bone weight while maintaining strength.
- **Marrow Cavity:** The central hollow region of the bone shaft, also known as the medullary cavity, which contains bone marrow responsible for producing blood cells.
- **Blood Vessels:** Shown entering and traversing the bone, these supply nutrients and oxygen to bone tissue and remove waste.

Table 7.4.1: Key anatomical features of a long bone and their corresponding labeled letters.

Feature/Structure	Corresponding Letter
Epiphysis	
Diaphysis	

Feature/Structure	Corresponding Letter
Articular cartilage	
Epiphyseal line	
Red bone Marrow	
Yellow bone marrow	
Periosteum	
Endosteum	
Compact bone	
Spongy bone	
Nutrient forâmen	

7.5: Activity 4

Identification of Skull Bones (Cranial and Facial)

The goal of this activity is to familiarize students with the anatomy of the skull by identifying the cranial and facial bones. This understanding is crucial for recognizing how these structures protect the brain and support facial features, as well as their roles in various physiological functions.

Procedure

1. Pick up skull models, diagrams, or images that detail the cranial and facial bones.
2. Carefully observe the model or diagram to locate each bone.
3. Document key characteristics of each bone, such as its function, shape, and location. Consider how these bones contribute to the overall structure of the skull.
4. Document your findings by writing down the letter corresponding to each term in the table.
5. After completing the identification, engage in a discussion with your classmates. Share your findings, clarify any uncertainties, and explore the significance of each bone in terms of protection and function.

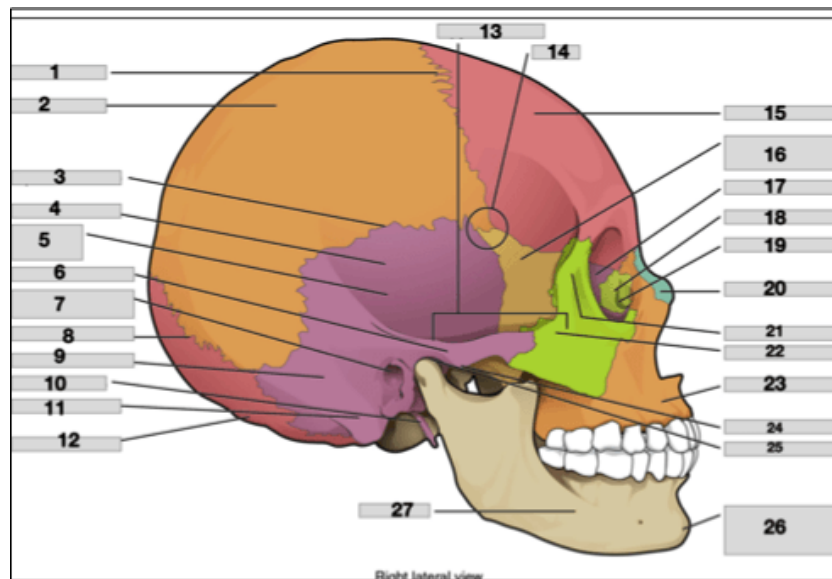


Figure 7.5.1: Lateral view of the human skull with labeled and color-coded bones. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekejevia via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 7.5.1 shows a right lateral view of a human skull, meaning it is viewed from the side. The diagram presents the full structure of the skull, including the curved dome of the cranium and the facial region. The surface of the skull is marked with various sutures—visible lines where bones are joined together. These sutures form distinct patterns across the top, side, and back of the skull.

The image also includes features such as openings, ridges, and projections that are part of the skull's anatomy. These structures contribute to the skull's role in protecting the brain, supporting facial muscles, and enabling jaw movement. The jawbone is visible at the bottom, connecting to the skull at a joint near the ear region.

Table 7.5.1: Numbered labels and corresponding bones in the right lateral view of the human skull.

Corresponding	Number Identified skull bones
1	

Corresponding	Number Identified skull bones
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	

7.6: Activity 5

Group Challenge: Odd Bone Out

Each of the following sets contains four cranial/facial bones. Compare the characteristics of each bone and look for the one that significantly differs in shape, number, location, or function compared to the others. One of the listed bones does not share a characteristic that the other three do. Use an articulated skull, and disarticulated skull bones to select and justify your answer.

1. From the following list, which one is the "odd bone"? Why is it the odd one out? Share reasoning.
 - a. Zygomatic
 - b. Maxilla
 - c. Vomer
 - d. Nasal
2. From the following list, which one is the "odd bone"? Why is it the odd one out? Share reasoning.
 - a. Parietal bone
 - b. Sphenoid bone
 - c. Frontal bone
 - d. Occipital bone
3. From the following list, which one is the "odd bone"? Why is it the odd one out? Share reasoning.
 - a. Lacrimal bone
 - b. Nasal bone
 - c. Zygomatic bone
 - d. Maxilla

7.7: Activity 6

Comparing Fetal Skull with Adult Skull

Observation skill is crucial in anatomy and healthcare because it allows medical professionals to accurately assess a patient's condition by carefully observing visual cues, physical signs, and behavioral changes, which are essential for making correct diagnoses and providing appropriate treatment plans; essentially, being able to "read" the body through detailed observation is a fundamental aspect of patient care and can significantly impact treatment outcomes.

In this activity, you will apply your observation skills to compare the anatomical differences between the fetal skull and the adult skull. By examining these two stages of human development, you will gain insights into the changes that occur in skull structure as a person matures.

Procedure

1. Obtain a human fetal/newborn skull and an adult skull, and study it carefully with your group to respond to the following prompts.
2. Write a brief summary of the differences between fetal and adult skull.
3. Locate the following fontanelles on the fetal skull: anterior (or frontal) fontanelle, mastoid fontanelle, sphenoidal fontanelle, and posterior (or occipital) fontanelle.
4. Describe at least two structural/functional advantages of fontanelles.

7.8: Activity 7

Identify Vertebral Bones Based on Distinctive Anatomical Features

In this lab activity, you will focus on identifying various vertebral bones by examining their unique anatomical features. Understanding the structure of vertebrae is crucial for grasping the complexities of the human spine and its role in supporting the body, protecting the spinal cord, and facilitating movement.

Helpful hints to tell the difference between the vertebrae:

- Only cervical vertebrae have a transverse foramen
 - Only the atlas lacks the vertebral body
 - Only the axis has a dense process, superior projection.
- Thoracic vertebrae articulate with the ribs and therefore have a costal facet on the sides of the body.
 - The spinous process is long and points inferiorly
 - Thoracic vertebrae look like a giraffe's head. The snout of the giraffe is the spinous process. The giraffe's horns are the superior articulating process, and the ears are the transverse process.
- Lumbar vertebrae have a large body. And they don't have a transverse foramina and costal facets!
 - The angle between the spinous and transverse process makes an "L" shape for lumbar.
 - Lumbar vertebrae look like a moose's head. The snout is the spinous process, and the horns are the superior articulating process.

Pick up disarticulated vertebral bones from cervical, thoracic and lumbar region. Divide the vertebrae (cervical, thoracic, lumbar) among the group members to identify the regional representatives in the image below. Also identify the specific bone features indicated by letters in the table.

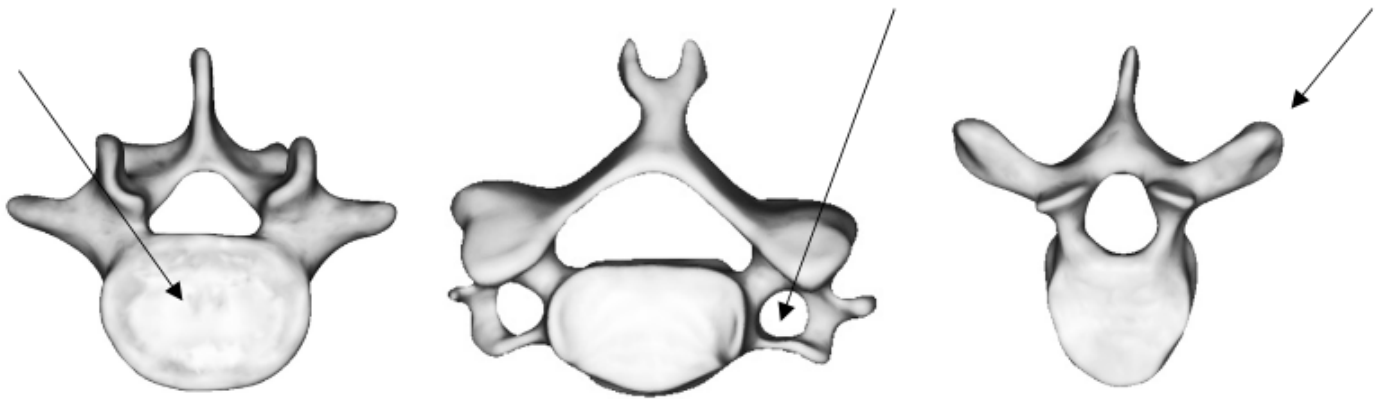


Figure 7.8.1: Three different vertebrae with arrows indicating specific anatomical features. (CC BY-NA-SC 4.0; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via [Post-Lab for Axial Skeleton](#))

Figure 7.8.1 displays three vertebrae, each shown from a different angle or type, arranged from left to right. Each vertebra has an arrow pointing to a specific anatomical feature:

- The first vertebra on the left highlights the vertebral body, the thick, weight-bearing portion at the front of the vertebra.
- The middle vertebra emphasizes the transverse foramen, a small opening found in cervical vertebrae that allows passage of blood vessels.
- The third vertebra on the right points to the spinous process, a bony projection extending backward, which serves as an attachment point for muscles and ligaments.

Table 7.8.1: Identification of bone features or markings corresponding to labels A, B, and C.

Corresponding Letter	Identification of bone features/markings
A	
B	
C	

Complete the table below with your observations on the features of the cervical, thoracic, and lumbar vertebrae.

Table 7.8.2: Comparison of anatomical features across cervical, thoracic, and lumbar vertebrae.

Features	Cervical	Thoracic	Lumbar
Size of body			
Shape of spinous process			
Costal facet (present/absent)			
Shape of transverse process			
Shape of vertebral foramen			

7.9: Activity 8

Case Study

In this lab activity, students will engage in critical thinking by analyzing the anatomical specialization of cervical vertebrae, particularly focusing on C1 (atlas) and C2 (axis). By examining how the unique structures of these vertebrae relate to their functions, students will deepen their understanding of how anatomical adaptations enable specific movements and stability in the cervical region.

Procedure

1. Collect disarticulated cervical vertebrae Atlas (C1) and Axis (C2). Identify Key Features.
2. Read the case study - Sarah reports experiencing neck pain and stiffness following a fall while jogging. She states that she landed awkwardly on her shoulder and has since experienced difficulty turning her head to the right, along with occasional tingling in her right arm.
3. Discuss Structure-Function Relationships:
 - Analyze how the unique structure of C1 allows for a greater range of motion in nodding.
 - Discuss how the dens of C2 stabilizes the head while allowing rotational movement.
 - Describe how injuries to these structures could affect movement and stability.

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7.10: Activity 9

Bone and Bone Markings of the Thoracic Cage

Materials required:

- Articulated skeleton
- Disarticulated skeleton
- Blue labeling tape
- Camera or phone for documentation

Instructions:

1. Work in groups. On one of the articulated skeletons in the lab, identify the following components of the thoracic cage with labeled blue tape.
 - False ribs
 - Floating ribs
 - Costal cartilage
 - Body of sternum
 - Manubrium
 - Xiphoid process
 - Jugular notch
 - Clavicular notch
2. Check with the instructor for correct identification.
3. Take a photograph. Attach the photograph with your worksheet.
4. Remove all the stickers after you are done.

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7.11: Activity 10

Case Study: “Car Accident Woes”

A family friend, Dr. Papadopoulos, has invited you to come to her office for a day to shadow her and the dental hygienist. The patient sustained a fractured jaw following a car accident when the air bag in the passenger seat where he was sitting failed to deploy. Thankfully, he was wearing a seat belt, which probably saved his life. His neck, chest, and face are all sore. His jaw appears disfigured. You are studying bones in your A&P class and pull out your notes to review which bones might be involved. You think that the jaw might be correctly termed the mandible, but the maxillae could also be involved. Dr. Papadopoulos confirms that the mandible is involved in the fracture, but the zygomatic and temporal bones are as well. She describes the fractured processes of the bones and discusses possible nerve damage. She asks you what a general term is for a bony passageway for nerve and blood vessels. You quickly answer, “a meatus.” She replies, “you are very close! But a better term would be ‘foramen’”. Slightly embarrassed, you decided it might be a good time to review general bone marking terms!

Given the information in the case study, list the bones that are likely fractured.

Key Terms and Definitions

- **Alveolar process of the mandible:** upper border of mandibular body that contains the lower teeth
- **Aveolar process of the maxilla:** curved, inferior margin of the maxilla that supports and anchors the upper teeth
- **Angle of the mandible:** rounded corner located at outside margin of the body and ramus junction
- **Angle of the rib:** portion of rib with greatest curvature; together, the rib angles form the most posterior extent of the thoracic cage
- **Anterior (ventral) sacral foramen:** one of the series of paired openings located on the anterior (ventral) side of the sacrum
- **Anterior cranial fossa:** shallowest and most anterior cranial fossa of the cranial base that extends from the frontal bone to the lesser wing of the sphenoid bone
- **Atlas:** first cervical (C1) vertebra
- **Axial skeleton:** central, vertical axis of the body, including the skull, vertebral column, and thoracic cage
- **Axis:** second cervical (C2) vertebra
- **Carotid canal:** zig-zag tunnel providing passage through the base of the skull for the internal carotid artery to the brain; begins anteromedial to the styloid process and terminates in the middle cranial cavity, near the posterior-lateral base of the sella turcica
- **Cervical curve:** posteriorly concave curvature of the cervical vertebral column region; a secondary curve of the vertebral column
- **Cervical vertebrae:** seven vertebrae numbered as C1–C7 that are located in the neck region of the vertebral column
- **Clavicular notch:** paired notches located on the superior-lateral sides of the sternal manubrium, for articulation with the clavicle
- **Coccyx:** small bone located at inferior end of the adult vertebral column that is formed by the fusion of four coccygeal vertebrae; also referred to as the “tailbone”
- **Condylar process of the mandible:** thickened upward projection from posterior margin of mandibular ramus
- **Condyle:** oval-shaped process located at the top of the condylar process of the mandible
- **Coronal suture:** joint that unites the frontal bone to the right and left parietal bones across the top of the skull
- **Coronoid process of the mandible:** flattened upward projection from the anterior margin of the mandibular ramus
- **Costal cartilage:** hyaline cartilage structure attached to the anterior end of each rib that provides for either direct or indirect attachment of most ribs to the sternum
- **Costal facet:** site on the lateral sides of a thoracic vertebra for articulation with the head of a rib
- **Costal groove:** shallow groove along the inferior margin of a rib that provides passage for blood vessels and a nerve
- **Cranium:** skull
- **Cribiform plate:** small, flattened areas with numerous small openings, located to either side of the midline in the floor of the anterior cranial fossa; formed by the ethmoid bone
- **Crista galli:** small upward projection located at the midline in the floor of the anterior cranial fossa; formed by the ethmoid bone
- **Dens:** bony projection (odontoid process) that extends upward from the body of the C2 (axis) vertebra
- **Ear ossicles:** three small bones located in the middle ear cavity that serve to transmit sound vibrations to the inner ear
- **Ethmoid air cell:** one of several small, air-filled spaces located within the lateral sides of the ethmoid bone, between the orbit and upper nasal cavity
- **Ethmoid bone:** unpaired bone that forms the roof and upper, lateral walls of the nasal cavity, portions of the floor of the anterior cranial fossa and medial wall of orbit, and the upper portion of the nasal septum
- **External acoustic meatus:** ear canal opening located on the lateral side of the skull
- **Facet:** small, flattened area on a bone for an articulation (joint) with another bone, or for muscle attachment
- **Facial bones:** fourteen bones that support the facial structures and form the upper and lower jaws and the hard palate
- **False ribs:** vertebrochondral ribs 8–12 whose costal cartilage either attaches indirectly to the sternum via the costal cartilage of the next higher rib or does not attach to the sternum at all
- **Floating ribs:** vertebral ribs 11–12 that do not attach to the sternum or to the costal cartilage of another rib
- **Fontanelle:** expanded area of fibrous connective tissue that separates the brain case bones of the skull prior to birth and during the first year after birth
- **Foramen magnum:** large opening in the occipital bone of the skull through which the spinal cord emerges and the vertebral arteries enter the cranium
- **Foramen ovale of the middle cranial fossa:** oval-shaped opening in the floor of the middle cranial fossa
- **Frontal bone:** unpaired bone that forms forehead, roof of orbit, and floor of anterior cranial fossa
- **Frontal sinus:** air-filled space within the frontal bone; most anterior of the paranasal sinuses

- **Greater wings of sphenoid bone:** lateral projections of the sphenoid bone that form the anterior wall of the middle cranial fossa and an area of the lateral skull
- **Hard palate:** bony structure that forms the roof of the mouth and floor of the nasal cavity, formed by the palatine process of the maxillary bones and the horizontal plate of the palatine bones
- **Head of the rib:** posterior end of a rib that articulates with the bodies of thoracic vertebrae
- **Horizontal plate:** medial extension from the palatine bone that forms the posterior quarter of the hard palate
- **Hyoid bone:** small, U-shaped bone located in upper neck that does not contact any other bone
- **Hypoglossal canal:** paired openings that pass anteriorly from the anterior-lateral margins of the foramen magnum deep to the occipital condyles
- **Hypophyseal (pituitary) fossa:** shallow depression on top of the sella turcica that houses the pituitary (hypophyseal) gland
- **Inferior articular process:** bony process that extends downward from the vertebral arch of a vertebra that articulates with the superior articular process of the next lower vertebra
- **Inferior nasal concha:** one of the paired bones that project from the lateral walls of the nasal cavity to form the largest and most inferior of the nasal conchae
- **Infraorbital foramen:** opening located on anterior skull, below the orbit
- **Internal acoustic meatus:** opening into petrous ridge, located on the lateral wall of the posterior cranial fossa
- **Intervertebral disc:** structure located between the bodies of adjacent vertebrae that strongly joins the vertebrae; provides padding, weight bearing ability, and enables vertebral column movements
- **Intervertebral foramen:** opening located between adjacent vertebrae for exit of a spinal nerve
- **Jugular (suprasternal) notch:** shallow notch located on superior surface of sternal manubrium
- **Jugular foramen:** irregularly shaped opening located in the lateral floor of the posterior cranial cavity
- **Kyphosis:** (also, humpback or hunchback) excessive posterior curvature of the thoracic vertebral column region
- **Lacrimal bone:** paired bones that contribute to the anterior-medial wall of each orbit
- **Lacrimal fossa:** shallow depression in the anterior-medial wall of the orbit, formed by the lacrimal bone that gives rise to the nasolacrimal canal
- **Lambdoid suture:** inverted V-shaped joint that unites the occipital bone to the right and left parietal bones on the posterior skull
- **Lamina:** portion of the vertebral arch on each vertebra that extends between the transverse and spinous process
- **Lateral sacral crest:** paired irregular ridges running down the lateral sides of the posterior sacrum that was formed by the fusion of the transverse processes from the five sacral vertebrae
- **Lesser wings of the sphenoid bone:** lateral extensions of the sphenoid bone that form the bony lip separating the anterior and middle cranial fossae
- **Lordosis:** (also, swayback) excessive anterior curvature of the lumbar vertebral column region
- **Lumbar curve:** posteriorly concave curvature of the lumbar vertebral column region; a secondary curve of the vertebral column
- **Lumbar vertebrae:** five vertebrae numbered as L1-L5 that are located in lumbar region (lower back) of the vertebral column
- **Mandible:** unpaired bone that forms the lower jaw bone; the only moveable bone of the skull
- **Mandibular foramen:** opening located on the inner (medial) surface of the mandibular ramus
- **Mandibular fossa:** oval depression located on the inferior surface of the skull
- **Mandibular notch:** large U-shaped notch located between the condylar process and coronoid process of the mandible
- **Manubrium:** expanded, superior portion of the sternum
- **Mastoid process:** large bony prominence on the inferior, lateral skull, just behind the earlobe
- **Maxillary bone:** (also, maxilla) paired bones that form the upper jaw and anterior portion of the hard palate
- **Maxillary sinus:** air-filled space located with each maxillary bone; largest of the paranasal sinuses
- **Median sacral crest:** irregular ridge running down the midline of the posterior sacrum that was formed from the fusion of the spinous processes of the five sacral vertebrae
- **Mental foramen:** opening located on the anterior-lateral side of the mandibular body
- **Middle cranial fossa:** centrally located cranial fossa that extends from the lesser wings of the sphenoid bone to the petrous ridge
- **Middle nasal concha:** nasal concha formed by the ethmoid bone that is located between the superior and inferior conchae
- **Nasal bone:** paired bones that form the base of the nose
- **Nasal cavity:** opening through skull for passage of air
- **Nasal conchae:** curved bony plates that project from the lateral walls of the nasal cavity; include the superior and middle nasal conchae, which are parts of the ethmoid bone, and the independent inferior nasal concha bone
- **Nasal septum:** flat, midline structure that divides the nasal cavity into halves, formed by the perpendicular plate of the ethmoid bone, vomer bone, and septal cartilage
- **Neck of the rib:** narrowed region of a rib, next to the rib head
- **Nucleus pulposus:** gel-like central region of an intervertebral disc; provides for padding, weight-bearing, and movement

between adjacent vertebrae

- **Occipital bone:** unpaired bone that forms the posterior portions of the brain case and base of the skull
- **Occipital condyle:** paired, oval-shaped bony knobs located on the inferior skull, to either side of the foramen magnum
- **Optic canal:** opening spanning between middle cranial fossa and posterior orbit
- **Orbit:** bony socket that contains the eyeball and associated muscles
- **Palatine bone:** paired bones that form the posterior quarter of the hard palate and a small area in floor of the orbit
- **Palatine process:** medial projection from the maxilla bone that forms the anterior three quarters of the hard palate
- **Paranasal sinuses:** cavities within the skull that are connected to the conchae that serve to warm and humidify incoming air, produce mucus, and lighten the weight of the skull; consist of frontal, maxillary, sphenoidal, and ethmoidal sinuses
- **Parietal bone:** paired bones that form the upper, lateral sides of the skull
- **Pedicle:** portion of the vertebral arch that extends from the vertebral body to the transverse process
- **Perpendicular plate of the ethmoid bone:** downward, midline extension of the ethmoid bone that forms the superior portion of the nasal septum
- **Posterior (dorsal) sacral foramen:** one of the series of paired openings located on the posterior (dorsal) side of the sacrum
- **Posterior arch:** posterior portion of the ring-like C1 (atlas) vertebra
- **Posterior cranial fossa:** deepest and most posterior cranial fossa; extends from the petrous ridge to the occipital bone
- **Primary curve:** anteriorly concave curvatures of the thoracic and sacrococcygeal regions that are retained from the original fetal curvature of the vertebral column
- **Ramus of the mandible:** vertical portion of the mandible
- **Ribs:** thin, curved bones of the chest wall
- **Sacral canal:** bony tunnel that runs through the sacrum
- **Sacral foramina:** series of paired openings for nerve exit located on both the anterior (ventral) and posterior (dorsal) aspects of the sacrum
- **Sacral hiatus:** inferior opening and termination of the sacral canal
- **Sacral promontory:** anterior lip of the base (superior end) of the sacrum
- **Sacrococcygeal curve:** anteriorly concave curvature formed by the sacrum and coccyx; a primary curve of the vertebral column
- **Sacrum:** single bone located near the inferior end of the adult vertebral column that is formed by the fusion of five sacral vertebrae; forms the posterior portion of the pelvis
- **Sagittal suture:** joint that unites the right and left parietal bones at the midline along the top of the skull
- **Scoliosis:** abnormal lateral curvature of the vertebral column
- **Secondary curve:** posteriorly concave curvatures of the cervical and lumbar regions of the vertebral column that develop after the time of birth
- **Sella turcica:** elevated area of sphenoid bone located at midline of the middle cranial fossa
- **Septal cartilage:** flat cartilage structure that forms the anterior portion of the nasal septum
- **Skull:** bony structure that forms the head, face, and jaws, and protects the brain; consists of 22 bones
- **Sphenoid bone:** unpaired bone that forms the central base of skull
- **Sphenoid sinus:** air-filled space located within the sphenoid bone; most posterior of the paranasal sinuses
- **Spinous process:** unpaired bony process that extends posteriorly from the vertebral arch of a vertebra
- **Squamous suture:** joint that unites the parietal bone to the squamous portion of the temporal bone on the lateral side of the skull
- **Sternal angle:** junction line between manubrium and body of the sternum and the site for attachment of the second rib to the sternum
- **Sternum:** flattened bone located at the center of the anterior chest
- **Styloid process:** downward projecting, elongated bony process located on the inferior aspect of the skull
- **Superior articular process:** bony process that extends upward from the vertebral arch of a vertebra that articulates with the inferior articular process of the next higher vertebra
- **Superior nasal concha:** smallest and most superiorly located of the nasal conchae; formed by the ethmoid bone
- **Superior orbital fissure:** irregularly shaped opening between the middle cranial fossa and the posterior orbit
- **Supraorbital foramen:** opening located on anterior skull, at the superior margin of the orbit
- **Supraorbital margin:** superior margin of the orbit
- **Suture:** junction line at which adjacent bones of the skull are united by fibrous connective tissue
- **Temporal bone:** paired bones that form the lateral, inferior portions of the skull, with squamous, mastoid, and petrous portions
- **Temporal process of the zygomatic bone:** short extension from the zygomatic bone that forms the anterior portion of the zygomatic arch
- **Thoracic cage:** consists of 12 pairs of ribs and sternum
- **Thoracic curve:** anteriorly concave curvature of the thoracic vertebral column region; a primary curve of the vertebral column

- **Thoracic vertebrae:** twelve vertebrae numbered as T1-T12 that are located in the thoracic region (upper back) of the vertebral column
- **Transverse foramen:** opening found only in the transverse processes of cervical vertebrae
- **Transverse process:** paired bony processes that extends laterally from the vertebral arch of a vertebra
- **True ribs:** vertebrosteral ribs 1-7 that attach via their costal cartilage directly to the sternum
- **Tubercle of the rib:** small bump on the posterior side of a rib for articulation with the transverse process of a thoracic vertebra
- **Vertebral (spinal) canal:** bony passageway within the vertebral column for the spinal cord that is formed by the series of individual vertebral foramina
- **Vertebral column:** entire sequence of bones that extend from the skull to the tailbone
- **Vertebral foramen:** opening associated with each vertebra defined by the vertebral arch that provides passage for the spinal cord
- **Vertebra:** individual bone in the neck and back regions of the vertebral column
- **Vomer bone:** unpaired bone that forms the inferior and posterior portions of the nasal septum
- **Xiphoid process:** small process that forms the inferior tip of the sternum
- **Zygomatic arch:** elongated, free-standing arch on the lateral skull, formed anteriorly by the temporal process of the zygomatic bone and posteriorly by the zygomatic process of the temporal bone
- **Zygomatic bone:** cheekbone; paired bones that contribute to the lateral orbit and anterior zygomatic arch
- **Zygomatic process of the temporal bone:** extension from the temporal bone that forms the posterior portion of the zygomatic arch

8: APPENDICULAR SKELETON, JOINTS (ARTICULATIONS) AND MOVEMENTS

Introduction

In this lab, students will primarily identify the bones of the pectoral and pelvic girdles and upper and lower limbs and their connecting joints, learn the names of key movements possible at each joint, and practice relating these movements to everyday activities like walking, running, reaching, and grasping; this includes understanding the different types of joints and how their structure allows for specific motions using anatomical terms.

Learning Objectives

- Identify the bones of the pectoral girdle (scapula, clavicle), upper limb (humerus, radius, ulna, carpals, metacarpals, phalanges), pelvic girdle (ilium, ischium, pubis), and lower limb (femur, tibia, fibula, tarsals, metatarsals, phalanges) on diagrams or models.
- Describe the key features and landmarks of bones that contribute to joint articulation.
- Differentiate between biological male and female pelvis anatomy in relation to structure and function.
- Classify joints by structure and function (ball-and-socket, hinge, pivot, condyloid) and explain how joint shape determines range of motion.
- Examine ligaments and tendons associated with joints and analyze their role in joint stability.
- Define anatomical terms of movement and demonstrate body movements (flexion, extension, abduction, adduction, rotation, circumduction) at major joints including the shoulder, elbow, wrist, hip, knee, and ankle.

8.1: Background Information

8.2: Activity 1

8.3: Activity 2

8.4: Activity 3

8.5: Activity 4

8.6: Activity 5

8.7: Activity 6

8.8: Activity 7

8.9: Activity 8

8.10: Glossary

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8.1: Background Information

Overview

The adult axial skeleton consists of 80 bones that form the head and body trunk. Attached to this are the limbs, whose 126 bones constitute the appendicular skeleton. These bones are divided into two groups: the bones that are located within the limbs themselves, and the girdle bones that attach the limbs to the axial skeleton. The bones of the shoulder region form the pectoral girdle, which anchors the upper limb to the thoracic cage of the axial skeleton. The lower limb is attached to the vertebral column by the pelvic girdle. The pectoral girdle connects the upper limbs to the thoracic cage of the axial skeleton, while the pelvic girdle attaches the lower limbs to the vertebral column.

Because we stand upright, the upper and lower limbs have different functions. The bones in the lower limbs are built for weight-bearing support and stability, helping us walk or run. In contrast, the upper limbs prioritize mobility and are designed for various activities. Their wide range of motion and the ability to manipulate objects with our hands and opposable thumbs have enabled humans to create the modern world around us.

The Pectoral Girdle

The pectoral girdle bones, providing the points of attachment of the upper limbs to the axial skeleton, consists of the clavicle (or collarbone) in the anterior, as well as the scapula (or shoulder blades) in the posterior.

Clavicle

The clavicles, S-shaped bones that position the arms on the body, lie horizontally across the front of the thorax (chest) just above the first rib. The flatter broader end is the acromial extremity (end), which articulates with the acromion process of the scapula. The superior surface of the acromial extremity is smoother than its inferior surface, which can help you determine whether a particular clavicle bone comes from the left or right. The more circular end is the sternal extremity (end), which articulates with the manubrium of the sternum. The clavicle anchored by muscles from above, serves as a strut that extends laterally to support the scapula. This in turn holds the shoulder joint superiorly and laterally from the body trunk, allowing for maximal freedom of motion for the upper limb. The clavicle also transmits forces acting on the upper limb to the sternum and axial skeleton.

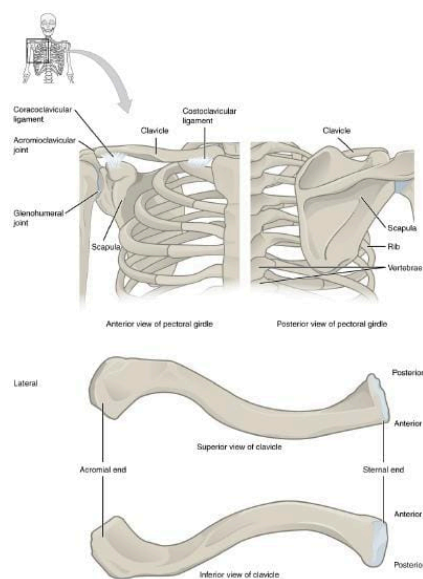


Figure 8.1.1: The pectoral girdle consists of the clavicle and the scapula, which serves to attach the upper limb to the sternum of the axial skeleton. (CC BY 3.0; Pectorial Girdle by OpenStax).

Figure 8.1.1 illustrates how the clavicle, or collarbone, and scapula, or shoulder blade, form the pectoral girdle. It shows where

the clavicle meets the scapula at the acromioclavicular, or AC, joint and identifies major landmarks of the clavicle in superior and inferior views.

The figure includes:

- an anterior, or front, view of the pectoral girdle,
- a posterior, or back, view of the pectoral girdle, and
- two isolated views of the clavicle: superior and inferior.

Top-left panel: anterior view of the pectoral girdle

- The clavicle connects the upper limb region to the trunk.
- The scapula is positioned along the upper lateral back, just below the clavicle.
- The clavicle meets the scapula at the acromioclavicular, or AC, joint at the top of the shoulder.
- The AC joint is located above the glenohumeral joint, or main shoulder joint.
- The coracoclavicular ligament connects the clavicle to the scapula near the AC joint.
- The costoclavicular ligament connects the clavicle to the upper part of the first rib.

Top-right panel: posterior view of the pectoral girdle

- This panel shows the clavicle and scapula from the back.
- The rib cage and vertebrae are also visible beneath the pectoral girdle.

Bottom panels: isolated clavicle views

- Superior view: The acromial end is broad and flattened where it meets the scapula at the AC joint. The clavicle then curves medially toward the sternal end, where it meets the sternum.
- Inferior view: The clavicle is shown from below, highlighting the underside of the bone and the same two ends: the acromial end laterally and the sternal end medially.

Scapula

The scapulae are flat, triangular bones that are located at the back of the pectoral girdle. They support the muscles crossing the shoulder joint. The spine runs across the back of the scapula; it is a good example of a bony protrusion that facilitates a broad area of attachment for muscles to bone.

The scapula is surrounded by muscles on both its anterior (deep) and posterior (superficial) sides, and thus does not articulate with the ribs of the thoracic cage. Scapula forms the shoulder joint or glenohumeral joint involving articulation between the glenoid cavity of the scapula and the head of the humerus.

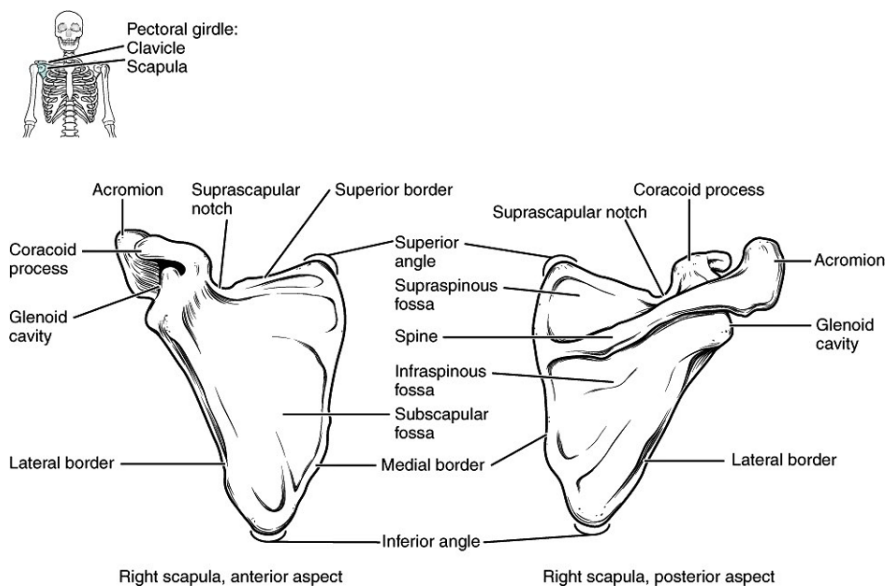


Figure 8.1.2: The scapula bone. Anterior view showing the acromion, coracoid process, suprascapular notch, subscapular fossa, superior border, lateral border, medial border, inferior angle, and medial border. The posterior view showing the suprascapular notch, coracoid process, acromion, glenoid cavity, superior angle and inferior angle are indicated on both views. (CC BY 4.0; via OpenStax).

Figure 8.1.2 is a labeled anatomy diagram of the right scapula (shoulder blade) shown in two views: anterior (front) aspect on the left and posterior (back) aspect on the right. A small inset at the top notes the pectoral girdle includes the clavicle and scapula.

Left image - Right scapula, anterior aspect (front surface). Labels identify:

- Acromion (a bony projection at the shoulder end)
- Coracoid process (a hook-like projection near the top front)
- Glenoid cavity (the socket where the upper arm bone articulates)
- Suprascapular notch
- Superior border
- Medial border
- Lateral border
- Inferior angle
- Subscapular fossa (broad depression on the anterior surface)

Right image - Right scapula, posterior aspect (back surface). Labels identify:

- Spine of scapula (a prominent ridge across the back)
- Suprascapular fossa (depression above the spine)
- Infraspinous fossa (depression below the spine)
- Acromion (continuous with the spine at the shoulder end)
- Coracoid process
- Glenoid cavity
- Suprascapular notch
- Superior angle
- Medial border
- Lateral border
- Inferior angle

This triangular bone has three sides called the medial, lateral, and superior borders. The suprascapular notch is located on the superior border. The scapula also has three corners, two of which are the superior and inferior angles. The third corner is occupied by the glenoid cavity. Posteriorly, the spine separates the suprascapular and infraspinous fossae, and then extends laterally as the acromial process. The subscapular fossa is located on the anterior surface of the scapula. The coracoid process projects anteriorly, passing inferior to the lateral end of the clavicle.

The Upper Limbs

The upper limbs contain 30 bones in three regions, the arm (shoulder to elbow), the forearm (ulna and radius), and the wrist and hand. The humerus is the largest and longest bone of the upper limb and the only bone of the arm. It articulates (joins) with the scapula at the shoulder and with the forearm at the elbow. The forearm, extending from the elbow to the wrist, consists of two bones: the ulna and the radius. The radius, located along the lateral (thumb) side of the forearm, articulates with the humerus at the elbow. The ulna, located on the medial aspect (pinky-finger side) of the forearm, is longer than the radius. It articulates with the humerus at the elbow. The radius and ulna also articulate with the carpal bones and with each other, which in vertebrates enables a variable degree of rotation of the carpus with respect to the long axis of the limb. The hand includes the eight bones of the carpus (wrist), the five bones of the metacarpus (palm), and the 14 bones of the phalanges (digits). Each digit consists of three phalanges, except for the thumb, which, when present, has only two.

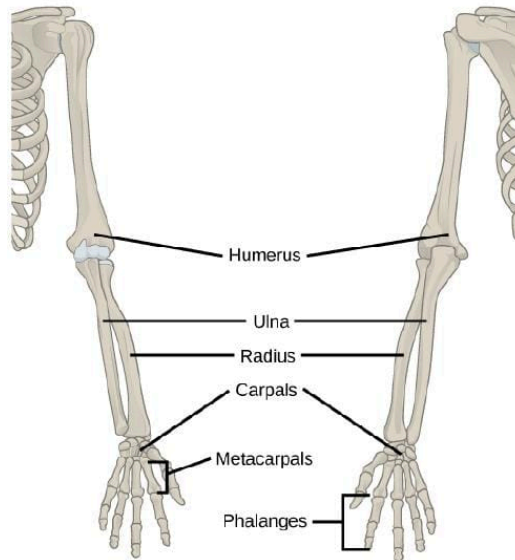


Figure 8.1.3: The upper limb consists of the humerus of the upper arm, the radius and ulna of the forearm, eight bones of the carpus, five bones of the metacarpus, and 14 bones of the phalanges. (CC BY-SA 4.0; via Boundless).

Figure 8.1.3 is a labeled anatomical diagram of the human arm and hand bones. It identifies the major bones including:

- Humerus is the upper arm bone
- Ulna and Radius is the two bones of the forearm
- Carpals is the small bones forming the wrist
- Metacarpals is the bones of the palm
- Phalanges is the bones of the fingers

The Humerus

The humerus is the single bone of the upper arm region. At its proximal end is the head of the humerus. This is the large, round, smooth region that faces medially. The head articulates with the glenoid cavity of the scapula to form the glenohumeral (shoulder) joint.

Proximal end features

- Large head
- Greater and lesser tubercles (for muscle attachment)
- Intertubercular groove (for passage of biceps tendons)
- Surgical neck, just below neck (named for commonness of fractures)

Distal end features

- Medial and lateral epicondyles

- Capitulum (lateral) - articulates with head of radius
- Trochlea (medial) - articulates with ulna
- Olecranon fossa, a deep depression located on the posterior (back) side of the humerus bone, provides a space for the olecranon process of the ulna bone to fit into when the elbow is extended receives olecranon process of ulna.
- Coronoid fossa, a small, medial depression on the anterior (front) surface of the distal humerus, located just above the trochlea. Its function is to receive the coronoid process of the ulna during elbow flexion (bending the elbow), allowing for full range of motion without obstruction.

The Ulna and Radius

The ulna is the medial bone of the forearm. It runs parallel to the radius, which is the lateral bone of the forearm. The proximal end of the ulna resembles a crescent wrench with its large, C-shaped trochlear notch. This region articulates with the trochlea of the humerus as part of the elbow joint. The inferior margin of the trochlear notch is formed by a prominent lip of bone called the coronoid process of the ulna. The posterior and superior portions of the proximal ulna make up the olecranon process, which forms the bony tip of the elbow.

The radius runs parallel to the ulna, on the lateral (thumb) side of the forearm. The head of the radius is a disc-shaped structure that forms the proximal end. The neck of the radius is the narrowed region immediately below the expanded head. The shaft of the radius is slightly curved and has a small ridge along its medial side. The distal end of the radius has a smooth surface for articulation with two carpal bones to form the radiocarpal joint or wrist joint.

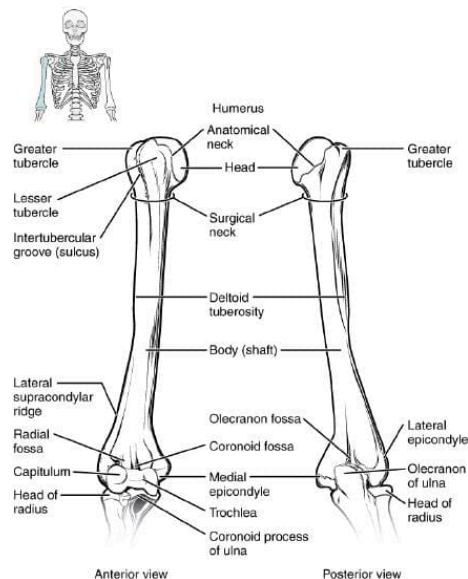


Figure 8.1.4: The humerus is the single bone of the upper arm region. It articulates with the radius and ulna bones of the forearm to form the elbow joint. Anterior and posterior view shown. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.4 presents the human humerus bone from two perspectives: anterior (front) and posterior (back). It shows two drawings of the humerus, the upper arm bone, one from the front and one from the back. Each view labels important landmarks of the bone. At the top of the humerus, the diagram highlights structures that form or support the shoulder joint:

- The rounded head is the part that fits into the shoulder socket (glenoid cavity of the scapula). This is the main articular surface for shoulder movement.
- Just below the head, the anatomical neck marks the boundary between the head and the rest of the bone.
- Farther down, the surgical neck is shown as a narrower region below the tubercles; it is clinically important because it is a common fracture site.
- The greater tubercle and lesser tubercle are prominent bumps where shoulder muscles attach. Their position helps you tell the front/back orientation:
 - The intertubercular groove (sulcus) lies between the tubercles and serves as a pathway for the tendon of the long head of the biceps, helping anchor and guide it near the shoulder.

Shaft (middle) - attachment and leverage. Along the long middle portion:

- The body (shaft) is labeled as the main length of the bone.
- The deltoid tuberosity is shown partway down the shaft as a roughened area where the deltoid muscle attaches, providing leverage for lifting the arm away from the body.

Distal end (bottom) - elbow-related landmarks (front vs. back differences). The bottom of the humerus shows structures that form the elbow region and differ depending on whether you view the bone from the front or back:

Anterior (front) view features:

- The capitulum and trochlea are the joint surfaces that articulate with the forearm bones (radius and ulna).
- The radial fossa and coronoid fossa are shallow depressions above the joint surfaces. They accommodate parts of the forearm bones during elbow flexion (bending), helping the joint move smoothly.

Posterior (back) view features:

- The olecranon fossa is a deeper depression on the back of the distal humerus. It receives the olecranon of the ulna when the elbow extends (straightens).
- The medial epicondyle and lateral epicondyle are prominent projections on either side of the distal humerus. These serve as major attachment points for forearm muscles and help identify the medial (inner) and lateral (outer) sides of the elbow.

Holdout your right forearm and observe it from two different angle, this image gives you both an anterior (front) view and a posterior (back) view of the radius and ulna, the two bones that make up your forearm. Figure 8.1.5 does just that. In the anterior view, starting at the top near the elbow, you'll observe that the radial notch of the ulna, which is where the head of the radius fits in to allow for rotation. Just below that is the neck of the radius, followed by the radial tuberosity, an important site for muscle attachment. Running down the forearm, we have the radius on the lateral (thumb) side and the ulna on the medial (pinky) side, with the interosseous membrane connecting the two bones. Moving lower, you'll find the distal radioulnar joint, which allows your wrist to rotate. Right next to it is the ulnar notch of the radius, which forms another key joint for movement. Finally, at the very bottom, you'll observe that the head of the ulna, along with the styloid processes of both the ulna and radius, which provide stability to the wrist.

Flipping to the posterior view, the image highlights the olecranon process, the bony part of your elbow that you can feel when you bend your arm. Just below it, the trochlear notch helps form the elbow joint, and the coronoid process provides additional stability. The proximal radioulnar joint is also visible, playing a crucial role in forearm rotation. Lower down, you will observe that the head and neck of the radius, the radius and ulna, and the styloid processes of both bones, ensuring wrist stability.

Altogether, this diagram provides a clear breakdown of the forearm's anatomy, helping you understand how these bones interact to allow movement, rotation, and support for the hand.

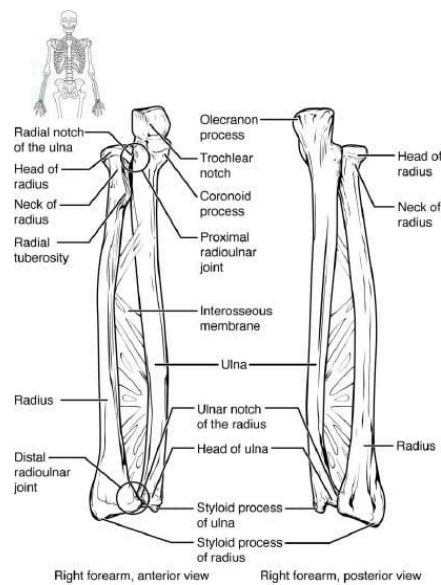


Figure 8.1.5: Right Ulna and Radius Shown in Anterior and Posterior View. The ulna is located on the medial side of the forearm, and the radius is on the lateral side. These bones are attached to each other by an interosseous membrane. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.5 shows two detailed drawings of the right forearm bones, the radius and ulna. It illustrates two coordinated functions of these bones: elbow hinge movement and forearm rotation.

Elbow hinge:

- The trochlear notch of the ulna is shaped to fit the humerus, allowing bending and straightening at the elbow.
- The olecranon process of the ulna forms the prominent upper part of the elbow and helps guide and limit extension.
- The coronoid process, located just below the trochlear notch, contributes to elbow stability during flexion.

Forearm rotation:

- The head of the radius is located near the elbow and is associated with the proximal radioulnar joint.
- The radial notch of the ulna marks the area where the radius aligns with the ulna, allowing the radius to rotate during pronation and supination.

Shaft, or middle region:

- The interosseous membrane extends between the radius and ulna along much of their length.
- This membrane links the two bones, helps stabilize the forearm, and transfers forces between the wrist and elbow.

Distal end near the wrist:

- The distal radioulnar joint shows where the radius and ulna meet near the wrist to support rotational movement.
- The ulnar notch of the radius provides space for the ulna to articulate and rotate.
- The styloid process of the radius and the styloid process of the ulna are pointed projections near the wrist that serve as attachment points for ligaments and are common landmarks in palpation and imaging.

Bones of the Wrist and Hand

The wrist and hand bones consist of 8 carpal bones in the wrist, 5 metacarpals in the palm, and 14 phalanges in the fingers. The carpals are arranged in two rows, the proximal row (scaphoid, lunate, triquetrum, and pisiform) and the distal row (trapezium, trapezoid, capitate, and hamate). The metacarpals connect to the phalanges, with each finger (except the thumb) having three phalanges and the thumb having two.

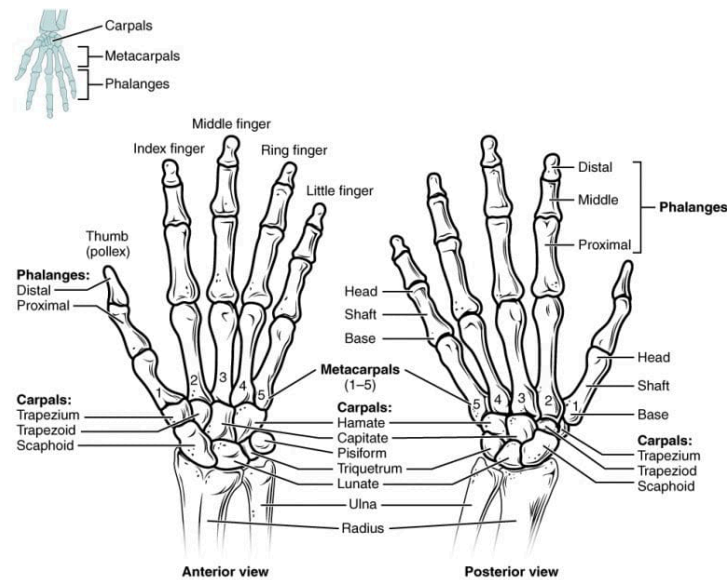


Figure 8.1.6: Bones of the Left Wrist and Hand. The eight carpal bones form the base of the hand. These are arranged into proximal and distal rows of four bones each. The metacarpal bones form the palm of the hand. The thumb and fingers consist of the phalanx bones.

(CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.6 explains the skeletal structure of the human hand and wrist and introduces anatomical terms that describe position and distance along the hand.

The hand is shown from two perspectives:

- The anterior view, which is the palm side of the hand
- The posterior view, which is the back of the hand

These two views show the same bones, but from opposite sides, helping clarify how the bones are arranged in space.

Before describing the bones themselves, it is important to understand three key anatomical terms that appear throughout the image:

- Proximal means closer to the center of the body.
- Distal means farther from the center of the body.
- Middle means between proximal and distal.

In the hand, this means:

- Bones closer to the wrist are proximal
- Bones closer to the fingertips are distal

The bones of the hand are arranged in three connected regions, moving outward from the arm:

1. Carpals – bones of the wrist
2. Metacarpals – bones of the palm
3. Phalanges – bones of the fingers

Wrist Bones: Carpals - At the base of the hand, closest to the forearm, are the carpal bones.

- These are eight small, irregularly shaped bones that form the wrist.
- Their compact shape allows strength while still permitting wrist movement.
- The carpals connect the hand to the radius and ulna, the two long bones of the forearm.

Because the carpals are closest to the body in the hand, they are the most proximal bones of the hand.

Palm Bones: Metacarpals - Extending forward from the wrist into the palm are the five metacarpal bones, one for each finger.

Each metacarpal has three parts:

- A base, which is the proximal end that connects to the carpals
- A shaft, the long middle portion
- A head, the distal end that forms the knuckle at the base of each finger

The metacarpals form the flat framework of the palm and create the space between the wrist and the fingers.

Finger Bones: Phalanges - The phalanges are the bones of the fingers and thumb. Their names directly use the directional terms proximal, middle, and distal.

Proximal Phalanx

- The proximal phalanx is the finger bone closest to the palm
- It connects to the metacarpal at the knuckle

Middle Phalanx

- The middle phalanx lies between the proximal and distal phalanges
- It is present only in the index, middle, ring, and little fingers

Distal Phalanx

- The distal phalanx is the bone farthest from the body
- It is located at the fingertip and supports the nail

Thumb Exception

- The thumb has only two phalanges:
 - A proximal phalanx
 - A distal phalanx
- The thumb does not have a middle phalanx

Bones of the Pelvic Girdle

The pelvic girdle (hip girdle) is formed by a single bone, the hip bone or coxal bone, which serves as the attachment point for each lower limb. Each hip bone, in turn, is firmly joined to the axial skeleton via its attachment to the sacrum of the vertebral column. The right and left hip bones also converge anteriorly to attach to each other. The hip bone (ilium) is the fan-like, superior region that forms the largest part of the hip bone. It is firmly united to the sacrum at the largely immobile sacroiliac joint. The ischium forms the postero-inferior region of each hip bone. It supports the body when sitting. The pubis forms the anterior portion of the hip bone. The pubis curves medially, where it joins to the pubis of the opposite hip bone at a specialized joint called the pubic symphysis.

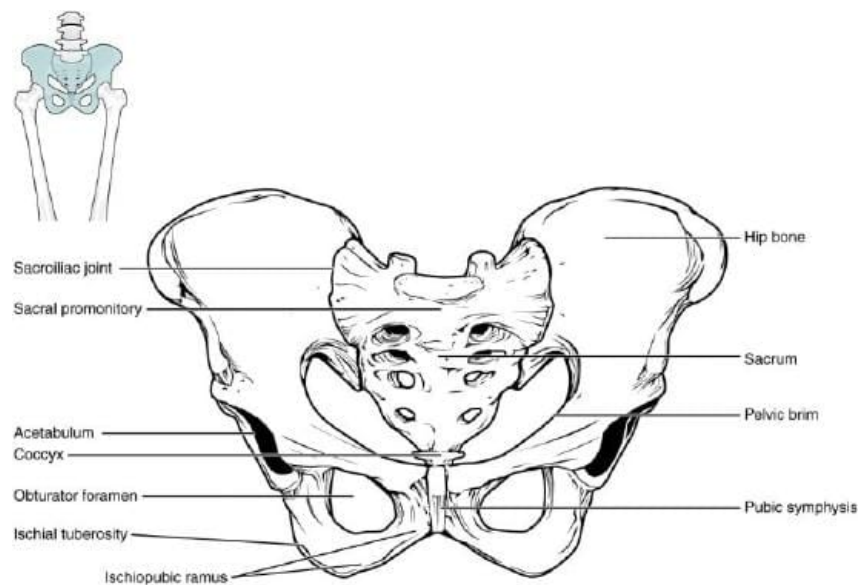


Figure 8.1.7: The pelvic girdle is formed by a single hip bone. The hip bone attaches the lower limb to the axial skeleton through its articulation with the sacrum. The right and left hip bones, plus the sacrum and the coccyx, together form the pelvis. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.7 illustrates the human pelvis with labeled components, providing a clear view of the skeletal structures involved in pelvic anatomy. Key Labeled Structures:

- **Sacroiliac Joint:** The joint connecting the sacrum and the ilium of the hip bone, located on both sides of the pelvis.
- **Sacral Promontory:** The prominent upper edge of the sacrum, marking the boundary of the pelvic inlet.
- **Acetabulum:** The cup-shaped socket on each side of the pelvis where the femur (thigh bone) articulates to form the hip joint.
- **Coccyx:** The small, triangular bone at the base of the sacrum, commonly referred to as the tailbone.
- **Obturator Foramen:** A large opening created by the ischium and pubis bones, allowing passage of nerves and blood vessels.
- **Ischial Tuberosity:** The roughened area of the ischium that bears weight when sitting.
- **Ischiopubic Ramus:** The bony ridge formed by the fusion of the ischium and pubis, contributing to the lower boundary of the obturator foramen.
- **Hip Bone:** Also known as the os coxae, composed of three fused bones: ilium, ischium, and pubis.
- **Sacrum:** A triangular bone at the base of the spine, formed by the fusion of five sacral vertebrae, connecting the spine to the pelvis.
- **Pelvic Brim:** The edge of the pelvic inlet, separating the true pelvis below from the false pelvis above.
- **Pubic Symphysis:** The cartilaginous joint uniting the left and right pubic bones at the front of the pelvis.
- **Ischium:** The posterior-inferior (back-and-lower) portion of the hip bone. It contributes to the ischial tuberosity and forms part of the obturator foramen.
- **Pubis:** The anterior-inferior (front-and-lower) portion of the hip bone. The left and right pubic bones meet at the pubic symphysis.
- **Ilium:** The superior (upper) portion of the hip bone (the broad “wing” region).

Os Coxa

The hip bone, or coxal bone, forms the pelvic girdle portion of the pelvis. The paired hip bones are the large, curved bones that form the lateral and anterior aspects of the pelvis. Each adult hip bone is formed by three separate bones that fuse together during the late teenage years. These bony components are the ilium, ischium, and pubis.

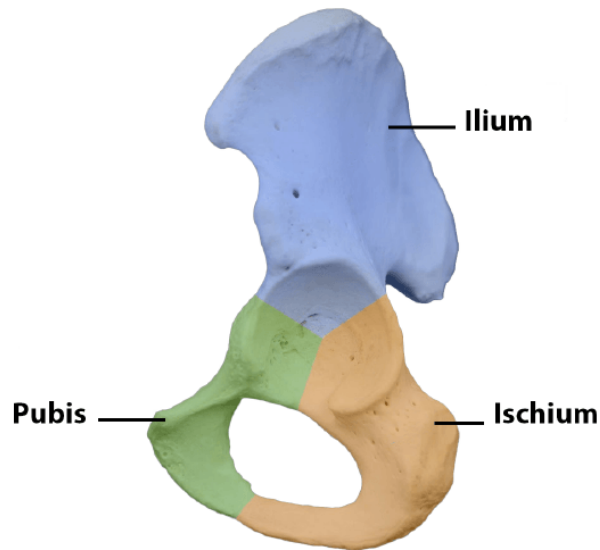


Figure 8.1.8: The adult coxal bone consists of three regions. The ilium, the largest and uppermost part, supporting abdominal organs and muscle attachments; the ischium, the lower posterior portion forming the "sit bones" for weight-bearing; and the pubis, the anterior section that connects with the opposite pubic bone at the pubic symphysis for pelvic stability. These three bones together form the hip structure, essential for movement, support, and weight distribution. (CC BY-NC 4.0 ; Jennifer Lange via BlueLink).

Figure 8.1.8 illustrates the human pelvic bone, divided into three distinct regions and labeled to highlight its structural components. Labeled Sections:

- **Ilium** - The uppermost and largest portion of the pelvic bone. It forms the broad, flaring part of the pelvis and connects to the sacrum at the sacroiliac joint. The ilium supports abdominal organs and provides attachment points for muscles of the trunk and lower limbs.
- **Pubis** - The anterior (front) lower portion of the pelvis. It forms the front part of the pelvic girdle and meets its counterpart at the pubic symphysis. The pubis contributes to the structure of the obturator foramen and supports the urinary bladder.
- **Ischium** - The posterior (back) lower portion of the pelvis. It includes the ischial tuberosity, which bears body weight when sitting. The ischium also contributes to the formation of the obturator foramen and supports the attachment of lower limb muscles.

Comparison of the Female and Male Pelvis

1. There are several diagnostic criteria for differentiating a male from a female pelvis:
2. The female pelvis is larger and broader than the male pelvis, which is taller (owing to a higher iliac crest), narrower, and more compact.
3. The distance between the ischium bones is small in males. This causes the sides of the male pelvis to converge from the inlet to the outlet, whereas the sides of the female pelvis are wider apart. This results in the female inlet being large and oval in shape, while the male inlet is more heart shaped.
4. The angle between the inferior pubic rami is acute (70 degrees) in men, but obtuse (90 to 100 degrees) in women. Accordingly, the angle is called the subpubic angle in men and pubic arch in women.
5. The greater sciatic notch is wider in females.
6. The ischial spines and tuberosities are heavier and project farther into the pelvic cavity in males.
7. The acetabula are wider apart and face more medially in females than in males. This change in the angle of the femoral head gives the female gait its characteristic swinging of hips.

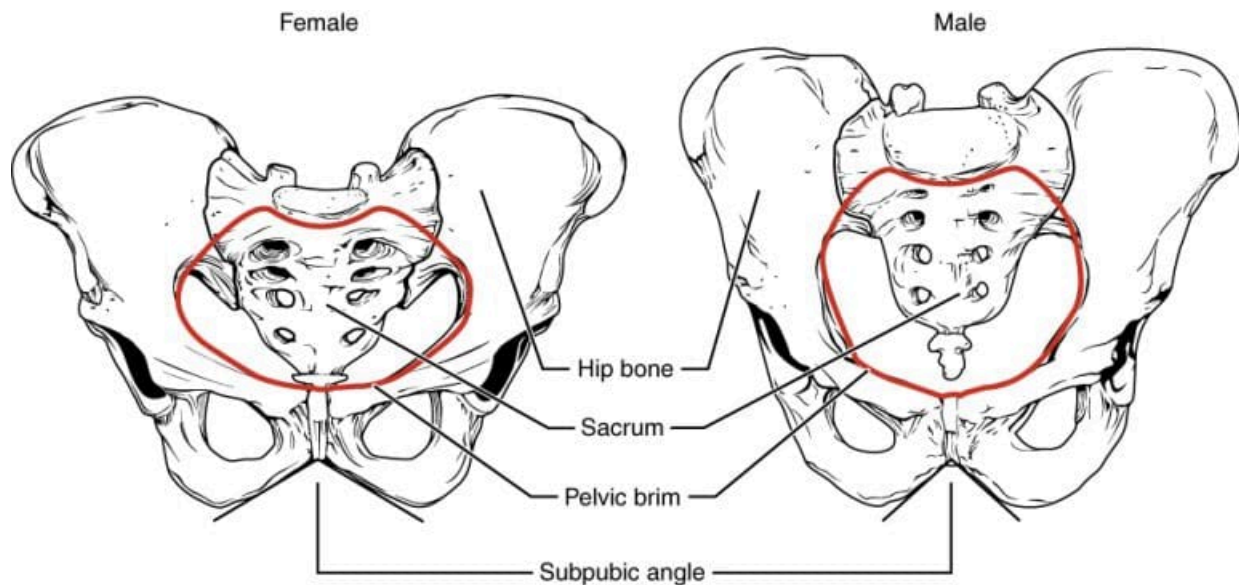


Figure 8.1.9: Male and Female Pelvis. The female pelvis is adapted for childbirth and is broader, with a larger subpubic angle and a wider pelvic brim than the male pelvis. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.9 presents a side-by-side comparison of the female pelvis (left) and male pelvis (right), highlighting structural differences. Both pelvises are labeled with key anatomical features. Common Labels on Both Sides:

- **Hip Bone:** The large, curved bone forming the lateral part of the pelvis.
- **Sacrum:** The triangular bone at the base of the spine, connecting to the hip bones.
- **Pelvic Brim:** The boundary line that separates the true pelvis (below) from the false pelvis (above). It is wider and more circular in the female pelvis, and narrower and more heart-shaped in the male pelvis.
- **Subpubic Angle:** The angle formed below the pubic symphysis. It is broader (greater than 80 degrees) in the female pelvis and narrower (less than 70 degrees) in the male pelvis.

The Lower Limbs

The lower limb, or lower extremity, consists of the thigh, leg, and foot, with a total of 30 bones. The thigh contains the femur, the leg contains the tibia and fibula, and the foot contains tarsals, metatarsals, and phalanges. The tarsal bones, located in the posterior foot, include the talus, calcaneus, navicular, cuboid, and three cuneiforms. The talus articulates with the tibia and fibula to form the ankle joint, while the calcaneus forms the heel. These bones, along with muscles, tendons, ligaments, nerves, and blood vessels, work together to provide support, stability, and mobility. The bones of the lower limbs are thicker and stronger than the bones of the upper limbs because of the need to support the entire weight of the body along with the resulting forces from locomotion.

The Femur

The femur bone, also known as the thigh bone, is the longest and strongest bone in the human body, with a proximal end (closest to the hip) featuring a rounded "head" that articulates with the acetabulum of the hip bone, a neck connecting the head to the shaft, and two prominent bony protrusions called the greater trochanter (on the lateral side of the femur, serving as a muscle attachment site) and lesser trochanters (on the posteromedial aspect of the femur); the distal end (closest to the knee) forms the condyles which articulate with the tibia and fibula of the lower leg; the long middle section is called the femoral shaft, which supports body weight and has prominent ridges like the linea aspera for muscle attachments.

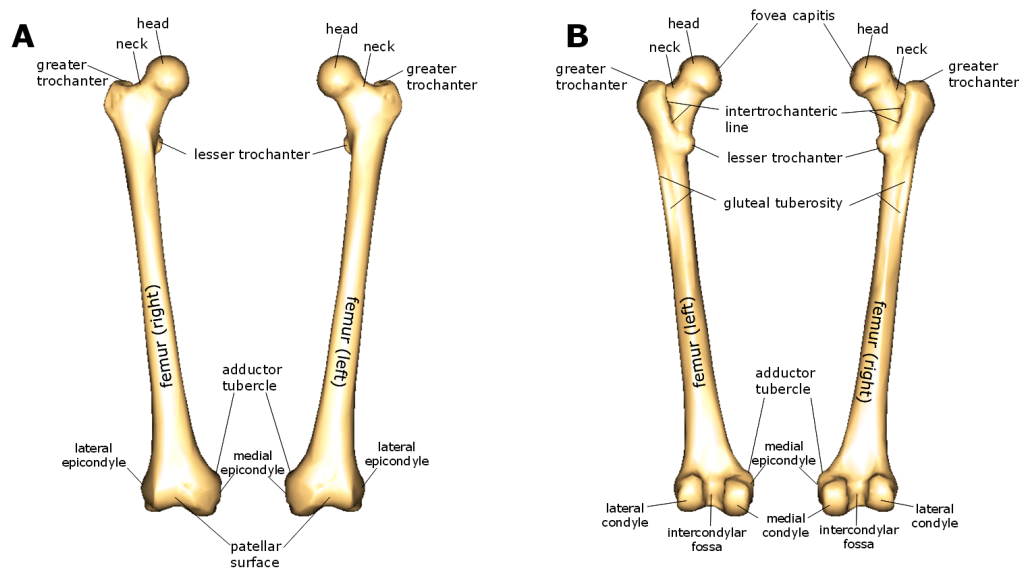


Figure 8.1.10: The right and left femur (A) anterior view and (B) posterior view showing the key anatomical features. The femur is the single bone of the thigh region. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.10 represents the femur from two perspectives to help identify landmarks and understand how the femur articulates at the hip (proximal end) and knee (distal end). The anterior view shows the front-facing features, and the posterior view shows the back-facing features.

Proximal (hip) end: articulation and muscle attachment

- Head: rounded proximal surface that fits into the acetabulum of the hip bone to form the hip joint.
- Fovea capitis: a small pit on the femoral head (visible on the posterior view) where a ligament attaches.
- Neck: narrowed region connecting the head to the shaft.
- Greater trochanter: large lateral projection for muscle attachment.
- Lesser trochanter: smaller projection on the medial/posterior side for muscle attachment.
- Intertrochanteric line: ridge/line between the trochanters (as labeled in the diagram).
- Gluteal tuberosity: roughened posterior area on the shaft for muscle attachment (as labeled in the diagram).

Shaft (body)

- Shaft: long cylindrical portion of the femur that transmits weight and provides leverage for movement.

Distal (knee) end: joint surfaces and stabilizing landmarks

- Medial condyle and lateral condyle: rounded distal regions that articulate with the tibia at the knee joint.
- Intercondylar fossa: posterior depression between the condyles (visible on the posterior view).
- Patellar surface: anterior distal surface where the patella (kneecap) articulates (visible on the anterior view).
- Medial epicondyle and lateral epicondyle: projections above the condyles for ligament and muscle attachment (as labeled in the diagram).
- Adductor tubercle: small prominence near the medial side above the condyle (as labeled in the diagram).

The femur's head forms the hip joint with the acetabulum; the condyles and patellar surface contribute to the knee joint; and features such as the trochanters, gluteal tuberosity, and epicondyles mark major muscle and ligament attachment areas.

The Tibia and Fibula

The tibia (shin bone) and fibula work together to form the lower leg, each playing a crucial role in movement and stability. The tibia, the larger and stronger of the two, is the main weight-bearing bone of the lower leg and is second only to the femur in length. As depicted in Figure 8.1.11 positioned medially, the tibia supports most of the body's weight, making it a critical component of walking, running, and standing. At its proximal (upper) end, the tibia expands significantly, forming the medial condyle and lateral

condyle, which articulate with the femur to create the knee joint. Just below these condyles, the tibial tuberosity is the patellar ligament's attachment site. The anterior border runs along the front of the bone, a sharp ridge that can be easily felt beneath the skin. Along its length, the tibia is connected to the fibula by the interosseous membrane, which provides additional structural stability. At the distal (lower) end, the medial malleolus forms the prominent inner ankle bump, while the articular surface at the bottom of the tibia helps form the ankle joint.

In contrast, the fibula is a slender bone located laterally to the tibia. Unlike the tibia, the fibula does not bear significant weight but instead serves as a primary attachment site for muscles and plays a role in stabilizing the ankle. The head of the fibula, at its proximal end, is a small, rounded structure that connects to the tibia. On the posterior surface of the tibia, the soleal line provides an attachment point for the soleus muscle, which assists in standing and walking. Moving downward, the fibula extends along the tibia's lateral side, ending in the lateral malleolus, the bony bump on the outer side of the ankle that is easy to feel. The articular surfaces of the medial and lateral condyles on the posterior view allow smooth movement at the knee joint, while the lateral malleolus and medial malleolus contribute to ankle stability.

Together, the tibia and fibula form a strong yet flexible framework, ensuring stability, weight distribution, and muscle support. The tibia takes on the burden of supporting the body, while the fibula enhances movement and provides attachment sites for key muscles. Understanding their structure helps us appreciate how these bones work harmoniously to enable everyday activities, from walking to high-impact athletic movements.

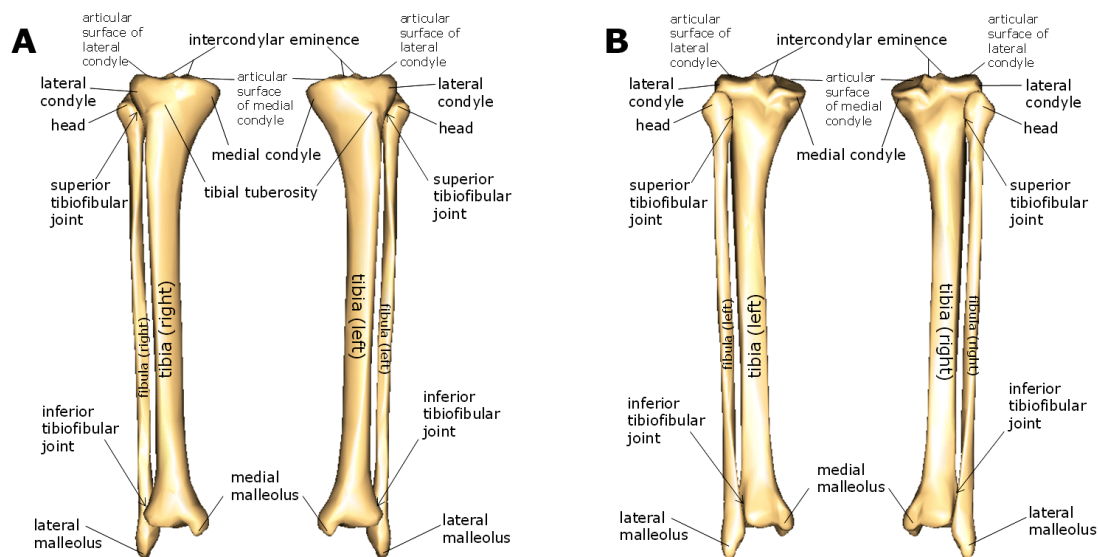


Figure 8.1.11: **Tibia and Fibula in Anterior and Posterior View.** The tibia is the larger, weight-bearing bone located on the medial side of the leg. The fibula is the slender bone of the lateral side of the leg and does not bear weight. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeew Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.11 presents the tibia and fibula bones of the lower leg from both anterior (front) and posterior (back) perspectives. Each view is labeled to highlight key structural features and articulation points.

Anterior View (Front of Leg):

- **Tibia:**
 - **Lateral Condyle and Medial Condyle:** Upper ends that articulate with the femur.
 - **Tibial Tuberosity:** A raised area below the condyles for ligament attachment.
 - **Anterior Border:** The sharp, vertical ridge running down the front of the tibia.
 - **Medial Malleolus:** The inner ankle projection at the distal end.
 - **Articular Surface:** The smooth area for joint articulation.
- **Fibula:**
 - **Lateral Malleolus:** The outer ankle projection at the distal end.
 - **Interosseous Membrane:** A fibrous sheet connecting the tibia and fibula along their lengths.

Posterior View (Back of Leg):

- **Tibia:**
 - Articular Surfaces of Medial and Lateral Condyles: Smooth areas for femur articulation.
 - Soleal Line: A diagonal ridge for muscle attachment.
 - Medial Malleolus: Visible from the back as the inner ankle projection.
- **Fibula:**
 - Head of Fibula: The proximal end that articulates with the tibia.
 - Lateral Malleolus: The outer ankle projection.
 - Interosseous Membrane: Also visible from the posterior view.

Bones of the Ankle and Foot

The foot and ankle comprise 26 bones, divided into three sections: the posterior foot (ankle and heel), mid-foot, and forefoot. The posterior foot contains the talus (ankle bone) and the calcaneus (heel bone). The mid-foot includes the navicular, cuboid, and three cuneiform bones. The forefoot consists of the five metatarsals and the 14 phalanges (toe bones), arranged in a similar manner as the phalanges of the fingers.

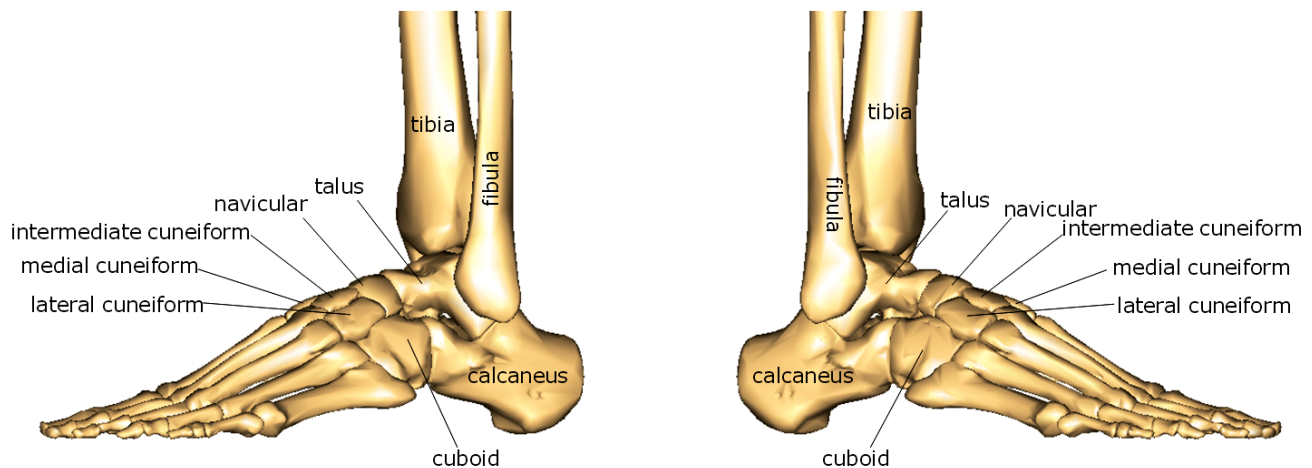


Figure 8.1.12: **Bones of the Foot.** The bones of the foot are divided into three groups. The posterior foot is formed by the seven tarsal bones. The mid-foot has the five metatarsal bones. The toes contain the phalanges. (CC BY 4.0; Aylin Marz; Ganesan Kamatchi; Joseph D'Silva; Krishnan Prabhakaran; Rajeev Chandra; and Solomon Isekeije via [Anatomy and Physiology Laboratory Manual for Nursing and Allied Health](#)).

Figure 8.1.12 presents two side (lateral) views of the ankle and foot skeleton. The purpose is to show how the leg bones (tibia and fibula) meet the talus at the ankle and how the talus connects to the other tarsal bones that form the back and midfoot. The two views repeat the same labeled bones to reinforce orientation and location. Labeled terms in the diagram (all labels included):

Lower leg bones (ankle region)

- Tibia
- Fibula

Hindfoot bones (back of the foot)

- Talus
- Calcaneus

Midfoot bones (arch region)

- Navicular
- Cuboid
- Medial cuneiform
- Intermediate cuneiform
- Lateral cuneiform

How the bones connect:

- The tibia and fibula are the two bones of the lower leg. At the ankle, they form a bracket around the top of the foot.
- The talus sits directly beneath the tibia and fibula and acts as the main bone that receives body weight from the leg at the ankle.
- The calcaneus (heel bone) sits beneath and behind the talus and forms the heel.
- Moving forward from the talus into the midfoot, the navicular sits in front of the talus on the inner side of the foot.
- The cuboid sits more laterally (toward the outside edge of the foot) and helps form the outer midfoot.
- In front of the navicular are three wedge-shaped bones—the medial cuneiform, intermediate cuneiform, and lateral cuneiform—which help form the arch region and connect toward the forefoot.

Joints and Skeletal Movement

The point at which two or more bones meet is called a joint, or articulation. Joints are responsible for movement, such as the movement of limbs, and stability, such as the stability found in the bones of the skull.

There are two ways to classify joints: on the basis of their structure or on the basis of their function. A structural classification of joints divides them into three categories: fibrous, cartilaginous, and synovial, based on the type of connective tissue connecting the bones, while a functional classification categorizes joints as synarthrosis (immobile), amphiarthrosis (slightly movable), and diarthrosis (freely movable) depending on their degree of movement.

Structural Classification:

- Fibrous Joints: These joints have dense connective tissue connecting the bones, providing minimal to no movement, like the sutures in the skull.
- Cartilaginous Joints: Bones are connected by cartilage, allowing for limited movement, such as the pubic symphysis or the intervertebral discs.
- Synovial Joints: The most common type, with a joint capsule containing synovial fluid, enabling a wide range of motion, including joints like the knee and shoulder.

Functional Classification:

- Synarthrosis (Immobile): Joints with no movement, like the sutures in the skull.
- Amphiarthrosis (Slightly movable): Joints with limited movement, like the intervertebral discs.
- Diarthrosis (Freely movable): Joints with a wide range of motion, including most synovial joints.

Movements of the Synovial Joints

The primary movements that occur at synovial joints include flexion, extension, abduction, adduction, rotation, and circumduction; these movements are categorized based on the angle between bones at the joint, with flexion decreasing the angle and extension increasing it, while abduction moves a limb away from the body midline and adduction moves it towards the midline; circumduction involves a circular motion combining flexion, extension, abduction, and adduction in sequence.

- Flexion - bringing two ventral surfaces closer together.
- Extension - moving two primary ventral surfaces farther apart.
- Dorsiflexion - bringing the toes toward the shin.
- Plantar Flexion - flexion of foot(curling of the toes).
- Abduction - movement of a limb away from the midline(note fingers).
- Adduction - movement of a limb toward the midline.
- Rotation - a bone pivots around its long axis.
- Pronation - make the palm face posterior in AP.
- Supination - make the palm face anterior in AP.
- Circumduction - the distal end of a bone describes a circle while the proximal end stays stationary.
- Inversion - turning sole of foot medially at ankle.
- Eversion - turning sole of foot laterally at ankle.
- Protraction - moving the mandible or clavicle anteriorly in a plane that is parallel with the ground.
- Retraction - opposite of protraction.

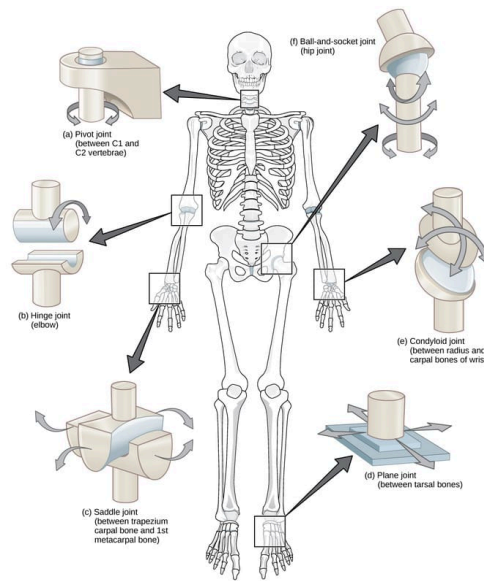


Figure 8.1.13: The six types of synovial joints allow the body to move in a variety of ways. (CC BY-SA 4.0; via Boundless).

Figure 8.1.13 shows a full human skeleton with six types of synovial joints highlighted and labeled. Each joint type includes a simplified illustration showing its structure and movement directions, indicated by arrows.

Labeled Joint Types:

- a. Pivot joint is between C1 and C2 vertebrae (Neck):
 - Allows rotational movement around a single axis.
 - Example: Turning the head side to side.
- b. Hinge joint is elbow:
 - Permits flexion and extension in one plane.
 - Example: Bending and straightening the arm.
- c. Saddle Joint is between trapezium carpal bone and 1st metacarpal bone (thumb):
 - Allows movement in two planes: flexion-extension and abduction-adduction.
 - Example: Thumb opposition and grasping.
- d. Plane Joint – Between Tarsal Bones (Foot):
 - Enables gliding or sliding movements.
 - Example: Subtle shifts in foot bones during walking.
- e. Condyloid Joint – Between Radius and Carpal Bones (Wrist):
 - Allows movement in two directions: flexion-extension and side-to-side (abduction-adduction).
 - Example: Wrist waving motion.
- f. Ball-and-Socket Joint – Hip Joint:
 - Permits movement in multiple directions including rotation, flexion-extension, abduction-adduction, and circumduction.
 - Example: Swinging the leg in a circular motion.

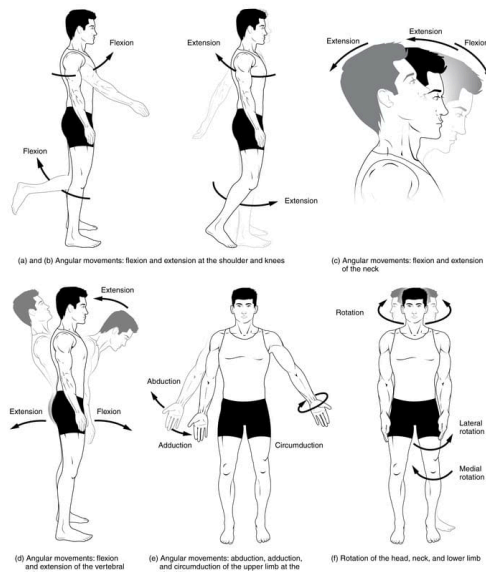


Figure 8.1.14: The diagram illustrates various angular movements of the human body, divided into six labeled sections. Flexion and extension at the shoulder and knees. Flexion and extension of the neck. Flexion and extension of the vertebral column. Abduction, adduction, and circumduction of the upper limb at the shoulder. Rotation of the head, neck, and lower limb. (CC BY-SA 4.0; via Boundless).

As displayed in Figure 8.1.14, the multi-panel figure explains common anatomical movement terms by showing the direction a body part moves and how the joint angle changes. Core movement ideas:

- Flexion: movement that decreases the angle at a joint (often “bending”).
- Extension: movement that increases the angle at a joint (often “straightening”).
- Abduction: movement away from the body’s midline (for limbs, moving out to the side).
- Adduction: movement toward the body’s midline (bringing the limb back in).
- Circumduction: a circular, cone-shaped motion that combines flexion, extension, abduction, and adduction.
- Rotation: turning a bone around its long axis. For limbs, rotation can be medial (toward the midline) or lateral (away from the midline).

Panels (a) and (b) - flexion and extension at the shoulder and knee. These panels show that:

- At the shoulder, moving the arm forward is an example of flexion, and moving it backward is extension.
- At the knee, bending the knee is flexion, and straightening the knee is extension.

Panel (c) - flexion and extension of the neck. This panel shows the head moving:

- Forward (chin toward chest) for neck flexion.
- Backward (looking upward) for neck extension.

Panel (d) - flexion and extension of the vertebral column. This panel shows the trunk moving:

- Forward bending for spinal flexion.
- Backward bending for spinal extension.

Panel (e) - abduction, adduction, and circumduction at the shoulder. This panel shows the arm moving:

- Out to the side away from the body for abduction.
- Back toward the body for adduction.
- In a circular path for circumduction, demonstrating a continuous sequence of motions around the shoulder joint.

Panel (f) - rotation of the head/neck and lower limb. This panel shows:

- Head/neck rotation: turning the head left or right around the vertical axis.
- Lower-limb rotation at the hip:
 - Medial rotation: turning the thigh so the front of the leg turns inward (toward the midline).

- Lateral rotation: turning the thigh so the front of the leg turns outward (away from the midline).

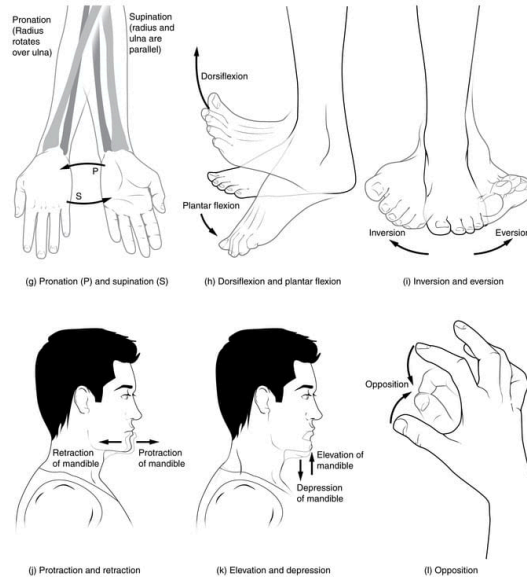


Figure 8.1.15: Special Movements: Diagram showing different types of body movements, including pronation, supination, dorsiflexion, plantar flexion, inversion, eversion, protraction, retraction, elevation, depression, and thumb opposition. (CC BY-SA 4.0; via Boundless).

Figure 8.1.15 illustrates special movements of the body.

Panel(g) - supination vs. pronation (Forearm):

- Supination: Turns the palm upward; radius and ulna are parallel.
- Pronation: Turns the palm downward; radius crosses over the ulna forming an “X.”

Panel(f) - dorsiflexion vs. plantar flexion (Foot):

- Dorsiflexion: Moves the top of the foot toward the leg.
- Plantar Flexion: Lifts the heel and points the toes downward.

Panel(i) - eversion vs. inversion (Foot):

- Eversion: Sole of the foot moves away from the midline.
- Inversion: Sole of the foot faces toward the midline.

Panel(j) - protraction vs. retraction (Mandible):

- Protraction: Pushes the chin forward.
- Retraction: Pulls the chin backward.

Panel(k) - depression vs. elevation (Mandible):

- Depression: Opens the mouth.
- Elevation: Closes the mouth.

Panel(l) - opposition (Thumb):

- Opposition: Tip of the thumb touches the tip of the fingers on the same hand.

8.2: Activity 1

Exploring the Clavicle: Structure and Orientation

In this lab activity, you will examine a clavicle from the disarticulated bone set, focusing on its anatomical structures. This exploration will help you understand the unique features of the clavicle and how to differentiate between the anatomical left and right. By observing the clavicle from all sides, you'll gain insights into its role in connecting the upper limb to the trunk and its importance in shoulder function.

Procedure

1. Obtain the disarticulated Clavicle bone.
 - Select a clavicle from the disarticulated bone set and ensure you have a clean workspace for examination.
2. Observe the structures/anatomical features
 - Carefully examine the clavicle from all angles, noting the following structures:
 - Acromial End: The end that connects to the scapula.
 - Shaft: The elongated body of the clavicle.
 - Conoid Tubercle: A small bump located on the inferior surface of the clavicle.
 - Sternal End: The end that connects to the sternum.
 - Costal Tuberosity: A roughened area on the inferior surface where ligaments attach.
3. Differentiate Anatomical Left from Right:
 - Place the smooth side of the acromial end facing superiorly.
 - Ensure the curve in the middle of the bone is facing anteriorly.
 - If the acromial end is on the right side, the clavicle is from the anatomical right; if it's on the left side, it's from the anatomical left.
4. Record Your Findings:
 - Answer the question: Did you pick up a right or left clavicle? Document your observations and reasoning for identifying the side.

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8.3: Activity 2

The Scapula and Humerus Anatomy

Identify the bone markings indicated by numbers in the figure below and match them in the table.

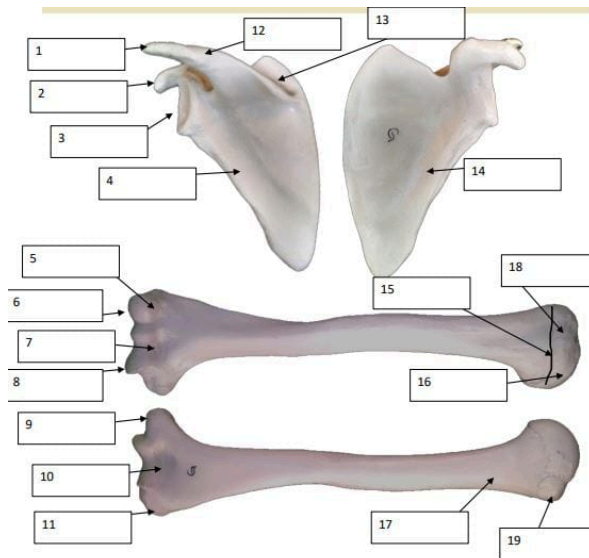


Figure 8.3.1: The scapula (anterior and posterior view on top) and the humerus bone with parts indicated by numbers for identification of bone markings as detailed in Table 8.3.1 (CC BY-NC-SA 4.0; by Yancy Aquino for Skyline College via Human Anatomy Lab Manual)

Table 8.3.1: The Scapula and Humerus anatomy

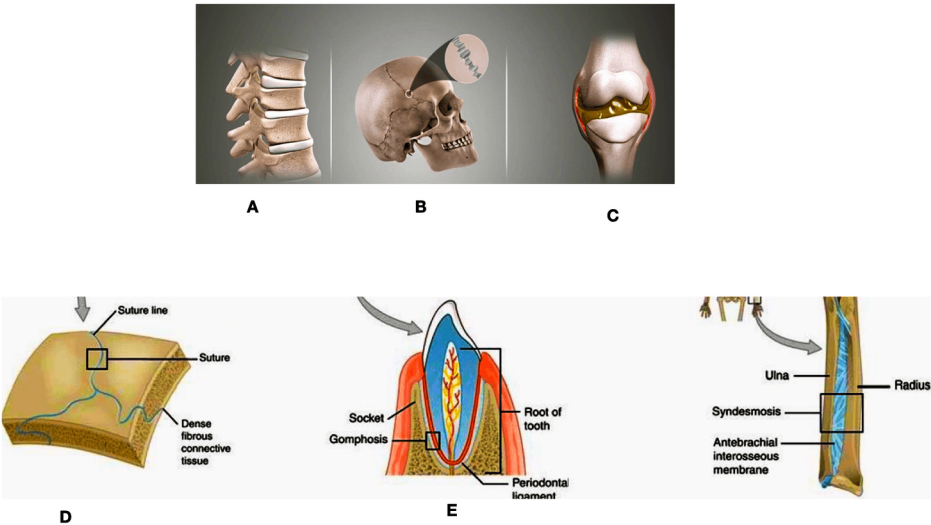
Posted Number	Identification of Bone Markings/Parts
	Scapula
	Spine
	Coracoid process
	Acromion
	Supra-spinous fossa
	Infra-spinous fossa
	Sub-scapular fossa

Posted Number	Identification of Bone Markings/Parts
	Glenoid cavity
	Humerus
	Head
	Radial fossa
	Lateral epicondyle
	Trochlea
	Olecranon fossa
	Capitulum
	Coronoid fossa
	Medial epicondyle
	Neck
	(surgical and anatomical)
	Greater tubercle
	Lesser tubercle

8.4: Activity 3

Identifying the Different Kinds of Joints

Examine the figures. Identify the joints structurally and functionally in Table below.



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Figure 8.4.1: Illustrations of six joint types: spine disc, skull suture, knee synovial, tooth gomphosis, fibrous suture, and forearm syndesmosis. (CC BY-NC-SA 4.0; by Yancy Aquino for Skyline College via Human Anatomy Lab Manual).

Table 8.4.1: A checklist of the Femur, Tibia, Fibula, and Patella anatomy

	Functional classification	Structural classification
A		
B		
C		
D		
E		
F		

8.5: Activity 4

Structures of the Shoulder Joint

Identify the bone markings indicated by numbers in the figure below and match them in the table below.

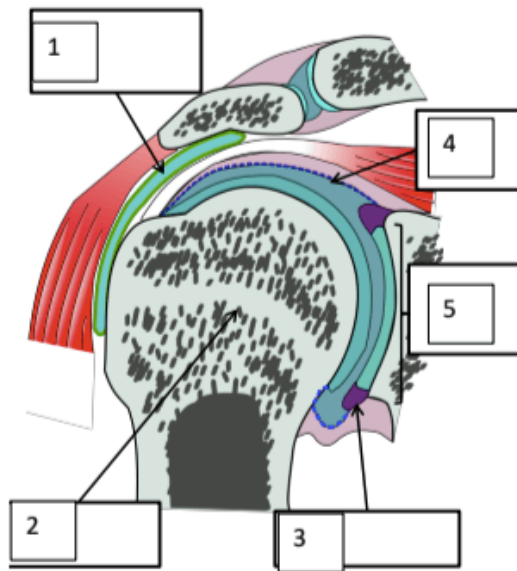


Figure 8.5.1: Anatomical diagram showing labeled parts of a structure with five numbered boxes. (CC BY-NC-SA 4.0; by Yancy Aquino for Skyline College via [Human Anatomy Lab Manual](#)).

Table 8.5.1: The components of the shoulder joint

Structures	Numbers
Bursa	
Glenoid labrum	
Synovial membrane	
Head (of humerus)	
Glenoid cavity of scapula	

8.6: Activity 5

Structure of the Knee Joint

Identify the bone markings indicated by numbers in the figure below and match them in the table.

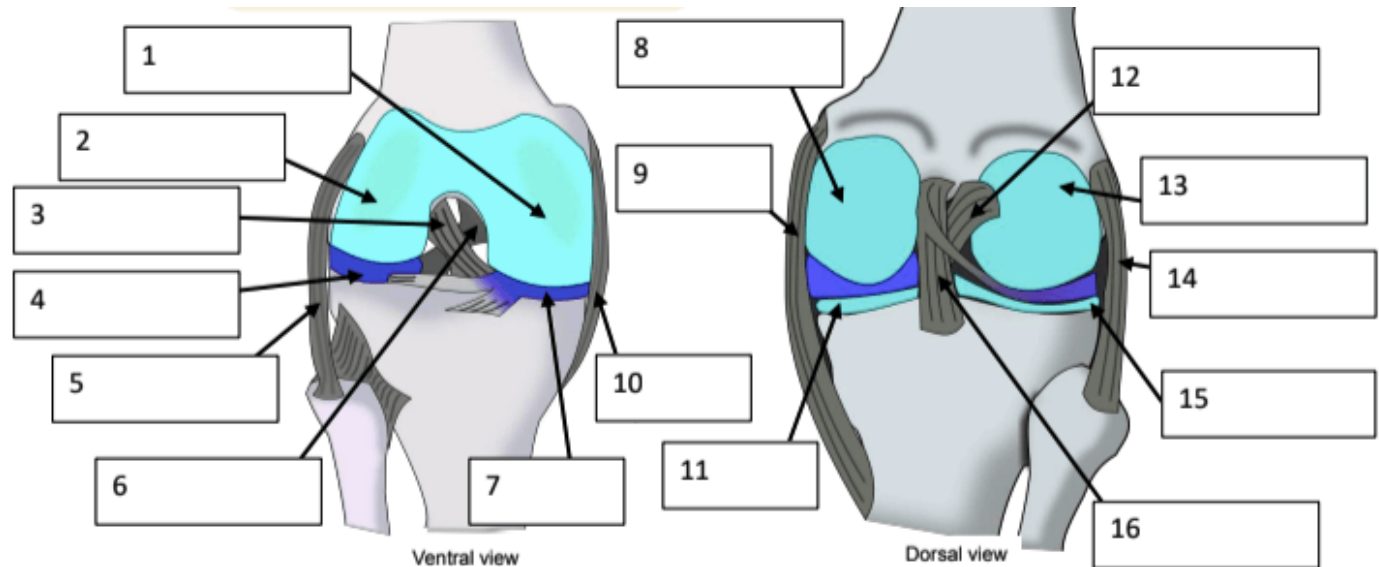


Figure 8.6.1: Anatomical diagram of the knee joint with labels for sixteen parts, showing ventral and dorsal perspectives indicated by numbers for identification of bone markings as detailed Table 8.6.1. (CC BY-NC-SA 4.0; by Yancy Aquino for Skyline College via Human Anatomy Lab Manual).

Table 8.6.1: Ventral view parts of knee joint

Posted Number	Identification of Bone Markings/Parts
	Ventral View
	Medial condyle
	Lateral condyle
	Medial collateral ligament
	Lateral collateral ligament
	Medial meniscus
	Lateral meniscus
	Anterior cruciate ligament
	Posterior cruciate ligament

Table 8.6.2: Dorsal view parts of knee joint

Posted Number	Identification of Bone Markings/Parts
	Dorsal View
	Anterior cruciate ligament
	Posterior cruciate ligament
	Medial collateral ligament
	Lateral collateral ligament
	Medial meniscus
	Lateral meniscus
	Medial condyle
	Lateral condyle

8.7: Activity 6

The Anatomy of the Knee Joint

Identify the bone markings indicated by numbers in the figure below and match them in the table.

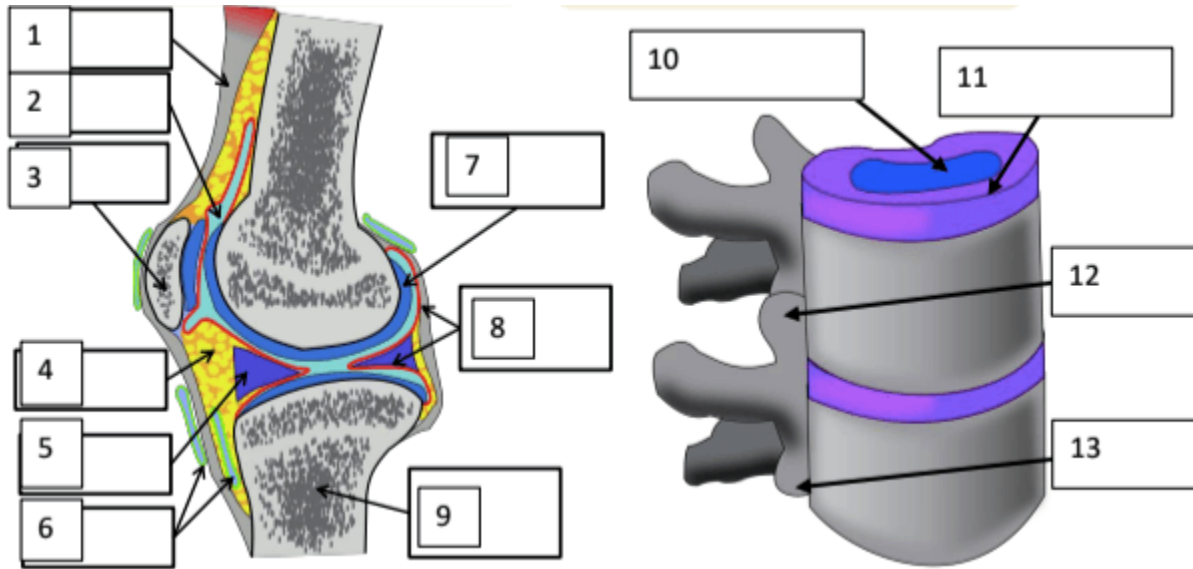


Figure 8.7.1: Anatomical diagram showing labeled parts of a knee joint and vertebra for educational reference indicated by numbers for identification of bone markings as detailed Table 8.7.1. (CC BY-NC-SA 4.0; by Yancy Aquino for Skyline College via Human Anatomy Lab Manual).

Table 8.7.1: Components of knee joint

Posted Number	Identification of Bone Markings/Parts
	Quadriceps femoris tendon
	Patella
	Bursae
	Fat pad
	Joint cavity
	Synovial membrane
	Meniscus
	Tibia
	Articular cartilage

8.8: Activity 7

Joints and Movements

For each letter on the figure 8.8.1, indicate the type of motion described from the choices given.

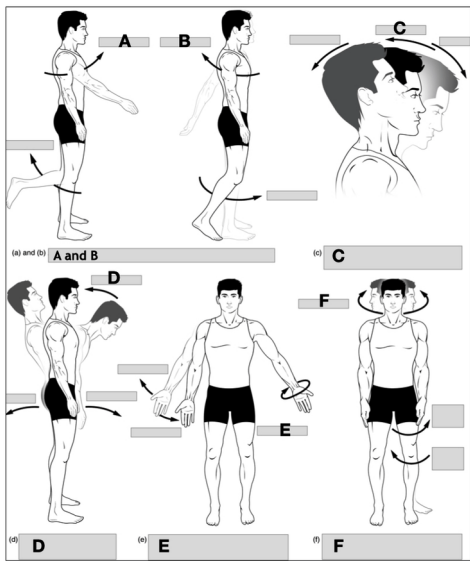


Figure 8.8.1: The diagram illustrates various angular movements of the human body, divided into six labeled sections:(a) and (b): Flexion and extension at the shoulder and knees, (c): Flexion and extension of the neck, (d): Flexion and extension of the vertebral column, (e): Abduction, adduction, and circumduction of the upper limb at the shoulder,(f): Rotation of the head, neck, and lower limb. (CC BY-SA 4.0; via [Boundless](#)).

Figure 8.8.1 displays a male figure performing six distinct body movements, each labeled from A to F. The movements are illustrated in separate panels or poses, showing variations in limb positioning and joint articulation. Each label corresponds to a specific type of movement, such as flexion, extension, abduction, adduction, rotation, or circumduction. The diagram is intended to help viewers visually identify and differentiate these common anatomical motions.

Table 8.8.1: Identification of movements

Letter	Movement
A	
B	
C	
D	
E	
F	

8.9: Activity 8

Demonstrate body movements in class

Students will volunteer to demonstrate and define movements at specified joint.

1. Hip Joint: Demonstrate and define abduction, adduction, flexion, extension, circumduction, external rotation, and internal rotation.
2. Shoulder Joint: Demonstrate and define abduction, adduction, flexion, extension, circumduction, internal rotation, external rotation, elevation, depression, protraction, and retraction.
3. Elbow Joint: Demonstrate and define supination, pronation, flexion, and extension.
4. Temporomandibular Joint: Demonstrate and define elevation, depression, protraction, and retraction.
5. Knee Joint: Demonstrate and define flexion, extension, hyperextension (be careful), and gentle rotation (be careful).
6. Vertebral Column (as a whole, includes joints of the thoracic and lumbar spine): Demonstrate and define flexion, extension, hyperextension, and lateral flexion.
7. Neck (includes the joints of C1 to C7): Demonstrate and define flexion, extension, hyperextension, lateral flexion, rotation.
8. Hand: Demonstrate and define flexion and extension of the metacarpophalangeal joints, opposition of the thumb; adduction and abduction of digit 5 at the metacarpophalangeal joint.
9. Ankle Joint: Demonstrate and define dorsiflexion, plantar flexion, inversion, and eversion.

Critical thinking question

As you've demonstrated and defined, the shoulder joint is highly mobile, whereas the knee joint allows for many fewer movements. What does it mean when we say that a joint sacrifices stability in favor of mobility? How does the shape of the joint surfaces influence either stability or mobility?

Key Terms and Definitions

- **Acetabulum:** large, cup-shaped cavity located on the lateral side of the hip bone; formed by the junction of the ilium, pubis, and ischium portions of the hip bone.
- **Acromial end of the clavicle:** lateral end of the clavicle that articulates with the acromion of the scapula.
- **Acromial process:** acromion of the scapula.
- **Acromioclavicular joint:** articulation between the acromion of the scapula and the acromial end of the clavicle.
- **Acromion:** flattened bony process that extends laterally from the scapular spine to form the bony tip of the shoulder.
- **adductor tubercle:** small, bony bump located on the superior aspect of the medial epicondyle of the femur.
- **Anatomical neck:** line on the humerus located around the outside margin of the humeral head.
- **Ankle joint:** joint that separates the leg and foot portions of the lower limb; formed by the articulations between the talus bone of the foot inferiorly, and the distal end of the tibia, medial malleolus of the tibia, and lateral malleolus of the fibula superiorly.
- **Anterior border of the tibia:** narrow, anterior margin of the tibia that extends inferiorly from the tibial tuberosity anterior inferior iliac spine: small, bony projection located on the anterior margin of the ilium, below the anterior superior iliac spine.
- **Anterior sacroiliac ligament:** strong ligament between the sacrum and the ilium portions of the hip bone that supports the anterior side of the sacroiliac joint anterior superior iliac spine: rounded, anterior end of the iliac crest.
- **Arcuate line of the ilium:** smooth ridge located at the inferior margin of the iliac fossa; forms the lateral portion of the pelvic brim.
- **Arm:** region of the upper limb located between the shoulder and elbow joints; contains the humerus bone.
- **Auricular surface of the ilium:** roughened area located on the posterior, medial side of the ilium of the hip bone; articulates with the auricular surface of the sacrum to form the sacroiliac joint.
- **Calcaneus:** heel bone; posterior, inferior tarsal bone that forms the heel of the foot.
- **Capitate:** from the lateral side, the third of the four distal carpal bones; articulates with the scaphoid and lunate proximally, the trapezoid laterally, the hamate medially, and primarily with the third metacarpal distally.
- **Capitulum:** knob-like bony structure located anteriorly on the lateral, distal end of the humerus.
- **Carpal bone:** one of the eight small bones that form the wrist and base of the hand; these are grouped as a proximal row consisting of (from lateral to medial) the scaphoid, lunate, triquetrum, and pisiform bones, and a distal row containing (from lateral to medial) the trapezium, trapezoid, capitate, and hamate bones.
- **Carpal tunnel:** passageway between the anterior forearm and hand formed by the carpal bones and flexor retinaculum.
- **Carpometacarpal joint:** articulation between one of the carpal bones in the distal row and a metacarpal bone of the hand.
- **Clavicle:** collarbone; elongated bone that articulates with the manubrium of the sternum medially and the acromion of the scapula laterally.
- **Coracoid process:** short, hook-like process that projects anteriorly and laterally from the superior margin of the scapula.
- **Coronoid fossa:** depression on the anterior surface of the humerus above the trochlea; this space receives the coronoid process of the ulna when the elbow is maximally flexed.
- **Coronoid process of the ulna:** projecting bony lip located on the anterior, proximal ulna; forms the inferior margin of the trochlear notch.
- **Coxal bone:** hip bone.
- **Cuboid:** tarsal bone that articulates posteriorly with the calcaneus bone, medially with the lateral cuneiform bone, and anteriorly with the fourth and fifth metatarsal bones.
- **Deltoid tuberosity:** roughened, V-shaped region located laterally on the mid-shaft of the humerus.
- **Distal radioulnar joint:** articulation between the head of the ulna and the ulnar notch of the radius.
- **Distal tibiofibular joint:** articulation between the distal fibula and the fibular notch of the tibia.
- **Elbow joint:** joint located between the upper arm and forearm regions of the upper limb; formed by the articulations between the trochlea of the humerus and the trochlear notch of the ulna, and the capitulum of the humerus and the head of the radius.
- **Femur:** thigh bone; the single bone of the thigh.
- **Fibula:** thin, non-weight-bearing bone found on the lateral side of the leg.
- **Fibular notch:** wide groove on the lateral side of the distal tibia for articulation with the fibula at the distal tibiofibular joint.
- **Flexor retinaculum:** strong band of connective tissue at the anterior wrist that spans the top of the U-shaped grouping of the carpal bones to form the roof of the carpal tunnel.
- **Foot:** portion of the lower limb located distal to the ankle joint.
- **Forearm:** region of the upper limb located between the elbow and wrist joints; contains the radius and ulna bones.
- **Fossa:** (plural = fossae) shallow depression on the surface of a bone.
- **Fovea capitis:** minor indentation on the head of the femur that serves as the site of attachment for the ligament to the head

of the femur.

- **Glenohumeral joint:** shoulder joint; formed by the articulation between the glenoid cavity of the scapula and the head of the humerus.
- **Glenoid cavity:** (also, glenoid fossa) shallow depression located on the lateral scapula, between the superior and lateral borders.
- **Gluteal tuberosity:** roughened area on the posterior side of the proximal femur, extending inferiorly from the base of the greater trochanter.
- **Greater pelvis:** (also, greater pelvic cavity or false pelvis) broad space above the pelvic brim defined laterally by the fan-like portion of the upper ilium.
- **Greater sciatic notch:** large, U-shaped indentation located on the posterior margin of the ilium, superior to the ischial spine.
- **Greater trochanter:** large, bony expansion of the femur that projects superiorly from the base of the femoral neck.
- **Greater tubercle:** enlarged prominence located on the lateral side of the proximal humerus.
- **Hallux:** big toe; digit 1 of the foot.
- **Hamate:** from the lateral side, the fourth of the four distal carpal bones; articulates with the lunate and triquetrum proximally, the fourth and fifth metacarpals distally, and the capitate laterally.
- **Hand:** region of the upper limb distal to the wrist joint.
- **Head of the femur:** rounded, proximal end of the femur that articulates with the acetabulum of the hip bone to form the hip joint.
- **Head of the fibula:** small, knob-like, proximal end of the fibula; articulates with the inferior aspect of the lateral condyle of the tibia.
- **Head of the humerus:** smooth, rounded region on the medial side of the proximal humerus; articulates with the glenoid fossa of the scapula to form the glenohumeral (shoulder) joint.
- **Head of the metatarsal bone:** expanded, distal end of each metatarsal bone.
- **Head of the radius:** disc-shaped structure that forms the proximal end of the radius; articulates with the capitulum of the humerus as part of the elbow joint, and with the radial notch of the ulna as part of the proximal radioulnar joint.
- **Head of the ulna:** small, rounded distal end of the ulna; articulates with the ulnar notch of the distal radius, forming the distal radioulnar joint.
- **Hip bone:** coxal bone; single bone that forms the pelvic girdle; consists of three areas, the ilium, ischium, and pubis.
- **Hip joint:** joint located at the proximal end of the lower limb; formed by the articulation between the acetabulum of the hip bone and the head of the femur.
- **Hook of the hamate bone:** bony extension located on the anterior side of the hamate carpal bone.
- **Humerus:** single bone of the upper arm.
- **Iliac crest:** curved, superior margin of the ilium iliac fossa: shallow depression found on the anterior and medial surfaces of the upper ilium ilium: superior portion of the hip bone.
- **Inferior angle of the scapula:** inferior corner of the scapula located where the medial and lateral borders meet.
- **Infraspinous fossa:** broad depression located on the posterior scapula, inferior to the spine.
- **Intercondylar fossa:** deep depression on the posterior side of the distal femur that separates the medial and lateral condyles.
- **Intermediate cuneiform:** middle of the three cuneiform tarsal bones; articulates posteriorly with the navicular bone, medially with the medial cuneiform bone, laterally with the lateral cuneiform bone, and anteriorly with the second metatarsal bone.
- **Interosseous border of the fibula:** small ridge running down the medial side of the fibular shaft; for attachment of the interosseous membrane between the fibula and tibia.
- **Interosseous border of the radius:** narrow ridge located on the medial side of the radial shaft; for attachment of the interosseous membrane between the ulna and radius bones.
- **Interosseous border of the tibia:** small ridge running down the lateral side of the tibial shaft; for attachment of the interosseous membrane between the tibia and fibula.
- **Interosseous border of the ulna:** narrow ridge located on the lateral side of the ulnar shaft; for attachment of the interosseous membrane between the ulna and radius.
- **Interosseous membrane of the forearm:** sheet of dense connective tissue that unites the radius and ulna bones.
- **Interosseous membrane of the leg:** sheet of dense connective tissue that unites the shafts of the tibia and fibula bones.
- **Interphalangeal joint:** articulation between adjacent phalanx bones of the hand or foot digits.
- **Intertrochanteric crest:** short, prominent ridge running between the greater and lesser trochanters on the posterior side of the proximal femur.
- **Intertrochanteric line:** small ridge running between the greater and lesser trochanters on the anterior side of the proximal femur.
- **Intertubercular groove (sulcus):** bicipital groove; narrow groove located between the greater and lesser tubercles of the humerus.
- **Ischial ramus:** bony extension projecting anteriorly and superiorly from the ischial tuberosity; joins with the inferior pubic

ramus to form the ischiopubic ramus.

- **Ischial spine:** pointed, bony projection from the posterior margin of the ischium that separates the greater sciatic notch and lesser sciatic notch.
- **Ischial tuberosity:** large, roughened protuberance that forms the posteroinferior portion of the hip bone; weight-bearing region of the pelvis when sitting.
- **Ischiopubic ramus:** narrow extension of bone that connects the ischial tuberosity to the pubic body; formed by the junction of the ischial ramus and inferior pubic ramus.
- **Ischium:** posteroinferior portion of the hip bone.
- **Knee joint:** joint that separates the thigh and leg portions of the lower limb; formed by the articulations between the medial and lateral condyles of the femur, and the medial and lateral condyles of the tibia.
- **Lateral border of the scapula:** diagonally oriented lateral margin of the scapula.
- **Lateral condyle of the femur:** smooth, articulating surface that forms the distal and posterior sides of the lateral expansion of the distal femur.
- **Lateral condyle of the tibia:** lateral, expanded region of the proximal tibia that includes the smooth surface that articulates with the lateral condyle of the femur as part of the knee joint.
- **Lateral cuneiform:** most lateral of the three cuneiform tarsal bones; articulates posteriorly with the navicular bone, medially with the intermediate cuneiform bone, laterally with the cuboid bone, and anteriorly with the third metatarsal bone.
- **Lateral epicondyle of the femur:** roughened area of the femur located on the lateral side of the lateral condyle.
- **Lateral epicondyle of the humerus:** small projection located on the lateral side of the distal humerus.
- **Lateral malleolus:** expanded distal end of the fibula.
- **Lateral supracondylar ridge:** narrow, bony ridge located along the lateral side of the distal humerus, superior to the lateral epicondyle.
- **Leg:** portion of the lower limb located between the knee and ankle joints.
- **Lesser pelvis:** (also, lesser pelvic cavity or true pelvis) narrow space located within the pelvis, defined superiorly by the pelvic brim (pelvic inlet) and inferiorly by the pelvic outlet.
- **Lesser sciatic foramen:** pelvic opening formed by the lesser sciatic notch of the hip bone, the sacrospinous ligament, and the sacrotuberous ligament.
- **Lesser sciatic notch:** shallow indentation along the posterior margin of the ischium, inferior to the ischial spine.
- **Lesser trochanter:** small, bony projection on the medial side of the proximal femur, at the base of the femoral neck.
- **Lesser tubercle:** small, bony prominence located on anterior side of the proximal humerus.
- **Ligament of the head of the femur:** ligament that spans the acetabulum of the hip bone and the fovea capitis of the femoral head.
- **Linea aspera:** longitudinally running bony ridge located in the middle third of the posterior femur.
- **Lunate:** from the lateral side, the second of the four proximal carpal bones; articulates with the radius proximally, the capitate and hamate distally, the scaphoid laterally, and the triquetrum medially.
- **Medial border of the scapula:** elongated, medial margin of the scapula
- **Medial condyle of the femur:** smooth, articulating surface that forms the distal and posterior sides of the medial expansion of the distal femur.
- **Medial condyle of the tibia:** medial, expanded region of the proximal tibia that includes the smooth surface that articulates with the medial condyle of the femur as part of the knee joint.
- **Medial cuneiform:** most medial of the three cuneiform tarsal bones; articulates posteriorly with the navicular bone, laterally with the intermediate cuneiform bone, and anteriorly with the first and second metatarsal bones.
- **Medial epicondyle of the femur:** roughened area of the distal femur located on the medial side of the medial condyle.
- **Medial epicondyle of the humerus:** enlarged projection located on the medial side of the distal humerus.
- **Medial malleolus:** bony expansion located on the medial side of the distal tibia.
- **Metacarpal bone:** one of the five long bones that form the palm of the hand; numbered 1–5, starting on the lateral (thumb) side of the hand.
- **Metacarpophalangeal joint:** articulation between the distal end of a metacarpal bone of the hand and a proximal phalanx bone of the thumb or a finger.
- **Metatarsal bone:** one of the five elongated bones that forms the anterior half of the foot; numbered 1–5, starting on the medial side of the foot.
- **Metatarsophalangeal joint:** articulation between a metatarsal bone of the foot and the proximal phalanx bone of a toe.
- **Midcarpal joint:** articulation between the proximal and distal rows of the carpal bones; contributes to movements of the hand at the wrist.
- **Navicular:** tarsal bone that articulates posteriorly with the talus bone, laterally with the cuboid bone, and anteriorly with the medial, intermediate, and lateral cuneiform bones.
- **Neck of the femur:** narrowed region located inferior to the head of the femur.
- **Neck of the radius:** narrowed region immediately distal to the head of the radius.

- **Obturator foramen:** large opening located in the anterior hip bone, between the pubis and ischium regions.
- **Olecranon fossa:** large depression located on the posterior side of the distal humerus; this space receives the olecranon process of the ulna when the elbow is fully extended.
- **Olecranon process:** expanded posterior and superior portions of the proximal ulna; forms the bony tip of the elbow.
- **Patella:** kneecap; the largest sesamoid bone of the body; articulates with the distal femur.
- **Patellar surface:** smooth groove located on the anterior side of the distal femur, between the medial and lateral condyles; site of articulation for the patella.
- **Pectoral girdle:** shoulder girdle; the set of bones, consisting of the scapula and clavicle, which attaches each upper limb to the axial skeleton.
- **Pelvic brim:** pelvic inlet; the dividing line between the greater and lesser pelvic regions; formed by the superior margin of the pubic symphysis, the pectineal lines of each pubis, the arcuate lines of each ilium, and the sacral promontory.
- **Pelvic girdle:** hip girdle; consists of a single hip bone, which attaches a lower limb to the sacrum of the axial skeleton.
- **Pelvic inlet:** pelvic brim.
- **Pelvic outlet:** inferior opening of the lesser pelvis; formed by the inferior margin of the pubic symphysis, right and left ischiopubic rami and sacrotuberous ligaments, and the tip of the coccyx.
- **Pelvis:** ring of bone consisting of the right and left hip bones, the sacrum, and the coccyx.
- **Phalanx bone of the foot:** (plural = phalanges) one of the 14 bones that form the toes; these include the proximal and distal phalanges of the big toe, and the proximal, middle, and distal phalanx bones of toes two through five.
- **Phalanx bone of the hand:** (plural = phalanges) one of the 14 bones that form the thumb and fingers; these include the proximal and distal phalanges of the thumb, and the proximal, middle, and distal phalanx bones of the fingers two through five.
- **Pisiform:** from the lateral side, the fourth of the four proximal carpal bones; articulates with the anterior surface of the triquetrum.
- **Pollex:** (also, thumb) digit 1 of the hand posterior inferior iliac spine: small, bony projection located at the inferior margin of the auricular surface on the posterior ilium.
- **Posterior sacroiliac ligament:** strong ligament spanning the sacrum and ilium of the hip bone that supports the posterior side of the sacroiliac joint.
- **Posterior superior iliac spine:** rounded, posterior end of the iliac crest.
- **Proximal radioulnar joint:** articulation formed by the radial notch of the ulna and the head of the radius.
- **Proximal tibiofibular joint:** articulation between the head of the fibula and the inferior aspect of the lateral condyle of the tibia.
- **Pubic arch:** bony structure formed by the pubic symphysis, and the bodies and inferior pubic rami of the right and left pubic bones.
- **Pubic body:** enlarged, medial portion of the pubis region of the hip bone.
- **Pubic symphysis:** joint formed by the articulation between the pubic bodies of the right and left hip bones.
- **Pubic tubercle:** small bump located on the superior aspect of the pubic body.
- **Pubis:** anterior portion of the hip bone.
- **Radial fossa:** small depression located on the anterior humerus above the capitulum; this space receives the head of the radius when the elbow is maximally flexed.
- **Radial notch of the ulna:** small, smooth area on the lateral side of the proximal ulna; articulates with the head of the radius as part of the proximal radioulnar joint.
- **Radial tuberosity:** oval-shaped, roughened protuberance located on the medial side of the proximal radius.
- **Radiocarpal joint:** wrist joint, located between the forearm and hand regions of the upper limb; articulation formed proximally by the distal end of the radius and the fibrocartilaginous pad that unites the distal radius and ulna bone, and distally by the scaphoid, lunate, and triquetrum carpal bones.
- **Radius:** bone located on the lateral side of the forearm.
- **Sacroiliac joint:** joint formed by the articulation between the auricular surfaces of the sacrum and ilium.
- **Sacrospinous ligament:** ligament that spans the sacrum to the ischial spine of the hip bone.
- **Sacrotuberous ligament:** ligament that spans the sacrum to the ischial tuberosity of the hip bone.
- **Scaphoid:** from the lateral side, the first of the four proximal carpal bones; articulates with the radius proximally, the trapezoid, trapezium, and capitate distally, and the lunate medially.
- **Scapula:** shoulder blade bone located on the posterior side of the shoulder.
- **Shaft of the femur:** cylindrically shaped region that forms the central portion of the femur.
- **Shaft of the fibula:** elongated, slender portion located between the expanded ends of the fibula.
- **Shaft of the humerus:** narrow, elongated, central region of the humerus.
- **Shaft of the radius:** narrow, elongated, central region of the radius.
- **Shaft of the tibia:** triangular-shaped, central portion of the tibia.
- **Shaft of the ulna:** narrow, elongated, central region of the ulna.

- **Spine of the scapula:** prominent ridge passing mediolaterally across the upper portion of the posterior scapular surface.
- **Sternal end of the clavicle:** medial end of the clavicle that articulates with the manubrium of the sternum.
- **Sternoclavicular joint:** articulation between the manubrium of the sternum and the sternal end of the clavicle; forms the only bony attachment between the pectoral girdle of the upper limb and the axial skeleton.
- **Styloid process of the radius:** pointed projection located on the lateral end of the distal radius.
- **Styloid process of the ulna:** short, bony projection located on the medial end of the distal ulna.
- **Subpubic angle:** inverted V-shape formed by the convergence of the right and left ischiopubic rami; this angle is greater than 80 degrees in females and less than 70 degrees in males.
- **Subscapular fossa:** broad depression located on the anterior (deep) surface of the scapula.
- **Superior angle of the scapula:** corner of the scapula between the superior and medial borders of the scapula.
- **Superior border of the scapula:** superior margin of the scapula.
- **Superior pubic ramus:** narrow segment of bone that passes laterally from the pubic body to join the ilium.
- **Supraglenoid tubercle:** small bump located at the superior margin of the glenoid cavity.
- **Suprascapular notch:** small notch located along the superior border of the scapula, medial to the coracoid process.
- **Supraspinous fossa:** narrow depression located on the posterior scapula, superior to the spine.
- **Surgical neck:** region of the humerus where the expanded, proximal end joins with the narrower shaft.
- **Talus:** tarsal bone that articulates superiorly with the tibia and fibula at the ankle joint; also articulates inferiorly with the calcaneus bone and anteriorly with the navicular bone.
- **Tarsal bone:** one of the seven bones that make up the posterior foot; includes the calcaneus, talus, navicular, cuboid, medial cuneiform, intermediate cuneiform, and lateral cuneiform bones.
- **Thigh:** portion of the lower limb located between the hip and knee joints.
- **Tibial tuberosity:** elevated area on the anterior surface of the proximal tibia.
- **Tibia:** shin bone; the large, weight-bearing bone located on the medial side of the leg.
- **Trapezium:** from the lateral side, the first of the four distal carpal bones; articulates with the scaphoid proximally, the first and second metacarpals distally, and the trapezoid medially.
- **Trapezoid:** from the lateral side, the second of the four distal carpal bones; articulates with the scaphoid proximally, the second metacarpal distally, the trapezium laterally, and the capitate medially.
- **Triquetrum:** from the lateral side, the third of the four proximal carpal bones; articulates with the lunate laterally, the hamate distally, and has a facet for the pisiform.
- **Trochlear notch:** large, C-shaped depression located on the anterior side of the proximal ulna; articulates at the elbow with the trochlea of the humerus.
- **Trochlea:** pulley-shaped region located medially at the distal end of the humerus; articulates at the elbow with the trochlear notch of the ulna.
- **Ulnar notch of the radius:** shallow, smooth area located on the medial side of the distal radius; articulates with the head of the ulna at the distal radioulnar joint.
- **Ulnar tuberosity:** roughened area located on the anterior, proximal ulna inferior to the coronoid process.
- **ulna:** bone located on the medial side of the forearm.

9: SKELETAL MUSCLE ORGANIZATION, MUSCULATURE AND PHYSIOLOGY

Introduction

When most people think of muscles, they think of the muscles that are visible just under the skin, particularly of the limbs. These are skeletal muscles, so-named because most of them move the skeleton. In humans, skeletal muscle comprises approximately 40% of total body weight and contains 50-75% of all body proteins. In this lab, we will focus on the various domains of muscle structure and function including properties, cytoskeletal architecture, excitation-contraction coupling, and force and power generation. In addition, study gross anatomy of a skeletal muscle, including origin, insertion, and action.

Learning Objectives

- Identify the key structural components of skeletal muscle tissue under a microscope, including muscle fibers, nuclei, sarcomeres, and the connective tissue layers (epimysium, perimysium, endomysium).
- Explain the sliding filament theory of muscle contraction and its relationship to the structure of the sarcomere.
- Describe the different muscle fiber types (fast twitch, slow twitch) and their functional implications.
- Identify the muscles of the body on a model or image using anatomical terms/vocabulary.
- Analyze the gross anatomy of a skeletal muscle, including its origin, insertion, and action.

9.1: Background Information

9.2: Activity 1

9.3: Activity 2

9.4: Activity 3

9.5: Activity 4

9.6: Activity 5

9.7: Activity 6

9.8: Glossary

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9.1: Background Information

Overview

The best-known function of skeletal muscle is its ability to contract and cause movement. Skeletal muscles act not only to produce movement but also to stop movement, such as resisting gravity to maintain posture. Muscles also prevent excess movement of the bones and joints, maintaining skeletal stability and preventing skeletal structure damage or deformation. Joints can become misaligned or dislocated entirely by pulling on the associated bones; muscles work to keep joints stable. Skeletal muscles are located throughout the body at the openings of internal tracts to control the movement of various substances. These muscles allow functions, such as swallowing, urination, and defecation, to be under voluntary control. Skeletal muscles also protect internal organs (particularly abdominal and pelvic organs) by acting as an external barrier or shield to external trauma and by supporting the weight of the organs.

Skeletal muscles contribute to the maintenance of homeostasis in the body by generating heat. Muscle contraction requires energy, and when ATP is broken down, heat is produced. This heat is very noticeable during exercise, when sustained muscle movement causes body temperature to rise, and in cases of extreme cold, when shivering produces random skeletal muscle contractions to generate heat.

- Skeletal muscles exhibit several properties that enable them to perform their functions effectively.
- Excitability - The ability of muscle fibers to respond to electrical or chemical stimuli.
- Contractility - The capability of muscle fibers to shorten and generate force.
- Extensibility - The ability of muscle fibers to be stretched without tearing.
- Elasticity - The tendency of muscle fibers to return to their original length after being stretched.

Skeletal Muscle Organization

Skeletal muscle is an organ composed of various integrated tissues, including muscle fibers, blood vessels, nerve fibers, and connective tissue. The connective tissue layers are:

- Epimysium: Surrounds the entire muscle.
- Perimysium: Encases fascicles (bundles of muscle fibers).
- Endomysium: Surrounds individual muscle fibers.

These layers organize muscle fibers, provide structural support, and allow blood vessels and nerves to pass through. At the muscle ends, the epimysium extends to form tendons that attach muscles to bones, refer to Figure 9.1.1. Skeletal muscle cells, known as muscle fibers, can be quite large, with diameters up to 100 μm and lengths reaching 30 cm in the Sartorius muscle of the upper leg. During development, myoblasts fuse to create multinucleated muscle fibers, allowing for increased protein and enzyme production essential for muscle contraction.

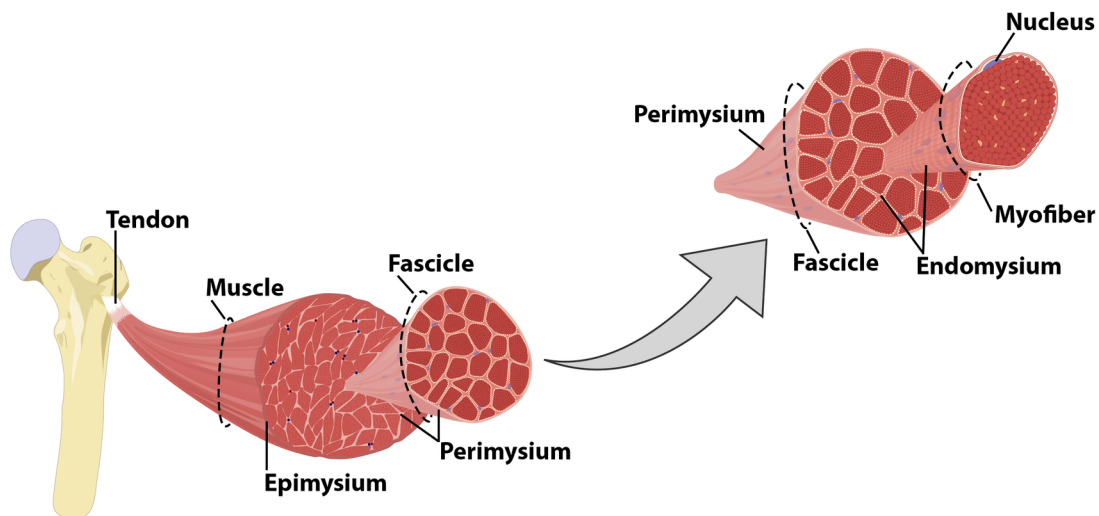


Figure 9.1.1: Skeletal Muscle Organ Structure. Each level of the organization of a skeletal muscle is wrapped in a connective tissue layer: the cell (myofiber) is surrounded by the endomysium, the bundle of cells (muscle fascicle) is surrounded by the perimysium, and the organ (muscle) is surrounded by the epimysium. (CC BY-NC-SA 4.0 ; Justin Greene via [Skeletal Muscle Organ Structure](#)).

Figure 9.1.1 showcases the intricate organization of skeletal muscle, highlighting its structure from the outer connective tissue to the individual muscle fibers. At the outermost layer, the tendon connects muscle to bone, providing stability and force transfer. The muscle body is enveloped by the epimysium, a connective tissue layer that protects and supports. Within the muscle body, bundles known as fascicles are wrapped in the perimysium. Each fascicle consists of individual muscle fibers called myofibers, encased in a fine layer called the endomysium. These myofibers contain nuclei, essential for muscle function and repair, illustrating the complex yet efficient organization of skeletal muscle tissue.

Another specialization of the skeletal muscle is the site where a motor neuron's terminal meets the muscle fiber—called the neuromuscular junction (NMJ). This is where the muscle fiber first responds to signaling by the motor neuron. Every skeletal muscle fiber in every skeletal muscle is innervated by a motor neuron at the NMJ. Excitation signals from the neuron are the only way to functionally activate the fiber to contract. The changes that takes place in the neuromuscular junctions (NMJ) are detailed in Figure 9.1.2.

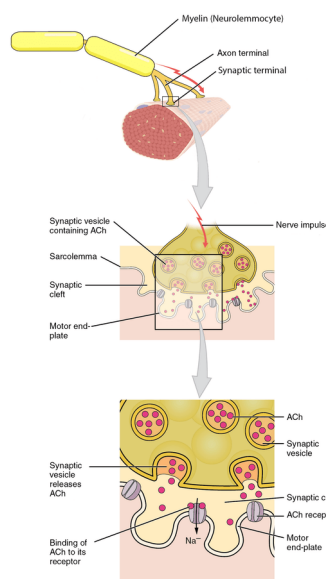


Figure 9.1.2: Motor End-Plate and Innervation. At the NMJ, the axon terminal releases ACh. The motor end-plate is the location of the ACh-receptors in the muscle fiber sarcolemma. When ACh molecules are released, they diffuse across a tiny space called the synaptic cleft and bind to the receptors. (CC BY-NC-SA 4.0 ; Motor Endplate and Innervation" by Jennifer Lange and Justin Greene via [Skeletal Muscle Organ Structure](#)).

Figure 9.1.2 explains how a motor neuron communicates with a muscle fiber at the neuromuscular junction. The diagram is arranged top to bottom to show the sequence of events.

Motor neuron - key structures are labeled:

- A motor neuron is shown with myelin around the axon.
- The neuron ends at the axon terminal (synaptic terminal) near the muscle fiber.
- An arrow indicates the direction of the nerve impulse traveling toward the terminal.
- A muscle fiber is shown below the neuron.

Neuromuscular junction - key structures are labeled:

- Synaptic terminal (end of the neuron)
- Synaptic vesicles containing acetylcholine (ACh) inside the terminal
- Synaptic cleft (gap between neuron and muscle)
- Sarcolemma (muscle cell membrane)
- Motor end plate (specialized region of the sarcolemma beneath the terminal)

Chemical signaling - key structures are labeled:

- Synaptic vesicles release acetylcholine (ACh) into the synaptic cleft.
- ACh moves across the cleft and binds to ACh receptors on the motor end plate.
- Receptor activation allows sodium ions (Na^+) to enter the muscle cell.
- This ion movement initiates a muscle electrical response that leads to contraction.

Muscle Shortening and Lengthening

When muscles contract, they tighten and bulge in the middle due to shortening; this is called a concentric contraction, where the muscle actively pulls to generate movement, like during a bicep curl. While concentric contractions are generally weaker, they help build strength through a range of motion. In contrast, eccentric contractions occur when a muscle lengthens while resisting a force, often controlling movement; this type is usually stronger and builds resilient muscle tissue. Examples of concentric movements include pushing up in a bench press and lifting a barbell in a dead lift.

The isometric contraction represents a middle ground, as muscles neither lengthen nor shorten; these movements involve holding a position without movement, improving strength in specific areas. Examples include handstand holds and the top position of a pull-up.

Structural changes occur at all levels of the muscle during contractions: as the muscle shortens, fascicles, myofibers, and myofibrils also shorten, while the myofilaments remain the same length.

The sarcomere, the functional unit of muscle, contracts by bringing Z-lines closer together through the interaction of myosin and actin, increasing their overlap. During stretching, Z-lines move apart, decreasing overlap. The I band shortens during contraction and lengthens when stretched as illustrated in Figure 9.1.3.

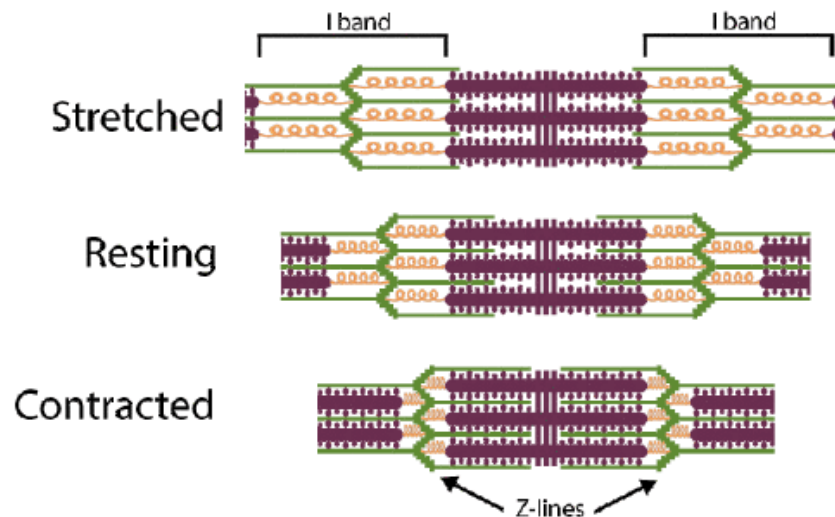


Figure 9.1.3: Sarcomere length showing the position of I band and Z lines in resting, stretched and contracted states. The change in muscle length results from the cumulative change in the length of the sarcomeres. (CC BY-NC-SA 4.0 ; "Sarcomere Length" by Mark Schaeffer via Skeletal Muscle Organ Structure).

Figure 9.1.3 compares a sarcomere (the basic contractile unit of skeletal muscle) in three conditions: stretched, resting, and contracted.

- Stretched: The Z-lines are far apart. The region labeled the I band is wide, indicating less overlap between thin and thick filaments.
- Resting: The Z-lines are closer together than in the stretched state. The I band is smaller, showing increased overlap.
- Contracted: The Z-lines are closest together. The I band is the smallest, showing the greatest overlap of filaments.

Naming Skeletal Muscles

Learning the names of the muscles in the body can seem daunting, but understanding their etymology can make it easier. Etymology is the study of the origin of words and how their meanings have evolved. Anatomists name skeletal muscles based on various criteria that describe their characteristics. Key Points About Muscle Naming Conventions:

- Location: For example, "Temporalis" refers to a muscle near the temple, while "sternocleidomastoid" attaches to the sternum, clavicle, and mastoid process.
- Shape: Muscles like "Deltoid" (triangular) and "trapezius" (trapezoid) are named for their shapes, while "orbicularis" indicates a circular form.
- Size: Terms like "Maximus" (largest), "Medius" (medium), and "Minimus" (smallest) describe the size of muscles.
- Fiber Direction: "Rectus" means straight, and "oblique" means angled, indicating the direction of muscle fibers.
- Number of Origins: Muscles may be named based on their origins, such as "Biceps" (two origins) and "Triceps" (three origins).

Example Muscle Names and Their Meanings:

- Biceps Brachii: "Bi" (two) + "ceps" (head) + "brachii" (arm).
- Gluteus Maximus: "Gluteus" (buttocks) + "maximus" (largest).
- Rectus Abdominis: "Rectus" (straight) + "abdominis" (abdomen).
- Serratus Anterior: "Serratus" (saw-like) + "anterior" (front).
- Orbicularis Oculi: "Orbicularis" (circular) + "oculi" (eye).

Taking the time to learn these roots is crucial for mastering the vocabulary of anatomy and physiology. While pronunciation may take practice, understanding the basic information will make it easier to accurately name and pronounce muscular terms.

Skeletal muscles are located throughout the body, including the head, neck, trunk, upper limbs, and lower limbs. Here are some examples of skeletal muscles by location are represented in the Table 9.1.1.

Table 9.1.1: Understanding a Muscle Name from the Latin roots

Example	Word	Latin Roots	Meaning	Translation
abductor digitiminimi	abductor	ab = away from; duct = to move	a muscle that moves away from	A muscle that moves the little finger or toe away
	digiti	digitus = digit	a finger or toe	
	minimi	minus = mini, tiny	little	
adductor digitiminimi	adductor	ad = to, toward; duct = to move	a muscle that moves towards	A muscle that moves the little finger or toe toward
	digiti	digitus = digit	a finger or toe	
	minimi	minus = mini, tiny	little	

Interactions of Skeletal Muscles in the Body

To pull on a bone, that is, to change the angle at its synovial joint by moving the skeleton, a skeletal muscle must also be attached to a fixed part of the skeleton. The end of the muscle attached to a fixed (stabilized) bone is called the origin and the moveable end of the muscle that attaches to the bone being pulled is called the muscle's insertion. The muscle's line of pull indicates the direction the body part will move when the insertion point is brought closer to the origin point Figure 9.1.4.

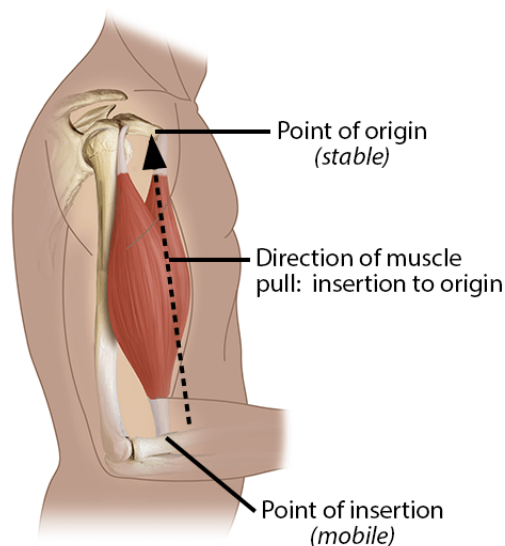


Figure 9.1.4: Origin and Insertion Points of skeletal muscle. When a muscle contracts and shortens, the bone at the point of insertion will move toward the bone at the point of origin (CC BY-NC-SA 4.0 ; "Origin and Insertion" by Justin Greene and Jennifer Lange via LibreTexts).

Figure 9.1.4 illustrates the origin and insertion points of a skeletal muscle, viewed from the right lateral side. The origin is situated near the shoulder, serving as the stable anchor point, while the insertion is located near the elbow, representing the mobile end. A dashed arrow along the muscle indicates the direction of muscle pull from the mobile insertion point to the stable origin. As the muscle contracts and shortens, it causes the bone at the insertion to move toward the bone at the origin. This movement is fundamental to understanding how muscles facilitate joint motion and leverage.

Understanding Muscle Roles in Body Movement: Prime Movers, Synergists, and Antagonists

Although a number of muscles may be involved in an action, the principal muscle involved is called the prime mover, or agonist. The muscle that acts as the prime mover (or agonist) during one action may become the antagonist during the opposite movement. This dynamic interplay between muscles is essential for coordinated and efficient movement. In the context of arm movement, for example, when flexing the elbow to lift a cup, the biceps brachii serves as the prime mover. Meanwhile, the

brachialis and brachioradialis act as synergists, assisting in the action. If you were to extend the elbow, the triceps brachii would take on the role of the agonist, while the biceps would become the antagonist. A synergist can function as a fixator, stabilizing the bone that serves as the attachment point for the prime mover's origin Figure 9.1.5

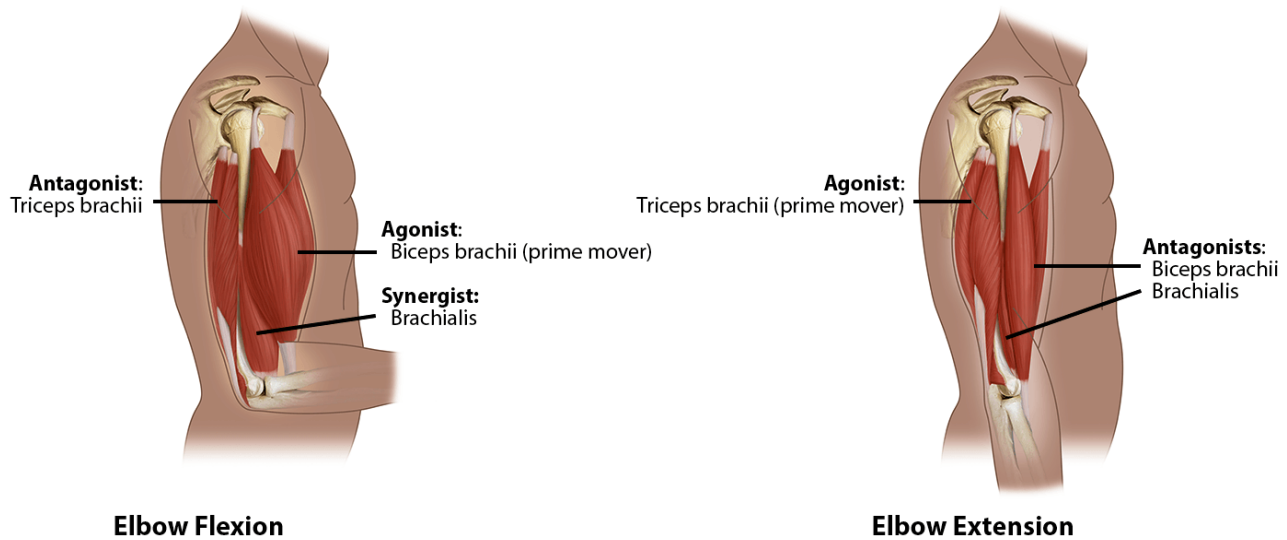


Figure 9.1.5: Role playing of muscles in elbow movements. Elbow Flexion (left) uses biceps brachii (agonist) and brachialis (synergist), while triceps brachii relaxes. For elbow Extension (right), triceps brachii leads, with biceps brachii and brachialis relaxing (antagonists). (CC BY-NC-SA 4.0; Agonist and Antagonist" by Justin Greene and Jennifer Lange via LibreTexts).

Figure 9.1.5 presents two diagrams of the human arm, illustrating the mechanics of elbow flexion and extension.

- Left demonstrates elbow flexion: the biceps brachii acts as the agonist, driving the movement, while the brachialis serves as the synergist, aiding in the action. The triceps brachii functions as the antagonist, relaxing to allow the bending of the elbow.
- Right, depicts elbow extension: the triceps brachii takes on the role of the agonist, facilitating the straightening of the arm. Biceps brachii and brachialis act as antagonists, lengthening to permit this motion.

To extend the knee, the quadriceps femoris group in the anterior thigh acts as the agonists. Conversely, to flex the knee, the hamstrings are activated as the antagonistic muscle group. These roles can be reversed depending on the action. For instance, if the action involves knee bending, the hamstrings become the agonists while the quadriceps femoris serve as the antagonists.

Refer to Table 9.1.2 for summary of the roles of agonist and antagonist muscles during movements of the elbow and knee joints, highlighting how these muscle groups work together to facilitate movement and stability.

Table 9.1.2: Agonist and Antagonist Skeletal Muscle Pairs for movements of the elbow and knee joints

Agonist	Antagonist	Movement/Action
Biceps brachii - in the anterior compartment of the arm.	Triceps brachii - in the posterior compartment of the arm.	The biceps brachii flexes the forearm, whereas the triceps brachii extends it.
Hamstrings: group of three muscles in the posterior compartment of the thigh.	Quadriceps femoris: group of four muscles in the anterior compartment of the thigh.	The hamstrings flex the leg, whereas the quadriceps femoris extend it.

Exercise and Stretching

When it comes to exercise, the significance of warming up and stretching cannot be overstated! Warming up prepares your muscles for the strain they're about to encounter by increasing blood flow, which enhances flexibility and reduces the risk of injury. Stretching, in particular, helps elongate the muscle fibers, making them more pliable and less prone to strains. Without a proper warm-up, muscle fibers can be damaged, or tendons might be pulled, leading to painful injuries characterized by swelling and limited mobility. In severe cases, these injuries can sideline you for an extended period, hindering your fitness goals.

Understanding Key Skeletal Muscles for Laboratory Studies

To effectively study the human body in a laboratory setting, it's essential to have a solid grasp of the major skeletal muscles, as they play crucial roles in movement, stability, and overall function. Below is a structured overview of the selected muscle groups:

1. Muscles that move the lower jaw (Mastication), these muscles are responsible for chewing and include:
 - Masseter: Elevates the mandible (jaw).
 - Temporalis: Assists in closing the jaw and retracting it.
2. Muscles that move and stabilize the head, these muscles help maintain head posture and facilitate movement:
 - Sternocleidomastoid: Rotates and flexes the neck.
 - Trapezius: Elevates, retracts, and rotates the scapula, also stabilizing the head.
3. Muscles that position the pectoral girdle (stabilize and move the shoulders):
 - Pectoralis Major: Helps in flexing and adducting the arm.
 - Serratus Anterior: Protracts and stabilizes the scapula.
4. Muscles of the Back (Key for posture and movement)
 - Latissimus Dorsi: Extends, adducts, and rotates the arm.
 - Rhomboids: Retracts the scapula, helping with shoulder stability.
5. Abdominal Wall Muscles (support for the trunk)
 - Rectus Abdominis: Flexes the vertebral column.
 - External and Internal Obliques: Rotate and flex the torso.
6. Muscles involved in breathing (ventilation)
 - Diaphragm
 - External intercostals
 - Internal intercostals
7. Muscles That Move the Humerus (vital for arm movement)
 - Deltoid: Abducts the arm.
 - Rotator Cuff Muscles: Stabilize the shoulder joint and allow for a wide range of motion.
8. Muscles of the Forearm (movements of the wrist and fingers)
 - Flexor Group: Flexes the wrist and fingers.
 - Extensor Group: Extends the wrist and fingers.
9. Gluteal Region Muscles That Move the Thigh (essential for hip movement):
 - Gluteus Maximus: Extends and laterally rotates the thigh.
 - Gluteus Medius and Minimus: Abduct the thigh and stabilize the pelvis.
 - Quadriceps group: Extends leg at the knee joint.
 - Hamstring group: Flexes leg at the knee joint.
10. Muscles of the Lower Leg (facilitate movement of the ankle and foot):
 - Gastrocnemius: Plantar flexes the foot and flexes the knee.
 - Soleus: Plantar flexes foot.
 - Tibialis Anterior: Dorsiflexes the foot.

Understanding these muscle groups will enhance your comprehension of human anatomy and physiology, crucial for effectively conducting laboratory work.

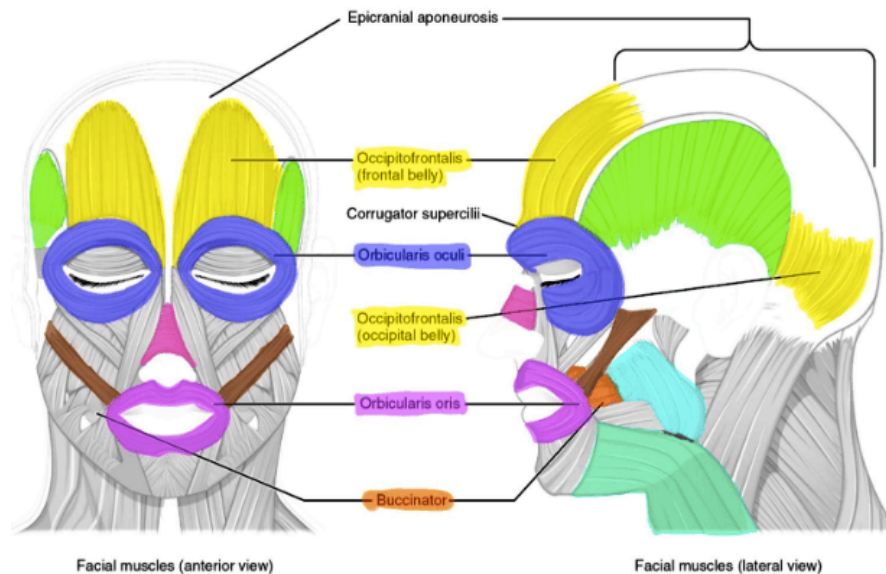


Figure 9.1.6: Muscles of the head and face involved in facial expression and chewing in anterior and lateral view. Highlighted parts include muscle like - Buccinator, orbicularis oris, orbicularis oculi, occipitofrontalis, and epicranial aponeurosis. (CC BY-NC-SA 4.0; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via [Muscles Lab](#)).

Figure 9.1.6 presents facial muscles in two views: an anterior (front) view and a lateral (side) view. Muscles and what they do:

- Epicranial aponeurosis: Connects and stabilizes the scalp.
- Occipitofrontalis: Raises the eyebrows.
- Corrugator supercilii: Draws the eyebrows together to produce frowning.
- Orbicularis oculi: Closes the eyelids (blinking and squinting).
- Orbicularis oris: Shapes and closes the mouth (puckering and lip movement).
- Buccinator: Keeps the cheeks taut to support chewing and helps prevent the cheeks from sagging inward.

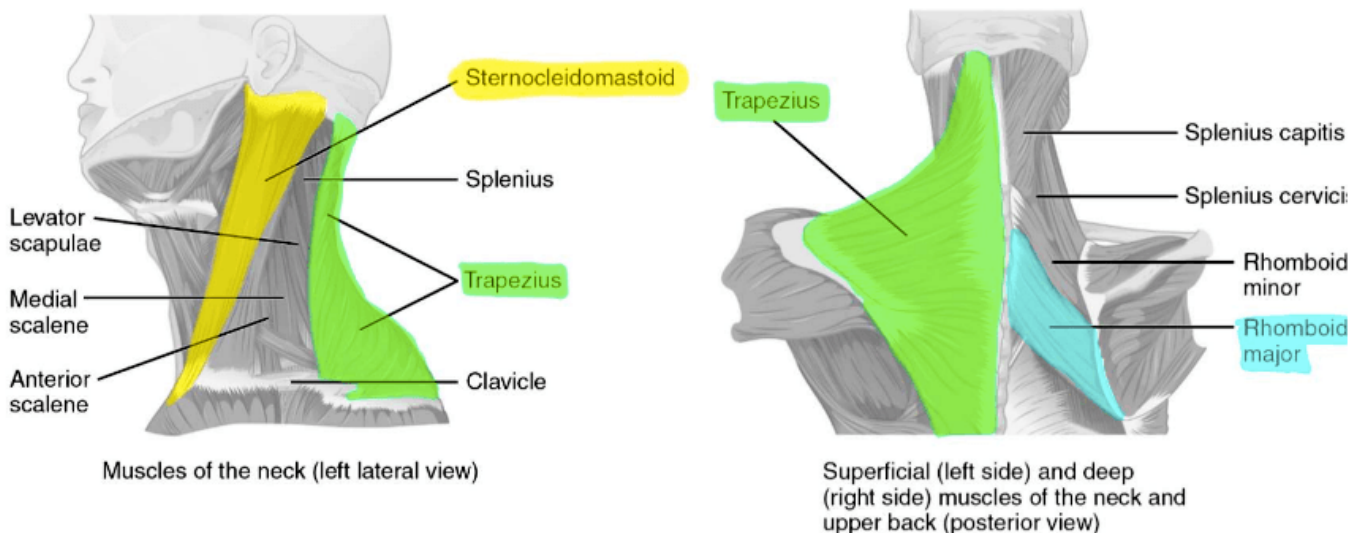


Figure 9.1.7: Muscles of the neck and back in lateral and posterior view. The skeletal muscles highlighted are sternocleidomastoid, trapezius, levator scapuli, scalene, splenius and rhomboid major and minor. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via [Pressbooks](#)).

Figure 9.1.7 shows two labeled anatomical diagrams of the neck and upper back muscles. The left panel shows a lateral (side) view of the neck, with the clavicle provided as a landmark. The following muscles are identified:

- Sternocleidomastoid - a long band of muscle running diagonally from just below and behind the ear to the collarbone
- Splenius - a broad muscle that pulls on the base of the skull and lies under the trapezius
- Trapezius - this is described below; the side view shows how the trapezius connects at the base of the skull and the to the

clavicle.

- Levator scapulae - a slender muscle located at the back of the neck, running from the first few vertebrae to the shoulder blade.
- Anterior scalene and medial scalene - these slender muscles are located deep within the neck.

The right panel shows a posterior (back) view of the neck and upper back, identifying the following muscles:

- Trapezius - a large superficial muscle in a triangular shape, oriented along the spine, with one corner attached to an area at the base of the skull, another attached to an area near a shoulder, and the other lower down on the back (not shown).
- Splenius capitis - located below the trapezius in the back of the neck, and running from the upper spine to the base of the skull.
- Splenius cervicis - located deep in the neck, along the spine.
- Rhomboid minor - a small, cylindrical muscle in the upper back, connecting the scapula to the spinal column, just under the trapezius.
- Rhomboid major - a wide band of muscle just below the Rhomboid minor, also connecting the scapula and the spinal column.

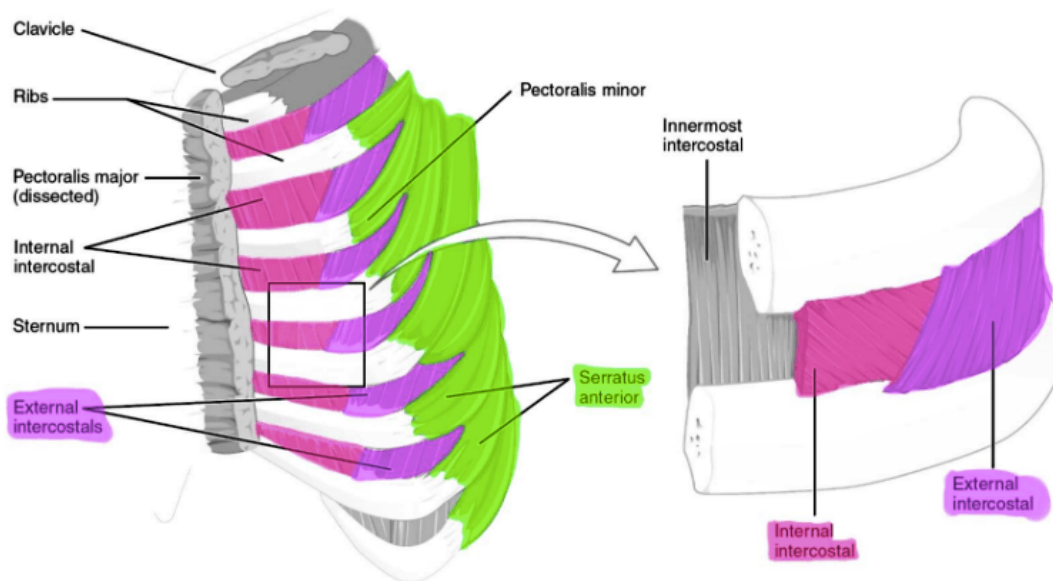


Figure 9.1.8: Skeletal muscles involved in breathing (ventilation) in anterior view. Muscles highlighted are pectoralis major, pectoralis minor, internal intercostals, external intercostals, serratus anterior. The image also shows the clavicle, sternum and ribs. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via [Pressbooks](#)).

Figure 9.1.8 focuses on the thoracic region, emphasizing on the anterior thoracic muscles. Chest wall muscles and intercostal layers (front/side view and cross-section)

Left panel: anterior and lateral view of the chest

- Bony landmarks are labeled: clavicle, ribs, and sternum.
- Pectoralis major is shown partially removed to reveal deeper structures.
- Pectoralis minor is shown beneath pectoralis major.
- Intercostal muscles are shown between the ribs in layers:
 - External intercostals (outer layer; fibers run diagonally downward)
 - Internal intercostals (beneath external; fibers run in the opposite direction)
- Serratus anterior is shown along the side of the rib cage with multiple attachments to the ribs.

Right panel: cross-section close-up between two ribs. This close-up emphasizes the three intercostal layers between adjacent ribs:

- External intercostal (outermost)
- Internal intercostal (middle)
- Innermost intercostal (deepest)

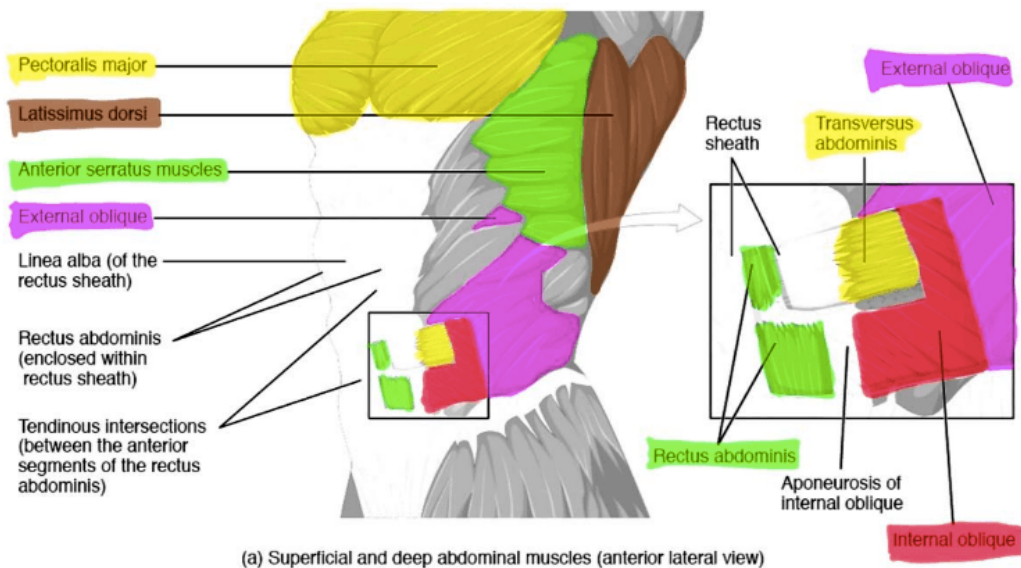


Figure 9.1.9: Superficial and deep muscles of the abdominal wall in anterior and lateral view. Highlighted muscles include pectoralis major, latissimus dorsi, rectus abdominis, transversus abdominis, external oblique, anterior serratus. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via Pressbooks).

Figure 9.1.9 illustrates the abdominal wall from an anterior-lateral (front/side) view. A main view highlights more superficial structures, and an inset view shows deeper layers.

Abdominal wall muscles (anterior-lateral view): superficial vs. deep layers:

- Pectoralis major at the upper chest
- Latissimus dorsi extending from the back toward the side of the torso
- Serratus anterior along the ribs
- External oblique covering the lateral abdomen
- Rectus abdominis within the rectus sheath, showing:
 - Tendinous intersections
 - The linea alba running vertically at the midline (part of the rectus sheath)

The inset highlights deeper structures beneath the superficial layer, including:

- Internal oblique
- Transversus abdominis
- Aponeurosis of the internal oblique, contributing to the rectus sheath around the rectus abdominis

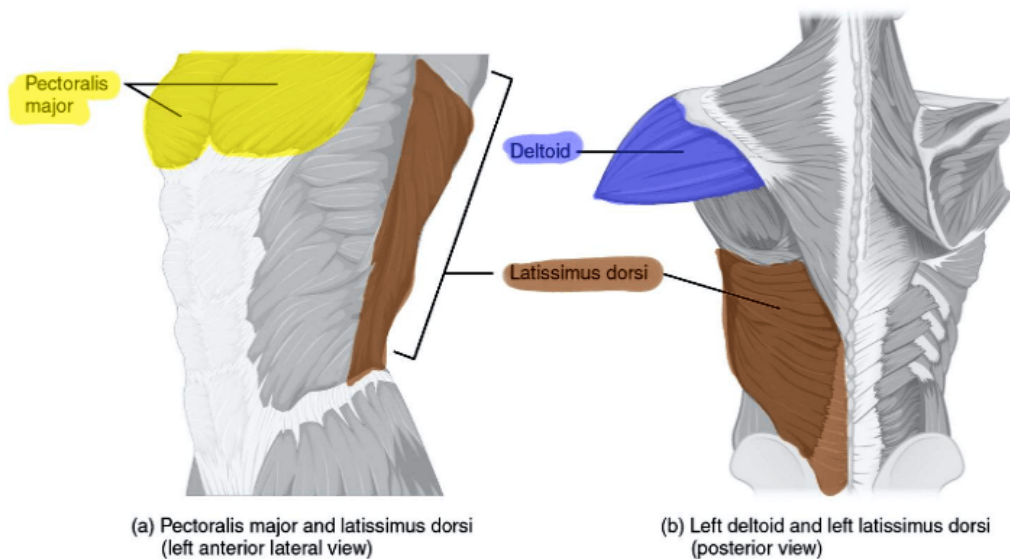


Figure 9.1.10: Superficial muscles of the shoulder (a) left anterior lateral view showing the pectoralis major and latissimus dorsi, (b) posterior view highlighting deltoid and latissimus dorsi. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via Pressbooks).

Figure 9.1.10 presents an anterior-lateral (front/side) view of the abdominal wall showing superficial and deep muscle layers. Muscles are labeled and grouped by region.

Labeled muscles and primary actions

- Pectoralis major: contributes to upper chest and shoulder movement.
- Latissimus dorsi: extends from the back and assists with arm movement.
- Serratus anterior: supports the rib cage and helps stabilize the shoulder region.
- External oblique: lateral abdominal muscle that assists with trunk rotation and side-bending (lateral flexion).
- Internal oblique: deeper lateral abdominal muscle that assists with trunk rotation and side-bending.
- Transversus abdominis: deep abdominal muscle that supports core stability and abdominal compression.
- Rectus abdominis: midline abdominal muscle shown with tendinous intersections; enclosed in the rectus sheath; supports trunk flexion and posture.

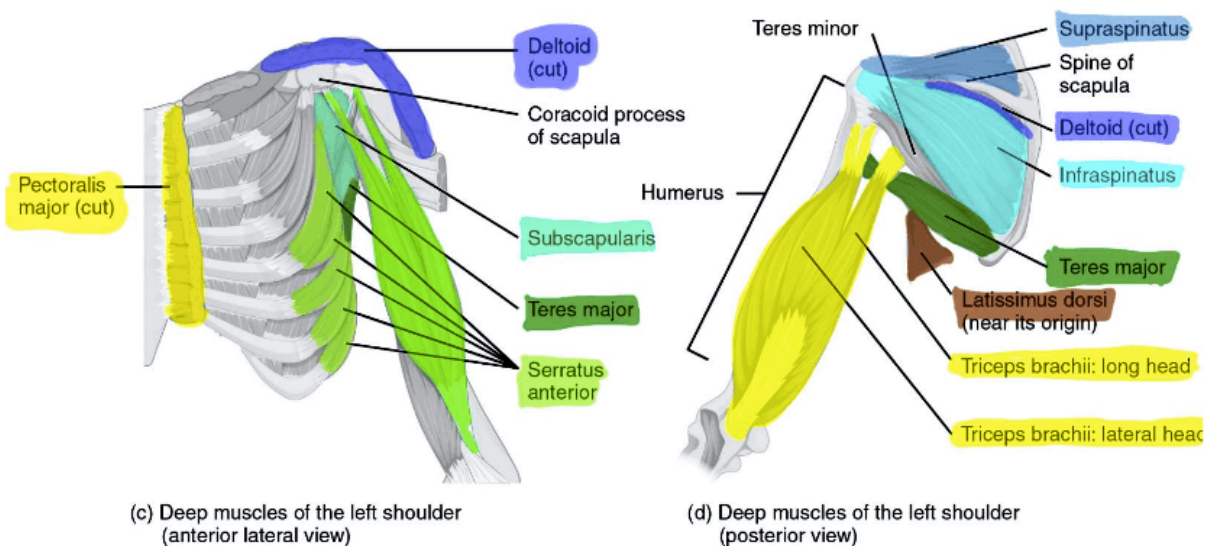


Figure 9.1.11: Deep muscles of the left shoulder (c) anterior lateral view highlighting deltoid, subscapularis, teres major, pectoralis major, serratus anterior and (d) posterior view highlighting teres minor, supraspinatus, infraspinatus, teres major, teres minor, latissimus dorsi and triceps brachii. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via Pressbooks).

Figure 9.1.11 presents labeled diagrams of the left shoulder's deep muscles, providing both an anterior lateral view on the left and a posterior view on the right.

- Anterior lateral view
 - Deltoid - along the top of the shoulder, plays a crucial role in arm movements such as abduction, flexion, internal and external rotation
 - Pectoralis major - large chest muscle, shown here along the sternum. Important for adduction, medial rotation of the arm at the shoulder joint.
 - Subscapularis - located on the scapula, between the scapula and the rib cage. It is crucial for shoulder stability and internal rotation.
 - Teres major - large, flat muscle that extends from the scapula to the humerus. It assists in arm adduction and medial rotation.
 - Serratus anterior - large, fan-shaped muscle that spans the upper ribs to the scapula. It supports scapular movement.
- Posterior view
 - Supraspinatus extends along the top of the scapula and is part of the rotator cuff
 - Infraspinatus extends along the posterior of the scapula, below its spine, and forms part of the rotator cuff
 - Teres major. This posterior view shows where it connects to the base of the scapula.
 - Latissimus dorsi. A portion of this large, flat muscle is shown near its origin just below the teres major. It is responsible for arm extension and adduction.
 - Triceps brachii extends along the humerus, from the shoulder to the elbow. From the elbow it branches into two sections: long head (medial) and lateral head. This muscle is vital for elbow extension and shoulder stabilization.

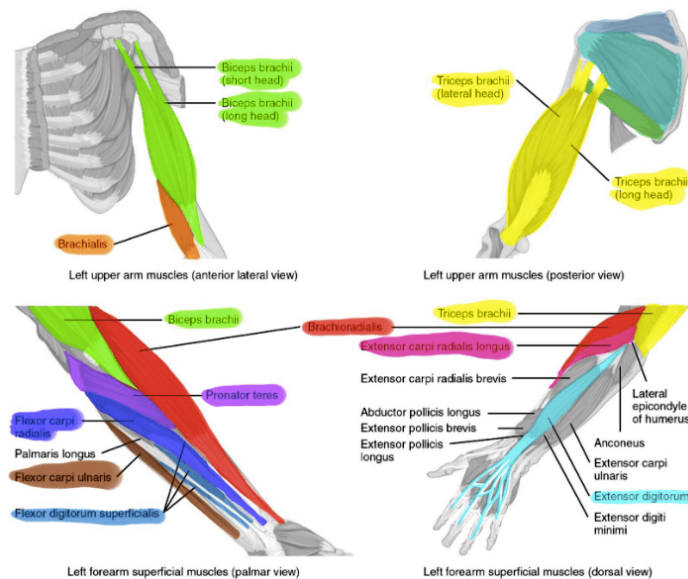


Figure 9.1.12: Muscles of the left upper arm in anterior lateral highlighting the biceps brachii short and long head and biceps brachii, and the posterior view indicating triceps brachii long head and lateral head). The left forearm superficial muscles palmar view (bottom image) showing the biceps brachii, brachialis, pronator teres, flexor carpi radialis, flexor carpi ulnaris and flexor digitorum superficialis and dorsal view highlighting triceps brachii, brachialis, extensor carpi radialis longus and extensor digitorum. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via Pressbooks).

Figure 9.1.12 presents an in-depth look at the muscles of the left upper arm and forearm.

- Top-left (anterior lateral view of the upper arm) showcases two muscles essential for flexing the elbow and facilitating arm movement.
 - The biceps brachii extends along the humerus, from the shoulder to just above the elbow. Similar to the triceps brachii, the muscle branches into two sections before it meets the shoulder. The short head attaches to the scapula, and the long head to just above the shoulder joint.
 - The brachialis runs along the humerus just below the biceps brachii.
- Top-right (posterior view of the upper arm) featuring the triceps brachii (lateral and long heads), crucial for elbow extension

and arm stabilization.

- Bottom-left diagram: Palmar view of the left forearm superficial muscles. These muscles are vital for wrist flexion, finger movement, and forearm rotation.
 - The brachioradialis extends along lateral side of the forearm, above the biceps branchii.
 - Four shorter and thinner muscles are shown along the medial side of the forearm, extending diagonally from the medial of the arm and moving down toward the wrist. From top to bottom, we see the pronator teres, flexor carpi ulnaris, palmaris longus, and flexor carpi radialis.
 - The flexor digitorum superficialis lies just below those muscles, extending in the same direction.
- Bottom-right diagram: Dorsal view of the left forearm superficial muscles, which are essential for thumb movement, wrist extension, and stabilizing the forearm.
 - The extensor carpi radialis longus runs parallel to the brachioradialis and just below it, originating at the lateral epicondyle of the humerus.
 - The anconeus extends from lateral epicondyle of the humerus to the upper ulna.
 - The extensor carpi radialis brevis runs parallel to and just below the extensor carpi radialis longus.
 - The extensor digitorum extends from the lateral epicondyle of the humerus down through the wrist, splitting into four tendons within the digits.
 - Along the medial of the arm, just above the wrist area, three muscles are indicated, but the specific locations are not identified: abductor pollicis longus, extensor pollicis brevis, and extensor pollicis longus.
 - Along the lateral of the arm, just above the wrist area, the extensor carpi ulnaris and extensor digiti minimi are indicated (but specific locations are not identified).
 - The following muscles are highlighted as being particularly important: triceps branchii, brachioradialis, extensor carpi radialis longus, and extensor digitorum.

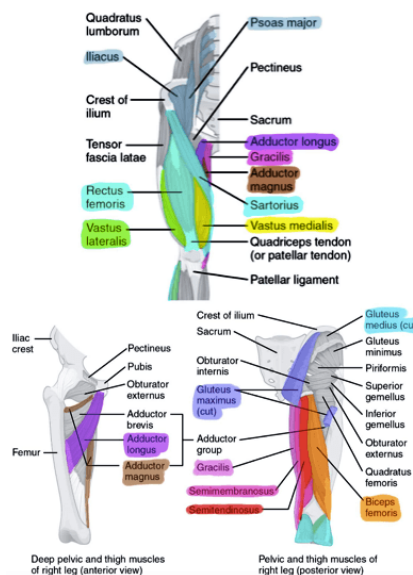


Figure 9.1.13: Muscles of the hip and thigh showing the superficial anterior (top) showing the adductor longus, gracilis, adductor magnus, sartorius, vastus medialis, vastus lateralis and rectus femoris; deep pelvic and thigh muscles of right leg in anterior view (bottom, left) highlighting the adductor longus and adductor magnus, and posterior (bottom, right) highlighting gluteus maximus, gluteus medius, gracilis, semimembranosus, semitendinosus and biceps femoris. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via Pressbooks).

Figure 9.1.13 provides set of three images of the hip and thigh muscles. The top diagram identifies the superficial anterior muscles that are crucial for hip adduction, leg flexion, and knee extension. To orient the viewer, the quadratus lumborum (an abdominal muscle) is shown at the top, just above the crest of ilium (top of the hip bone), with the iliacus muscle within the pelvis, and then the sacrum.

- The psoas major appears deep in the thigh, running vertically from an area just above the crest of ilium and alongside the iliacus until it is obscured by the sartorius.
- The pectineus is shown just below the sacrum. Running vertically along the pectin pectineus, we see the adductor longus, gracilis, and adductor magnus.
- The sartorius appears as a long band originating at the crest of ilium and wrapping horizontally to just below and over the adductor magnus.

- The vastus medialis is a broad muscle that appears directly below and under the sartorius, on the medial side.
- Just below the vastus medialis the quadriceps tendon (or patellar tendon) and patellar ligament are called out to orient the viewer.
- Along the lateral side of the leg, extending from the crest of ilium we see the tensor fascia latae.
- The vastus lateralis appears directly below the tensor fascia latae and continues to the knee.
- The largest muscle shown is the rectus femoris, a superficial muscle located in the middle of the thigh. It originates at the pelvis and runs down to the patella.
- These muscles are highlighted as being particularly important: iliacus, psoas major, adductor longus, gracilis, adductor magnus, sartorius, rectus femoris, vastus lateralis and vastus medialis.

The bottom left diagram focuses on the deep pelvic and thigh muscles that are crucial for stabilizing the pelvis and facilitating thigh movement. The right leg is shown. To orient the viewer, the Iliac crest (or crest of iliac, the top of the hip bone), pectineus, and pubis are shown at the top, with the femur along the right side of the diagram.

- The obturator externus muscle covers the pelvis, directly below the pubis.
- The adductor magnus lies deep within the thigh and extends from the pelvis to the knee.
- The adductor brevis is a short muscle shown wrapping over the adductor magnus.
- The adductor longus runs diagonally over the adductor brevis, connecting the pubis to the femur.
- The adductor longus and adductor magnus are highlighted as being particularly important.

The bottom-right diagram presents a posterior view highlighting pelvic and thigh muscles that play a significant role in activities such as walking and running. The right leg is shown. To orient the viewer, the crest of ilium (top of the hip bone) and the sacrum are identified at the top of the diagram.

- A portion of the gluteus maximus is shown as a thick band wrapping over the hip bone and sacrum.
- On the right side of the diagram, a portion of the gluteus medius is shown on the surface of the ilium, underneath the gluteus maximus.
- Just below the gluteus medius, a set of muscles are indicated, but not highlighted as being of interest. From top to bottom: gluteus minimus, piriformis, superior gemellus,
- inferior gemellus, obturator externus, quadratus femoris, and adductor group. A small section of the gluteus maximus is visible near the adductor group.
- In the middle of the thigh, the biceps femoris is shown as a thick vertical band originating at the pelvis and moving horizontally past the lateral side of the knee.
- Three thinner bands of muscle are shown parallel to the biceps femoris, but moving past the medial side of the knee. From left to right: Gracilis, semimembranosus, and semitendinosus.
- The following muscles are highlighted: gluteus medius, gluteus maximus, gracilis, semimembranosus, semitendinosus, and biceps femoris.

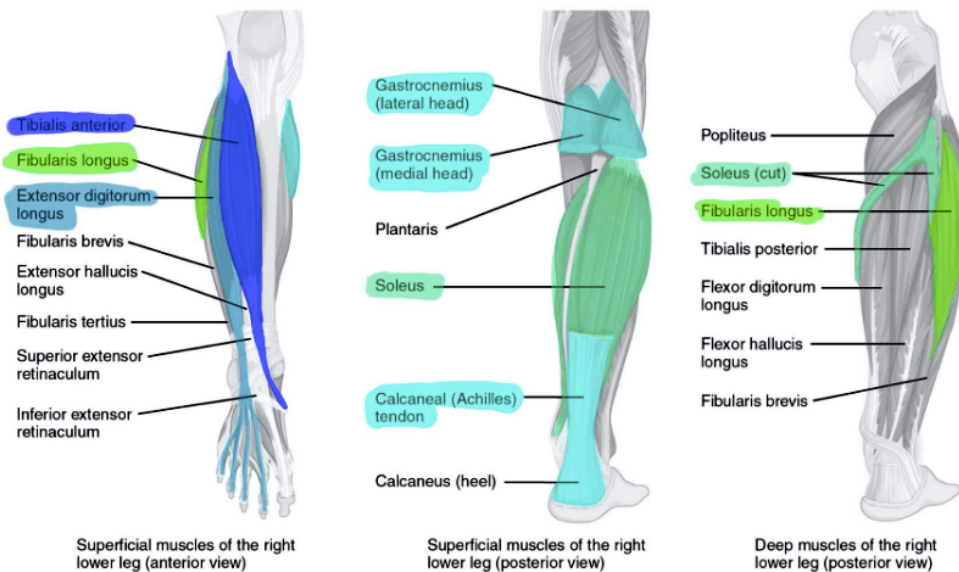


Figure 9.1.14: Muscles of the right lower leg. Superficial muscles, anterior view (left) highlighting tibialis anterior, fibularis longus, and extensor digitorum longus; superficial muscles, posterior view (middle) highlighting the gastrocnemius, soleus and calcaneal tendon; and deep muscles, posterior view (right) highlighting the soleus and fibularis longus. (CC BY-NC-SA 4.0 ; Gillian Backus; Heidi W. Wangerin; and Paula Rodgers via Pressbooks).

Figure 9.1.14 presents a comprehensive view of the right lower leg, highlighting both superficial and deep muscles from different perspectives.

The left diagram presents an anterior view of the superficial muscles of the right lower leg. The most prominent muscle, the tibialis anterior, originates from the upper tibia and runs along the shin, terminating in the foot above the hallux (great toe). Directly to the left in the diagram, the extensor digitorum longus runs parallel to the tibialis anterior, extending to the ankle and branching into four tendons that reach into each toe.

- The fibularis longus runs vertically along the lateral side of the leg; the diagram does not show where it terminates.
- Just below the fibularis longus, the fibularis brevis and fibularis tertius are indicated, both appear to continue vertically down the leg.
- The extensor hallucis longus is shown underneath the tibialis anterior.
- The superior and inferior extensor retinacula are shown underneath the tibialis anterior and extensor digitorum longus. The superior extensor retinaculum appears just above the ankle joint, while the inferior extensor retinaculum is a band across the foot, just below the ankle joint.

The middle diagram presents a posterior view of superficial muscles of the right lower leg that are essential for plantar flexion, providing power for movements like jumping and running.

- Just behind the knee we see the gastrocnemius, which has a medial head and a lateral head.
- The soleus, or calf muscle, originates just below the knee and under the gastrocnemius, joining the calcaneal (Achilles) tendon and terminating at the calcaneus (heel).

The right diagram shows a posterior view of the deep muscles of the right lower leg that are crucial for stabilizing the leg and foot, as well as enabling intricate movements like toe flexion and inversion.

- The popliteus is shown as a band of muscle directly behind the knee joint.
- A portion of the soleus appears in this deeper view as an inverted Y just below the popliteus at the top of the calf area.
- The fibularis longus is visible as a wide band running along the lateral side of the calf area.
- The tibialis posterior is a band of muscle deep in the middle of the lower leg, originating below the popliteus. Its lower end lies underneath the flexor digitorum longus and flexor hallucis longus.
- The flexor digitorum longus and flexor hallucis longus are shown as two vertical bands of muscle that originate from the medial (flexor digitorum longus) and lateral (flexor hallucis longus) sides of the leg and both appear to terminate at the ankle.
- The tibialis brevis is shown as a thin band running along the lateral side of the lower leg, parallel to the flexor hallucis longus.

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9.2: Activity 1

Skeletal Muscle Structure Matching (Connective Tissue Layers)

Matching the structures/parts of a skeletal muscle indicated by letters to the terms indicated on the image.

Table 9.2.1: Matching Skeletal Muscle Structures to Their Corresponding Labels in Figure 9.2.1

Structure for identification	Epimysium	Endomysium	Muscle fiber	Perimysium	Fascicle
Matching Letter					

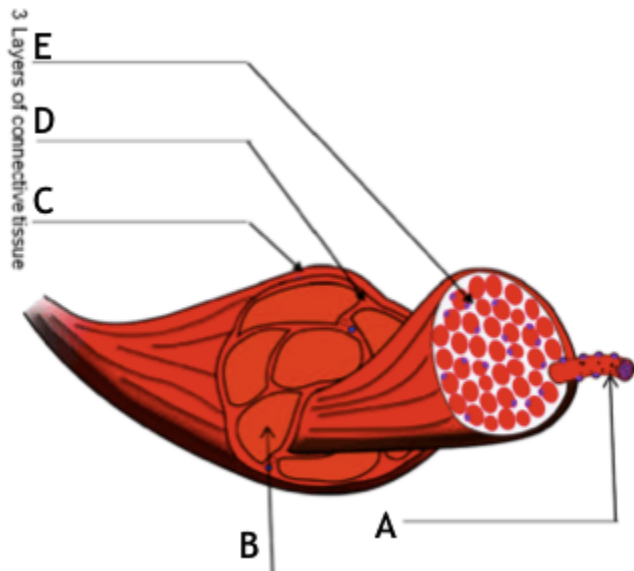


Figure 9.2.1: Connective tissue sheaths and skeletal muscle organization. (CC BY-NC-SA 4.0; Rosanna Hartline via LibreTexts).

9.3: Activity 2

Muscle Attachment & Action Matching

Matching the structures/parts of a skeletal muscle indicated by letters to the following terms.

Table 9.3.1: Matching Skeletal Muscle Structures to Letters in Figure 9.3.1 – Elbow Joint and Musculoskeletal Components

Structure for identification	Origin	Insertion	Flexor muscle	Extensor muscle
Matching Letter				

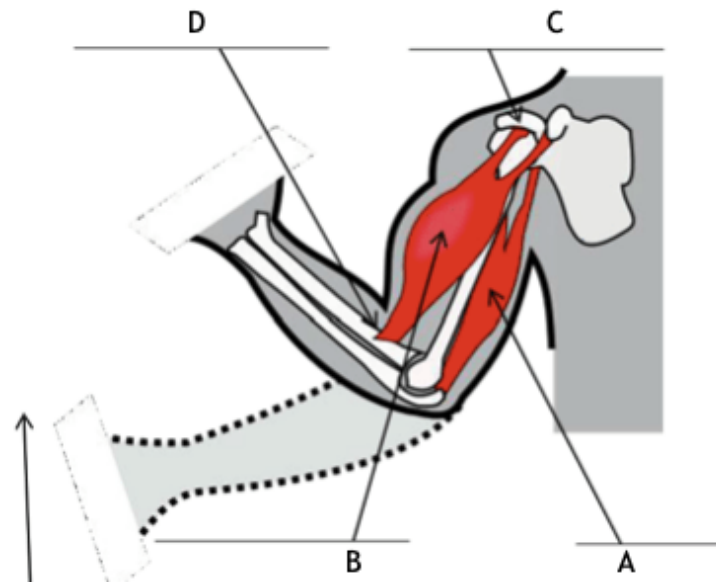


Figure 9.3.1: Diagram of the elbow joint illustrating key components of the musculoskeletal system. The diagram highlights the origin and insertion points of major muscles involved in elbow movement. It distinguishes between flexor muscles, such as the biceps brachii, which facilitate arm bending, and extensor muscles, like the triceps brachii, which enable arm straightening. Arrows indicate the direction of movement during flexion and extension, providing a clear visual representation of how these muscle groups work together at the elbow joint. (CC BY-NC-SA 4.0; Rosanna Hartline via LibreTexts).

9.4: Activity 3

Muscle Contraction Role Play: The Sliding Filament Theater

To grasp the sliding filament theory of muscle contraction in a fun and interactive way, this role playing activity allows students to embody the components of muscle contraction. By stepping into the shoes (or roles) of actin, myosin, calcium ions, and ATP, students will learn about the dynamic interactions that occur during muscle movement.

Objective

Materials Needed

- Costumes/Props: Simple items to represent different components (for example colored headbands, paper cutouts, or scarves).
 - Actin: Green headbands or scarves.
 - Myosin: Yellow headbands or scarves.
 - Calcium ions: Small balls or tokens.
 - ATP: Flashlights (to represent energy).
- Space: A large area for movement and interaction.
- Script/Guidelines: A handout explaining each role and the sequence of actions.

Detailed Activity Steps

- Brief explanation of the sliding filament theory and the roles of actin, myosin, calcium ions, and ATP in muscle contraction.
- Students are divided into groups based on the roles:
 - Actin: The filaments that slide and provide structure.
 - Myosin: The heads that pull on actin to create contraction.
 - Calcium ions: The activators that initiate the contraction process.
 - ATP: The energy provider that powers the movement.
- Students are given a few minutes to come up with a simple costume or prop to represent their roles.
- Explaining the sequence of actions:
 - Actin stands in a line, representing the muscle fiber.
 - Myosin will approach Actin and mimic the pulling action.
 - Calcium ions will move to activate Myosin, represented by throwing their tokens (the small balls) toward them.
 - ATP will shine their flashlights on Myosin when energy is needed for movement.

Note: Emphasize that the act of pulling should be synchronized, demonstrating how myosin heads interact with actin.

- Simulation starts with a countdown.
- Calcium ions activate the contraction by throwing their tokens to Myosin.
- Myosin will then move toward Actin and simulate pulling them inward.
- After a few seconds, the ATP group shines their flashlights to signify the need for energy, allowing Myosin to pause and "reset" (relaxation phase).
- The cycle is repeated a few times to show both contraction and relaxation.
- Summarize the key takeaways from the role play, reinforcing how the actin and myosin interaction works during muscle movement.

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9.5: Activity 4

Identification of Selected Skeletal Muscles on Laboratory Models.

The goal of this part of the lab is to familiarize students with the structure and actions (movements) of skeletal muscles by identifying various skeletal muscles on human models, diagrams, and slides by working as pairs. By the end of this lab, students should be able to identify and name selected skeletal muscles of the human body, including their origin, insertion and action.

Part I - Muscle Identification and Labeling Challenge

Briefly explain the importance of understanding muscle anatomy and its relevance in fields like health, fitness, and medicine.

Materials Needed:

- Blue Tape: For labeling each identified muscle.
- Markers: For writing the names of the muscles legibly on the blue tape (NO marking directly on the model).
- Anatomical Models to assist with identification.

List of Skeletal Muscles for Identification

To effectively study the human body in a laboratory setting, it's essential to have a solid grasp of the major skeletal muscles, as they play crucial roles in movement, stability, and overall function.

Below is a structured overview of the selected muscle groups:

1. Muscles That Move the Lower Jaw (Mastication) - These muscles are responsible for chewing and include:
 - Masseter: Elevates the mandible (jaw).
 - Temporalis: Assists in closing the jaw and retracting it.
2. Muscles That Move and Stabilize the Head - These muscles help maintain head posture and facilitate movement:
 - Sternocleidomastoid: Rotates and flexes the neck.
 - Trapezius: Elevates, retracts, and rotates the scapula, also stabilizing the head.
3. Muscles That Position the Pectoral Girdle (stabilize and move the shoulders):
 - Pectoralis Major: Helps in flexing and adducting the arm.
 - Serratus Anterior: Protracts and stabilizes the scapula.
4. Muscles of the Back (Key for posture and movement):
 - Latissimus Dorsi: Extends, adducts, and rotates the arm.
 - Rhomboids: Retracts the scapula, helping with shoulder stability.
5. Abdominal Wall Muscles (support for the trunk):
 - Rectus Abdominis: Flexes the vertebral column.
 - External and Internal Obliques: Rotate and flex the torso.
6. Muscles involved in breathing (ventilation):
 - Diaphragm
 - External intercostals
 - External intercostals

7. Muscles That Move the Humerus (vital for arm movement):

- Deltoid: Abducts the arm.
- Rotator Cuff Muscles: Stabilize the shoulder joint and allow for a wide range of motion.
- Four muscles (SITS): Supraspinatus, Infraspinatus, Teres minor, Subscapularis

8. Muscles of the upper limb (movements of the elbow, wrist and fingers):

- Biceps Brachii: Located in the front of the upper arm, this muscle flexes (bends) the elbow and also helps to supinate the forearm (turn the palm up).
- Brachialis: A deep muscle under the biceps that also flexes the elbow.
- Triceps Brachii: Located on the back of the upper arm, it extends (straightens) the elbow.
- Brachioradialis: Originates on the humerus and inserts on the radius; it's a primary elbow flexor, especially when the forearm is half-pronated.
- Flexor Carpi Radialis: Flexes and radially deviates (abducts) the wrist.
- Flexor Carpi Ulnaris: Flexes and ulnarly deviates (adducts) the wrist.
- Palmaris Longus: A superficial muscle that weakly flexes the wrist.
- Extensor Carpi Radialis Longus: Extends and abducts the wrist.
- Extensor Carpi Ulnaris: Extends and adducts (ulnar deviates) the wrist.
- Extensor Digitorum: Extends the fingers.

9. Gluteal Region Muscles That Move the Thigh (essential for hip movement):

- Gluteus Maximus: Extends and laterally rotates the thigh.
- Gluteus Medius and Minimus: Abduct the thigh and stabilize the pelvis.
- Quadriceps group: Extends leg at the knee joint
 - Rectus femoris: A straight muscle that extends from the pelvis to the patella.
 - Vastus lateralis: A large muscle on the outer side of the thigh.
 - Vastus medialis: A large muscle on the inner side of the thigh.
 - Vastus intermedius: A deep muscle located between the rectus femoris and vastus lateralis.
- Hamstring group: Flexes leg at the knee joint
 - Semitendinosus: Originates from the ischial tuberosity and inserts into the medial side of the upper tibia.
 - Semimembranosus: Originates from the ischial tuberosity and inserts into the posterior medial side of the upper tibia.
 - Biceps femoris: Has two heads (long and short) that originate from the ischial tuberosity and insert into the lateral side of the upper tibia (long head) and the head of the fibula (short head).

10. Muscles of the Lower Leg (facilitate movement of the ankle and foot):

- Gastrocnemius: Plantar flexes the foot and flexes the knee.
- Soleus: Plantar flexes foot.
- Tibialis Anterior: Dorsiflexes the foot.

Understanding these muscle groups will enhance your comprehension of human anatomy and physiology, crucial for effectively conducting laboratory work.

Note - Mnemonics help students remember origins, insertions, or actions. For example:

- For rotator cuff muscles: SITS (Supraspinatus, Infraspinatus, Teres Minor, Subscapularis).
- Muscles involved in elbow flexion: "Three Bs Bend the Elbow" : Biceps brachii, Brachialis, Brachioradialis

For an effective in-person lab activity focused on identifying skeletal muscles, students can showcase their work. Each group can capture photographs of laboratory models, with muscles clearly labeled using blue tape. This visual documentation should cover at least two anatomical regions, such as the upper limb, lower limb, or posterior torso. However, all students are responsible for all the selected muscles.

- **Label Clearly:** Use blue tape to label each muscle on the model, ensuring the text is legible in photographs.
- **Capture Quality Photos:** Ensure good lighting and focus in photographs to clearly show the labeled muscles and their placements.
- **Organize and Submit:** Compile the images into a digital format for easy submission and review by instructors.

Part II - Exploring Origins, Insertions, and Actions of selected skeletal muscles

Understanding the origin, insertion, and action of skeletal muscles is fundamental to grasping how they function in movement and stability. This lab activity will help students systematically gather and organize information about selected skeletal muscles, reinforcing their knowledge of human anatomy.

Instructions

- The list of selected skeletal muscles is provided, each group will be assigned a set of tables to research and complete required information.
 - Muscle Name: The name of the muscle.
 - Origin: Where the muscle begins, typically the stationary bone.
 - Insertion: Where the muscle attaches to the bone that moves.
 - Action: The primary movement the muscle performs when it contracts.
- Students will work collaboratively, discussing their findings and ensuring accuracy.
- Once the tables are completed, one group will pair up with another group to review each other's work.
- Each pair should check for accuracy and clarity, providing constructive feedback.
- Class Discussion
 - Which muscle was the most interesting to research?
 - How do the origins and insertions relate to muscle actions?

Table 9.5.1: Selected Skeletal Muscles of the Head and Face - Actions, Origins, and Insertions

Skeletal muscle	Prime mover action	Muscle Origin	Muscle Insertion
Frontalis	Raise eyebrows, draw scalp anteriorly	Epicranial aponeurosis	Subcutaneous tissue of eyebrows
Occipitalis			
Temporalis	Elevate mandible to close mouth		
Massetter			
Orbicularis oculi	Close eyelid; wink eye; blink eyes	Frontal bone; maxilla	Skin of eyelid

Table 9.5.2: Selected Skeletal Muscles of the Neck, thorax and back

Skeletal muscle	Prime mover action	Muscle Origin	Muscle Insertion
Sternocleidomastoid			
Pectoralis major	Flex, adduct, and medially rotate humerus	Clavicle, sternum, cartilages of ribs 1-7	Crest of greater tubercle of humerus
Trapezius			Clavicle, acromion, scapular spine
Latissimus dorsi			
Rectus abdominis	Flex vertebral column; compress abdominal wall	Crest of pubis, pubic symphysis	

Table 9.5.3: Selected Skeletal muscles of Upper limb and Pectoral girdle

Skeletal muscle	Prime mover action	Muscle Origin	Muscle Insertion
Deltoid			
Biceps brachii			
Triceps brachii			
Brachioradialis			
Supraspinatus			

Skeletal muscle	Prime mover action	Muscle Origin	Muscle Insertion
Teres major			
Palmaris longus			
Flexor carpi radius			
Flexor carpi ulnaris			
Extensor digitorum			

Table 9.5.4: Selected Skeletal Muscles of the Hips and Lower Limb - Actions, Origins, and Insertions

Skeletal muscle	Prime mover action	Muscle Origin	Muscle Insertion
Gluteus maximus			
Tensor fasciae latae			
Sartorius			
Gracilis			
Gastrocnemius			
Soleus			
Biceps femoris			
Rectus femoris			
Tibialis anterior			
Semitendinosus			

9.6: Activity 5

Temperature and Handwriting: Exploring Effects on Fine Motor Skills

Handwriting is a complex fine motor skill that relies on the coordination of small muscles in the hands and fingers. Temperature can play a significant role in muscle performance, potentially affecting handwriting quality and speed. This lab activity will allow students to investigate how different temperature conditions influence their handwriting skills through a series of writing tasks.

Objective

To explore the effects of temperature on handwriting performance by measuring legibility, speed, and overall quality under varying temperature conditions.

Testable Hypothesis

If the temperature of the water bath is increased, then students' handwriting speed and legibility will improve, as measured by the time taken to complete the writing tasks and the legibility scores assigned by peers.

- Independent Variable: Temperature of the water bath (cold, room temperature, warm).
- Dependent Variables:
 - Handwriting speed (time taken to complete writing tasks).
 - Handwriting legibility (scores assigned by peers).

Materials

For this exercise, you will need a pencil, a bowl with warm water, a bowl with ice cold water, and a timer or stopwatch.

NOTE: As you engage in this handwriting activity, please remember that the assessment of handwriting legibility is not a personal comment on any individual's handwriting skills. The primary goal of this activity is to explore and understand the effects of temperature on fine motor skills, specifically how it can influence handwriting performance.

- Focus on Learning: The emphasis is on observing changes in handwriting speed and legibility due to temperature variations, rather than evaluating personal handwriting abilities.
- Constructive Environment: Approach this activity with the mindset of gaining insights into muscle function and coordination, allowing for a supportive and collaborative learning atmosphere.

Procedure

1. Students will rotate through three temperature conditions: cold (ice bath), room temperature water (baseline), and warm (warm water bath - 40°C to 45°C or 104°F to 113°F). This range is warm enough to relax the hand muscles without causing discomfort or risk of burns. It is essential to ensure that all participants feel comfortable at this temperature.
2. Using the tiny pencil provided to you, write "Exploring effects of temperature on fine motor skills" 3 times on a piece of paper (baseline).
3. Submerge your writing hand in ice cold water for 3 minutes, then remove your hand from the water and write "Exploring effects of temperature on fine motor skills" 3 times just below the writing in baseline condition. Label "Cold".
4. Submerge your writing hand in nice, warm water (not hot!) for 3 minutes, then remove your hand from the water and write "Exploring effects of temperature on fine motor skills" 3 times just below the writing in 'Cold' condition. Label "Warm".
5. Legibility Assessment: After writing, the instructor or peers will evaluate the legibility of each participant's handwriting on a scale of 1 to 5. (1 being very poor, 5 being excellent).
6. Once all groups have completed the tasks, discuss trends observed in the data.
 - a. Did the data support or refute the hypothesis that increasing the temperature of the water bath improves handwriting speed and legibility?
 - b. Did you experience differences in the pressure applied to the pen when writing in cold versus warm environments?

- c. What might be the physiological reasons behind these changes?

9.7: Activity 6

The Effect of Muscle Fatigue on Fine Motor Skills Using Beans

Fine motor skills are essential for tasks that require precise hand movements, such as writing, typing, or performing delicate tasks. This lab activity investigates the impact of muscle fatigue on these skills, specifically focusing on how fatigue affects the ability to perform a simple task of moving beans using the thumb and ring finger.

Hypothesis

If muscle fatigue is induced in the dominant hand, then the number of beans moved within 60 seconds will decrease compared to the number moved before fatigue, demonstrating that muscle fatigue negatively affects fine motor skills.

Variables

- Independent Variable: Muscle fatigue (before and after inducing fatigue).
- Dependent Variable: Number of beans moved in 60 seconds.

Materials

- Beans (any small type, such as kidney or pinto beans)
- Beaker, cup, or mug (with an opening smaller than a fist)
- Stopwatch or timer

Procedure

- Part A Fine Motor Skills Before Muscle Fatigue:
 - The subject will move beans from a tabletop into the cup using only the thumb (1st digit) and ring finger (4th digit) of their dominant hand.
 - When the timekeeper says "go," the subject will start moving the beans one at a time for 60 seconds.
 - Record the number of beans moved in Trial 1 in the data table.
- Part B Fine Motor Skills After Muscle Fatigue:
 - To induce fatigue, the subject will make a tight fist and hold it for 3-5 minutes until they feel fatigued.
 - After the fatigue is produced, the subject will move beans again using the same method as in Part A, for another 60 seconds.
 - Record the results for Trial 1 in the "after fatigue" column.
- Repeat Trials:
 - Repeat the steps of Parts A and B for Trials 2 and 3, ensuring to record the number of beans moved in each trial.

Table 9.7.1: Effect of Fatigue on Number of Beans Moved

Trial	Before Fatigue (number of beans moved)	After Fatigue (number of beans moved)
1		
2		
3		

Reflection Questions

1. What conclusions can you make about the effect of muscle fatigue on fine motor skills for your subject?
2. Did the subject's performance improve after fatigue? If so, why do you think this could have happened?

3. Select (circle) the type of muscle fibers (slow-twitch or fast-twitch) and their characteristics in the muscles of the hand. Why? Justify your selection based on your understanding of muscle physiology.

Key Terms and Definitions

- **A band** – region of the sarcomere where myosin is present
- **acetylcholine (ACh)** – neurotransmitter that binds at a motor end-plate to trigger depolarization
- **actin** – protein that makes up most of the thin myofilaments in a sarcomere muscle fibre
- **action potential** – change in voltage of a cell membrane in response to a stimulus that results in transmission of an electrical signal; unique to neurons and muscle fibers
- **aponeurosis** – broad, tendon-like sheet of connective tissue that attaches a skeletal muscle to another skeletal muscle or to a bone
- **depolarize** – to reduce the voltage difference between the inside and outside of a cell's plasma membrane (the sarcolemma for a muscle fibre), making the inside less negative than at rest
- **endomysium** – loose, and well-hydrated connective tissue covering each muscle fibre in a skeletal muscle
- **epimysium** – outer layer of connective tissue around a skeletal muscle
- **excitation-contraction coupling** – sequence of events from motor neuron signaling to a skeletal muscle fibre to contraction of the fiber's sarcomeres
- **fascicle** – bundle of muscle fibers within a skeletal muscle
- **H zone** – region of the sarcomere surrounding the M line where only myosin is present
- **I band** – also known as the light band; region of the sarcomere where only actin is present
- **M line** – center structure of a sarcomere that serves to anchor myosin filaments
- **motor end-plate** – sarcolemma of muscle fibre at the neuromuscular junction, with receptors for the neurotransmitter acetylcholine
- **myofibril** – long, cylindrical organelle that runs parallel within the muscle fibre and contains the sarcomeres
- **myofilament** – groups of proteins that make up myofibrils
- **myosin** – protein that makes up most of the thick cylindrical myofilament within a sarcomere muscle fibre
- **neuromuscular junction (NMJ)** – synapse between the axon terminal of a motor neuron and the section of the membrane of a muscle fibre with receptors for the acetylcholine released by the terminal
- **neurotransmitter** – signaling chemical released by nerve terminals that bind to and activate receptors on target cells
- **perimysium** – connective tissue that bundles skeletal muscle fibres into fascicles within a skeletal muscle
- **sarcomere** – longitudinally, repeating functional unit of skeletal muscle, with all the contractile and associated proteins involved in contraction
- **sarcolemma** – plasma membrane of a skeletal muscle fiber
- **sarcoplasm** – cytoplasm of a muscle cell
- **sarcoplasmic reticulum (SR)** – specialized smooth endoplasmic reticulum, which stores, releases, and retrieves Ca^{2+}
- **skeletal muscle fiber** – multinucleated skeletal muscle cells usually attached to bone, under voluntary control, each cell is a fiber that is multinucleated and striated
- **synaptic cleft** – space between a nerve (axon) terminal and a motor end-plate
- **T-tubule** – projection of the sarcolemma into the interior of the cell
- **terminal cisternae** – enlarged regions of the sarcoplasmic reticulum found on either side of the T-tubules
- **thick filament** – the thick myosin strands and their multiple heads projecting from the centre of the sarcomere toward, but not all the way to, the Z-discs
- **thin filament** – thin strands of actin and its troponin-tropomyosin complex projecting from the Z-discs toward the centre of the sarcomere
- **triad** – the grouping of one T-tubule and two terminal cisternae
- **troponin** – regulatory protein that binds to actin, tropomyosin, and calcium
- **tropomyosin** – regulatory protein that covers myosin-binding sites to prevent actin from binding to myosin
- **voltage-gated sodium channels** – membrane proteins that open sodium channels in response to a sufficient voltage change, and initiate and transmit the action potential as Na^{+} enters through the channel
- **Z-line (Z-disc)** – structure that forms the border of a sarcomere and serves as the anchorage site for thin filaments

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GLOSSARY

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