

URINALYSIS ATLAS: A PICTORIAL GUIDE TO FORMED ELEMENTS IN URINE (DOTY AND TAYLOR)



Dawn Taylor and Caroline Doty

Urinalysis Atlas: A Pictorial Guide to Formed Elements in Urine (Doty and Taylor)

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Introduction

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About this Open Educational Resource (OER) Project

In Medical Laboratory Science (MLS) Urinalysis course, students learn to evaluate normal and abnormal formed urinary elements through microscopic examination of urine sediment. They learn to interpret results and correlate with other laboratory data to identify disease. Access to quality atlases are a vital tool in the students' learning process. Because the cost of printing pictures is so great, the price of printed atlases is high. The number of images included is limited. And many excellent atlases are now out of print.

This project seeks to eliminate those challenges for students by giving access to an Open Educational Resource (OER) atlas for urinalysis. This format is easily accessed during students' time on campus and will continue into their careers as medical laboratory scientists. There are currently not many medical subject resources available as open resources. It is our hope that other healthcare professionals will find these resources beneficial. This project is unique in that students are the main contributors of the pictures used. While not entirely comprehensive at this point, the OER platform will allow for continual updating as new images and information become available.

Acknowledgements

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Reviewers

1: Cellular Elements

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1.1 Red Blood Cells (RBC)

Morphology: Normal RBC vary from 6-9 micrometers in size. They are round and biconcave. In hypertonic urine the cells appear crenated; shrunken with small spikes. In hypotonic urine the cells will increase in size and appear colorless. Dysmorphic RBC can arise from glomerular diseases and will appear misshaped, fragmented and/or have protrusions. "Ghost cells" is a term used to describe RBCs that have lysed leaving behind their outer membrane.

Disease correlation and clinical significance: Pathological causes of RBCs in urine include, glomerular membrane damage/disease, urinary tract infections, kidney stones, and trauma to kidneys. Non-pathological causes to RBCs are typically due to menstrual contamination.

Helpful Hints: RBC, yeast and oil droplets look similar and need to be differentiated. To distinguish between RBC and yeast, acetic acid (1:1) can be added to urine sediment. RBC will lyse in the presence of acetic acid but yeast will remain intact. To distinguish RBC from oil droplets, use lipid stains such as Oil Red O or Sudan III.

RBC 1.1

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RBC1.2

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RBC 1.3

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1.2 White Blood Cells (WBC)

Morphology: WBCs are 10-14 micrometers in size. The most common WBC seen in urine is a neutrophil. Thus, most WBCs in the urine will appear granular, except for lymphocytes and monocytes.

Disease correlation and clinical significance: Pathological causes of WBCs in urine include urinary tract infections, inflammation and glomerular diseases. Presence of eosinophils in urine are associated with interstitial nephritis.

Helpful Hints: When distinguishing WBC from RBC, WBCs look more granular and “fuzzy” compared to RBCs. Also note the size difference, WBCs are typically larger than RBCs.

WBC 1.1

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WBC 1.2

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1.3 Squamous Epithelial Cells

Morphology: Squamous cells are the largest of the cells at 50-100 micrometers. The cell has an irregular shape and consists of a nucleus the size of a large RBC. The edges of the cell membrane are often folded, irregular or wrinkled in appearance. Squamous epithelial cells originate from the lower urethra and outer mucosa of the genitalia.

Disease correlation and clinical significance: No pathological significance.

Helpful Hints: When squamous cells are folded they can resemble a cast. To differentiate between a cast and a squamous cell look for the nucleus, a cast does not have a nucleus.

SQE 1.1

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SQE 1.2

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1.4 Transitional Epithelial Cells

Morphology: The size of a transitional epithelial cell is smaller than a squamous cell but larger than a RTE cell and WBC. They typically have a centralized nucleus and can come in various shapes such as oval, pear, spherical and caudate. The boarder of a transitional epithelial cell membrane is more defined and has higher contrast than the boarder of a squamous cell. Transitional epithelial cells originate from the upper urethra, bladder, ureter and renal pelvis.

Disease correlation and clinical significance: Pathological causes of transitional epithelial cells in urine include, infection, kidney stones, inflammation, and bladder cancer. Non-pathological causes for transitional epithelial cells in urine are typically due to catheterization.

Helpful Hints: To distinguish from squamous cells, look for the rounded, more defined cell membrane and smaller size.

Transitonal 1.1

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Transitonal1.2

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1.5 Renal Tubule Epithelial Cells (RTE)

Morphology: Renal tubule epithelial cells (RTE) are smaller than squamous and transitional epithelial cells but typically larger than WBCs. They come in various shapes including, round, oval, cuboidal and oblong. Many forms have an eccentric nucleus, with less cytoplasm than a transitional or squamous epithelial cell. RTE cells originate from the tubules within the nephron; proximal convoluted tubule, loop of Henle, distal convoluted tubule and collecting duct.

Disease correlation and clinical significance: Pathogenic causes of RTE cells in the urine include damage to renal tubules, ischemic events in the nephron and viral infections.

Helpful Hints: Use size, amount of cytoplasm, and position of nucleus to help differentiate an RTE from a transitional epithelial cell and squamous epithelial cell. Typically, RTE cells are the smallest of the epithelial cells, have less cytoplasm and have an eccentric nucleus. Some RTE cells have a flat edge on their outer membrane which can help to distinguish them from transitional cells.

RTE 1.1

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RTE 1.2

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1.6 Oval Fat Bodies

Morphology: Oval fat bodies are RTE cells that contain fat droplets. Due to the cells containing fat, oval fat bodies may demonstrate Maltese cross formation under a polarizing microscope. The fat droplets cause oval fat bodies to be highly refractile.

Disease correlation and clinical significance: Pathogenic causes of oval fat bodies in urine include nephrotic syndrome and renal tubule damage.

Helpful Hints: A specimen that contains oval fat bodies will typically contain free floating fat droplets. If oval fat bodies are suspected use lipid stains or polarizing microscopy to confirm.

OFB 1.1

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OFB 1.3

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1.6.A Fat Droplets

Fat droplets are not a cellular elements but can be seen in conjugation with Oval Fat Bodies. Fat droplets are lipids composed of either triglycerides, neutral fats or cholesterol, or a combination of these lipids. Pathologic causes for fat droplets in urine includes nephrotic syndrome and glomerular damage. Fat droplets appear round, vary in size and are highly refractile. Fat droplets look similar to RBCs, to differentiate use lipid stains such as Oil Red O or Sudan III.

Fat droplets 1.1

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2. Casts

1. [2.1 Hyaline Casts](#)
2. [2.2 Cellular casts](#)
3. [2.3 Granular Casts](#)
4. [2.4 Waxy and Broad Casts](#)

2.1 Hyaline Casts

Morphology: Hyaline casts are colorless and have a low refractive index. Hyaline casts are composed of a protein called uromodulin, which is secreted by RTE cells. The shape of the cast is derived from the renal tubule it was molded in. They have parallel sides with rounded ends. The casts may have rare to occasional granules. Few to many granules within the cast matrix is classified as a granular cast.

Disease correlation and clinical significance: Pathogenic causes for hyaline casts include chronic renal disease, congestive heart failure, fever and dehydration. Non-pathogenic causes for hyaline casts found in healthy individuals occur due to strenuous exercise, dehydration and stress.

Helpful Hints: Hyaline casts are often missed due to their low refractive index, to prevent this use low light and lower the condenser. Fibers and mucus are often misidentified as casts due to their similar appearance. Fibers have a higher refractive index than hyaline casts, and will appear refractile under high light. Mucus is typically thinner than hyaline casts and it lacks the parallel sides with rounded ends.

Hyaline Casts 1

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Hyaline Casts 2

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2.2 Cellular casts

Morphology:

RBC casts: RBC casts have parallel sides with rounded ends and contain multiple RBCs within the cast matrix. The cells will be embedded in the matrix of the cast not attached to the sides. The latter is most likely a hyaline cast with free floating RBCs attached. The casts range in color from pink to red to brown.

WBC casts: WBC casts have parallel sides with rounded ends and contain multiple WBCs within the cast matrix. The cells will be embedded in the matrix of the cast not attached to the sides. The latter is most likely a hyaline cast with free floating WBCs

attached.

RTE casts: RTE casts have parallel sides with rounded ends and contain multiple RTE cells within the cast matrix.

Disease correlation and clinical significance:

RBC casts: Pathologic causes associated with RBC casts include glomerular nephritis and glomerular damage.

WBC casts: Pathologic causes associated with WBC casts include pyelonephritis, interstitial nephritis and inflammation.

RTE casts: RTE casts are associated with acute tubular necrosis or damage to renal tubules.

Helpful Hints: WBC casts and RTE casts can often be mistaken for one another. For WBC casts look for the presence of free-floating WBCs in the urine. Additionally look for the segmented nucleus found in WBCs vs the mono nucleus of RTE cells. Supravital stains can be used to help distinguish nuclear details for differentiation of RTE vs WBC casts.

Cellular Casts 1

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2.3 Granular Casts

Morphology: Granular casts have parallel sides with rounded ends and contain multiple granules. Casts can be either fine or coarsely granulated. Coarsely granulated casts tend to be dark in color whereas finely granulated will be lighter in color.

Disease correlation and clinical significance: Pathologic causes associated with granular casts include urinary stasis, glomerulonephritis, tubular damage and pyelonephritis. Non-pathologic causes associate with granular casts can arise from stress or strenuous exercise.

Helpful Hints: All casts are enumerated under low power but are differentiated on high power.

Granular Casts 1

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Granular Casts 2

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2.4 Waxy and Broad Casts

Morphology:

Waxy Casts: Waxy casts have parallel sides; their ends can be rounded or blunt. The casts are typically darker than hyaline casts and are highly refractile. The casts have a sliced wax appearance.

Broad casts: Broad casts have parallel sides; their ends can be rounded or blunt. Broad casts get the name “broad” because they are significantly wider than other casts, as they are produced in the collecting duct. Broad casts can be granular or waxy in appearance.

Disease correlation and clinical significance: Pathologic causes for both waxy and broad casts are associated with extreme urinary stasis, chronic renal failure and end stage renal disease.

Helpful Hints: The presence of waxy and/or broad casts will be accompanied by the presence of other cast types. Waxy casts are often misidentified as they look similar to fibers. Look for the presence of other cast types in the sample before calling a waxy cast.

Broad Casts 1

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Waxy Casts 1

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Waxy Casts 2

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3. CRYSTALS

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2. 3.1.A Amorphous
3. 3.1.B Calcium Oxalate
4. 3.1.C Hippuric Acid
5. 3.1.D Sodium Urate
6. 3.1.E Uric Acid
7. 3.1.F Ammonium Biurate
8. 3.1.G Calcium Carbonate
9. 3.1.H Calcium Phosphate
10. 3.1.I Triple Phosphate
11. 3.1.J Bilirubin
12. 3.1.K Cystine
13. 3.1.L Cholesterol
14. 3.1.M Leucine
15. 3.1.N Tyrosine
16. 3.1.O Sulfonamide
17. 3.1.P Radiographic Dye
18. 3.1.Q Ampicillin

3.1 Crystals

Crystals are the product of precipitation of solutes in urine. There are multiple variables that contribute to crystallization of solutes in urine including decreased temperature, solute concentration, and pH. The purpose of identification is to detect abnormal urinary crystals that are clinically significant and are associated with disease.

Crystal	pH	Morphology & Color	Normal or Abnormal Disease Association
Amorphous Urates	Acidic	<ul style="list-style-type: none"> •Non-crystalline, no defined size or shape •Colorless, Yellow, Pink, Brown 	Normal
Calcium Oxalate	Acidic to slightly Alkaline	<ul style="list-style-type: none"> •Octahedral (envelope), ovoid, rectangular, dumbbell •Colorless •Birefringent 	Normal
Hippuric Acid	Acidic	<ul style="list-style-type: none"> •Six sided prisms, needles, rhombic plates •Colorless 	Normal

Sodium Urate	Acidic	<ul style="list-style-type: none"> •Thin rectangular sticks •Colorless or Yellow 	Normal
Uric Acid	Acidic	<ul style="list-style-type: none"> •Barrel, rhombic, rosettes, 6-sided •Colorless, Yellow, Brown •Birefringent 	Normal
Amorphous Phosphates	Alkaline	<ul style="list-style-type: none"> •Non-crystalline, no defined size or shape •Colorless, Yellow, White 	Normal
Ammonium Biurate	Alkaline	<ul style="list-style-type: none"> •Round, "Thorny Apple", •Yellow, Brown 	Normal
Calcium Carbonate	Alkaline	<ul style="list-style-type: none"> •Dumbbell, round •Colorless 	Normal
Calcium Phosphate	Alkaline	<ul style="list-style-type: none"> •Wedge, flat plates, rosettes •Colorless 	Normal
Triple Phosphate	Alkaline	<ul style="list-style-type: none"> •Prism shaped, "Coffin lid", triangle •Colorless •Birefringent 	Normal
Bilirubin	Acidic	<ul style="list-style-type: none"> •Needles or round with needle projections (needles often stick to WBC) •Yellow, Orange 	Abnormal Liver disease
Cystine	Acidic	<ul style="list-style-type: none"> •Hexagonal plates •Colorless 	Abnormal Cystinuria

Cholesterol	Acidic	<ul style="list-style-type: none"> •Flat plates with notched corners •Colorless •Birefringent 	Abnormal Nephrotic syndrome
Leucine	Acidic	<ul style="list-style-type: none"> •Round with concentric rings, radial striations on outer edge •Yellow, Brown 	Abnormal Liver disease
Tyrosine	Acidic	<ul style="list-style-type: none"> •Fine needles •Colorless, Yellow 	Abnormal Liver disease
Sulfonamide	Acidic	<ul style="list-style-type: none"> •Needles, “wheat stacks”, sheaves, spheroids •Colorless, Yellow, Light Brown 	Abnormal Medication
Radiographic dye	Acidic	<ul style="list-style-type: none"> •Flat needles or sheaves •Colorless 	Abnormal Radiographic procedure

3.1.A Amorphous

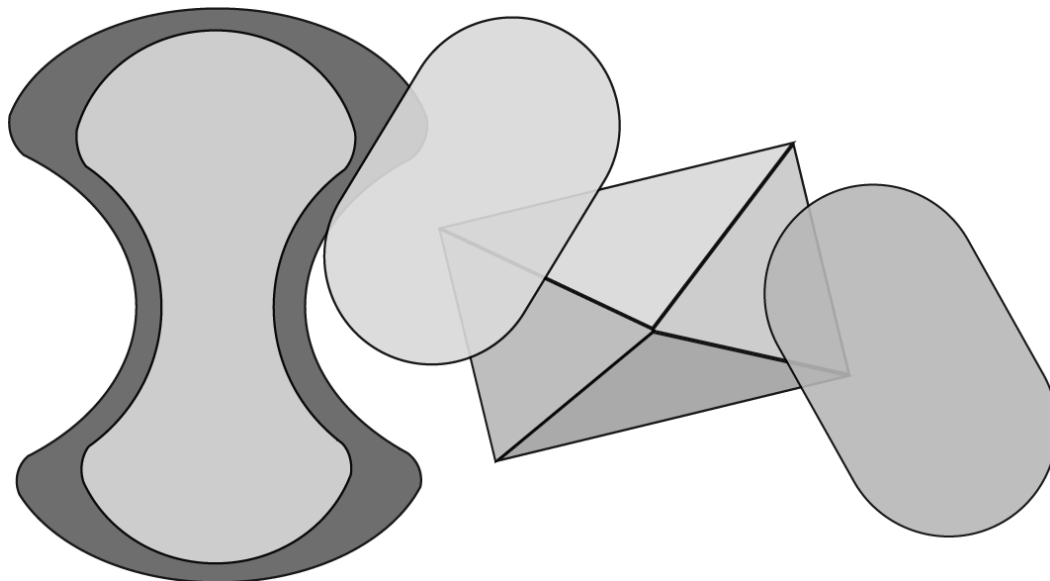
Amorphous 1

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3.1.B Calcium Oxalate



Calcium Oxalate 1

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Calcium Oxalate 2

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Calcium Oxalate 3

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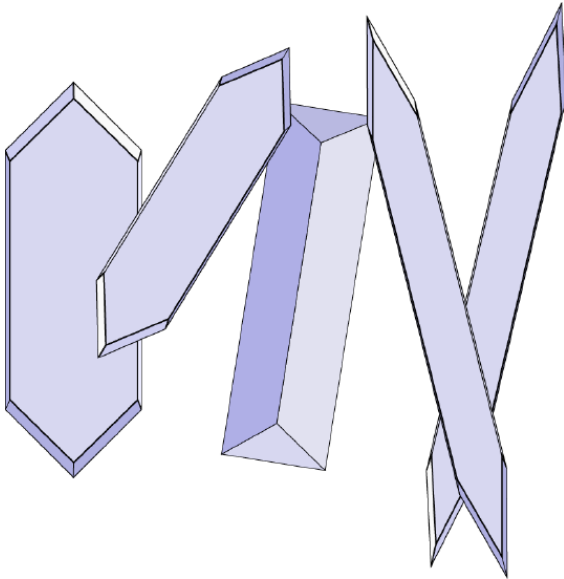
Calcium Oxalate 4

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3.1.C Hippuric Acid



Hippuric acid 1

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3.1.D Sodium Urate

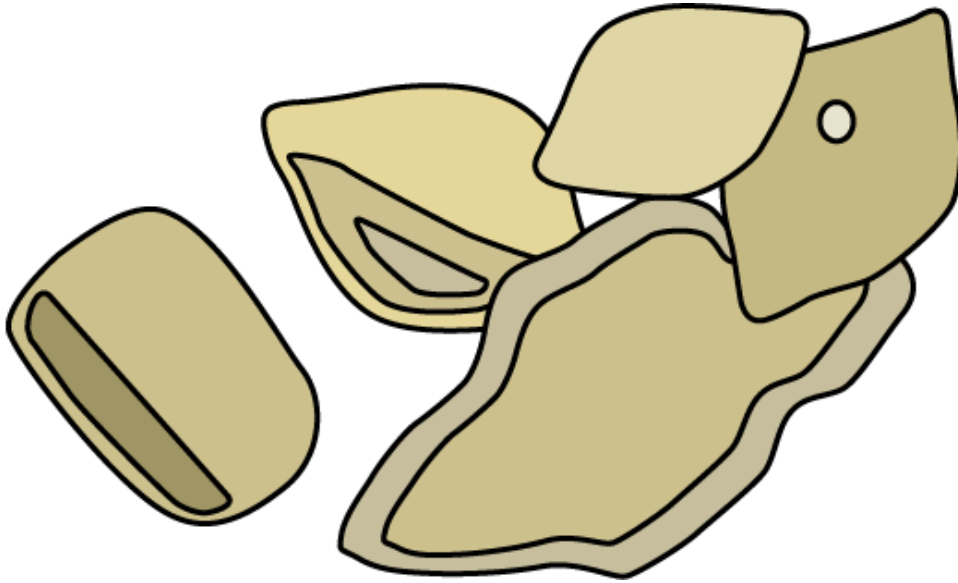
Sodium Urate 1

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3.1.E Uric Acid



Uric Acid 1

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Uric Acid 10x2

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Uric Acid 40x3

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Uric Acid 4

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3.1.F Ammonium Biurate

Ammonium Biurate1

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3.1.G Calcium Carbonate

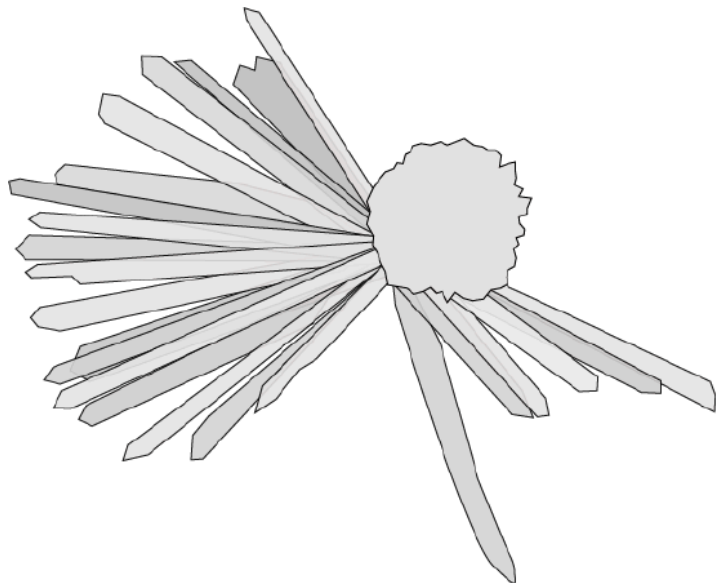
Calcium Carbonate 1

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3.1.H Calcium Phosphate



Calcium Phosphate 1

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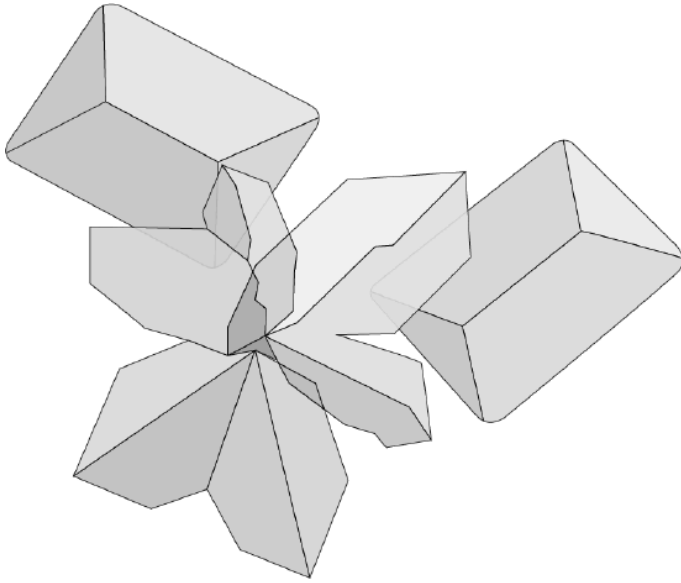
Calcium Phosphate 2

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3.1.I Triple Phosphate



Triple Phosphate 1

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Triple Phosphate 2

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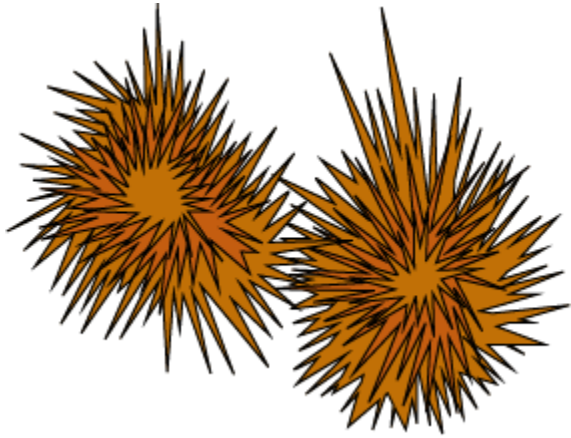
Triple Phosphate 3

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3.1.J Bilirubin



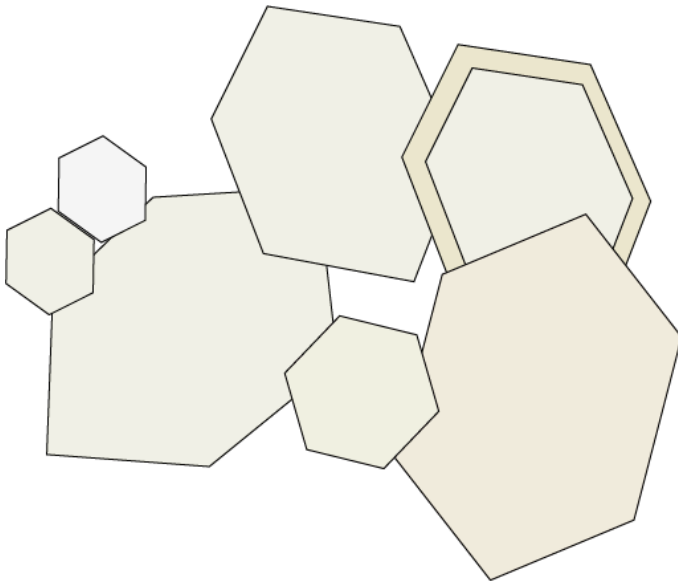
Bilirubin 1

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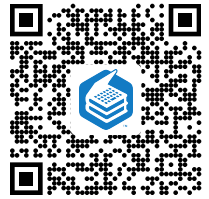
3.1.K Cystine



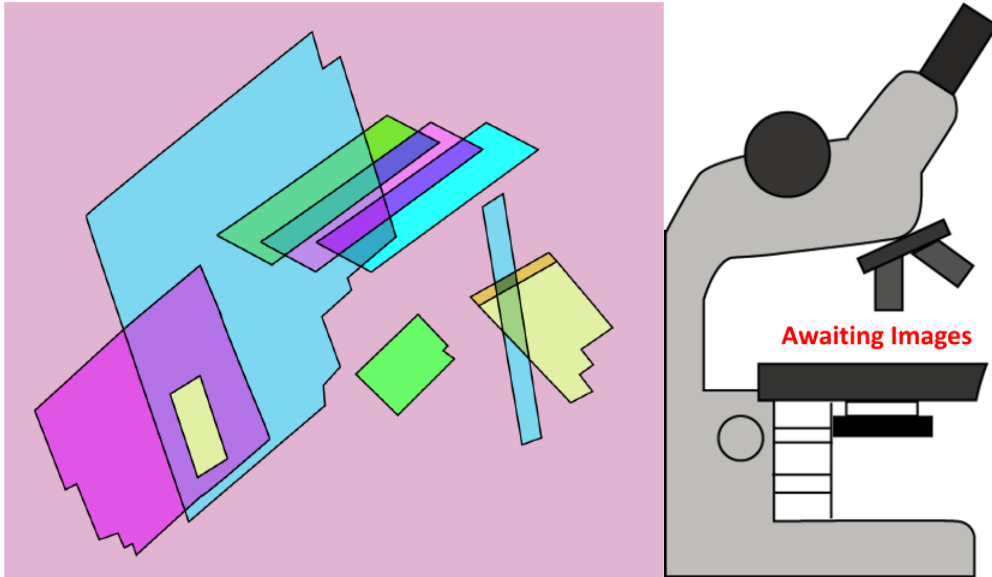
Cystine 1

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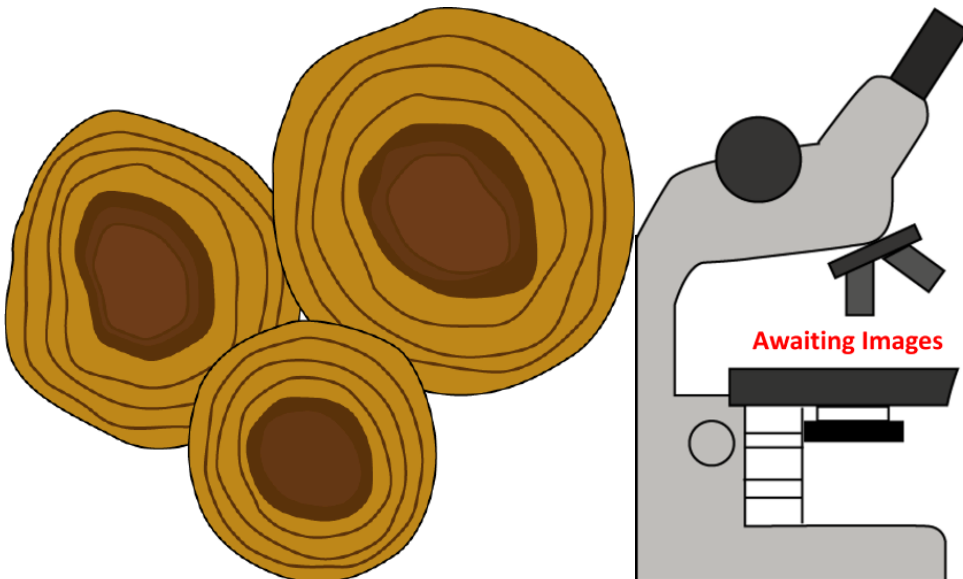
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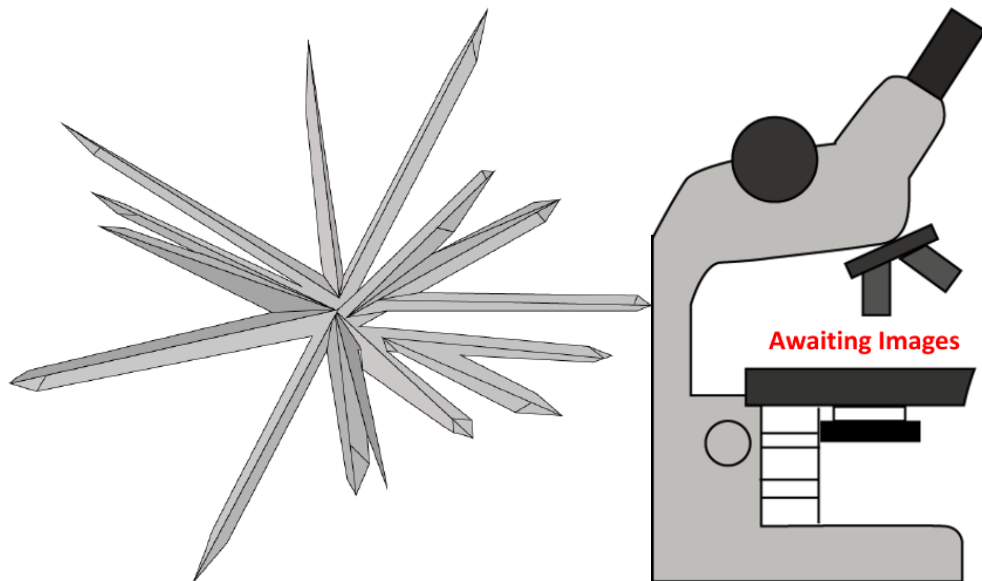
3.1.L Cholesterol



3.1.M Leucine



3.1.N Tyrosine



3.1.O Sulfonamide

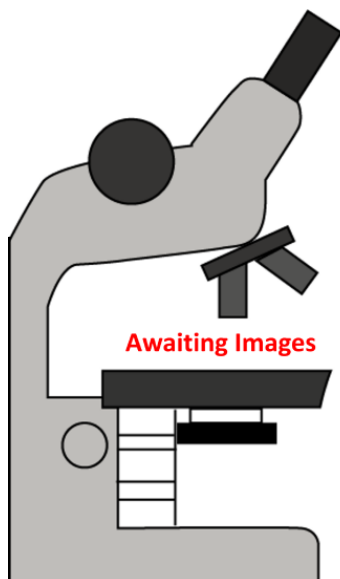
Sulfonamide1

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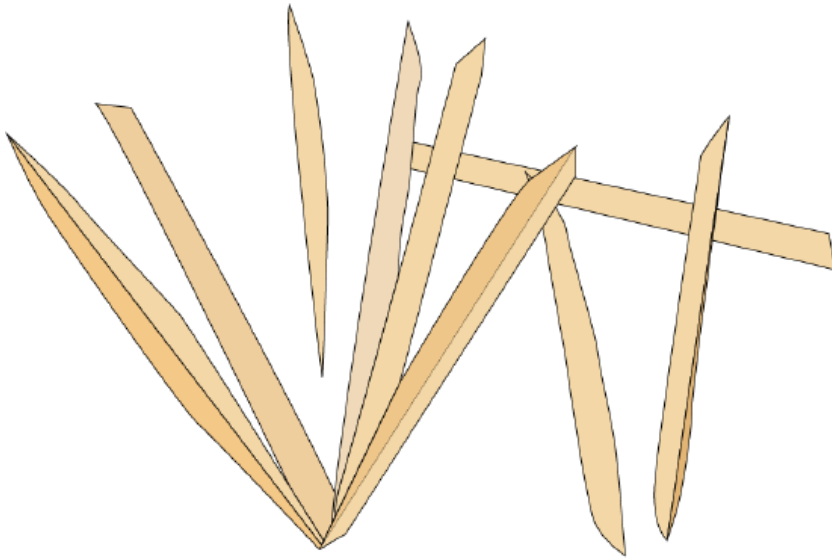
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3.1.P Radiographic Dye



3.1.Q Ampicillin



Amorphous Urates and Phosphates
Sodium Urate

Amorphous Urates and Phosphates

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Sodium Urate

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4. YEAST, PARASITES AND BACTERIA

1. 4.1 Yeast
2. 4.2 Pinworm (*Enterobius vermicularis*)
3. 4.3 Trichomonas
4. 4.4 Bacteria

4.1 Yeast

Morphology: Yeast appear as small round or oval shaped structures, similar in size to RBCs. They are typically more refractile than RBCs. Yeast can be seen in multiple forms including single celled, budding cells (footprint appearance), pseudo-hyphae and branching hyphae.

Disease correlation and clinical significance: Yeast can cause urinary tract infections. Individuals who are immunocompromised or diabetic are more susceptible to yeast related UTIs than the general population. In urine samples from women, the presence of yeast may occur due to contamination from a vaginal yeast infection.

Helpful Hints: Single celled yeast and RBCs look similar in structure. To distinguish between RBCs and yeast, acetic acid (1:1) can be added to urine sediment. RBC will lyse in the presence of acetic acid but yeast will remain intact.

Yeast 1

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Yeast 2

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4.2 Pinworm (*Enterobius vermicularis*)

Morphology: Pinworm eggs are oval shaped with one side slightly flatter than the other. They have a large nucleus and a thick cellular wall. The size of the egg varies but is similar to the size of a squamous cell or larger.

Disease correlation and clinical significance: Pinworm eggs in urine are typically from fecal contamination and suggest an intestinal pinworm infection.

Pinworm 1

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4.3 Trichomonas

Morphology: Trichomonas are similar in size and appearance to WBCs and RTE cells, however trichomonas are slightly pear shaped and have a tail-like flagella.

Disease correlation and clinical significance: Trichomoniasis is a sexually transmitted parasitic disease. Trichomonas in female urine arises due to contamination from vaginal secretions when the female has a *Trichomonas vaginalis* infection.

Helpful Hints: Trichomonads look similar to WBCs and RTE cells, to differentiate look for movement of the flagella.

Trichomonas 1

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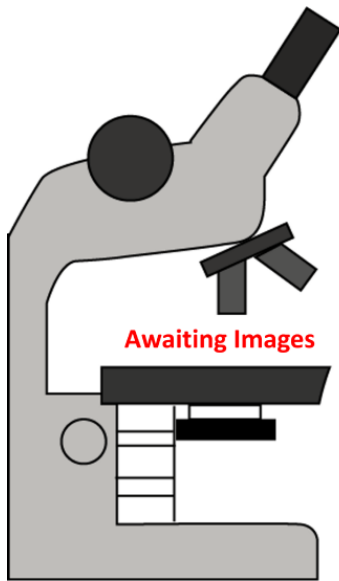


Trichomonas 2

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4.4 Bacteria

Morphology: Bacteria can appear as small round or rod-shaped structures.

Disease correlation and clinical significance: Bacteria are associated with urinary tract infections but can also be normal flora of the outer genitalia. Bacteria associated with a UTI will also show the presence of WBCs in urine and/or be leukocyte esterase positive on the chemical strip test.

Helpful Hints: It is difficult to distinguish bacteria from amorphous crystals. To differentiate, bacteria will exhibit motility whereas amorphous crystals will not.

Bacteria 1

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Yeast

Yeast

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5. Artifacts and Mucus

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5.1 Mucus

Morphology: Thread-like appearance that varies in length. Low refractive index.

Helpful Hint: Typically quantified on 10X but low light is needed due to low refractive index. Can often be misidentified as casts, thus it is important to look for the parallel sides of the cast matrix. More frequently seen in female specimens than male specimens.

Mucus 1

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5.2 Artifacts

Artifacts are contaminants found in urine, typically due to improper collection, contaminated containers or products applied to outer genitalia. The most common artifacts seen are starch (found in baby powders, feminine powders), Fibers (clothing, toilet paper), talc powder, pollen grains and air bubbles. In most labs artifacts are not quantified, but may be noted as "present" on the microscopic evaluation.

5.2.A Talc

Morphology: Clear, flat, irregular sheets of varying sizes.

Helpful Hint: Don't confuse these with Cholesterol crystals. To differentiate, use a polarizer- Cholesterol crystals with polarize but talc will not. Cholesterol crystals also have flat sides with notches on the corners.

Talc 1

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5.2.B Fiber

Morphology: Distinct edges, refractile, long, look similar to casts, some are birefringent

Helpful hint: Fibers are often confused for casts. Typically the edges of the fiber are darker (they have more contrast) than a cast and they are more refractile.

Fiber 1

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5.2.C Starch

Morphology: Slightly round with a center indentation (larger crystals). The indentation looks like a "Y" or like a belly button. Crystals vary in size and are birefringent.

Helpful hint: Starch crystals are birefringent and exhibit a pseudo-maltese cross formation under a polarizer.

Starch 1

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Strasinger, S. K., & Schaub, D. L. M. (2021). *Urinalysis and body fluids*. F.A. Davis Company.

Brunzel, N. A. (2023). *Fundamentals of Urine & Body Fluid Analysis*. Elsevier.

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