BIOLOGY
THROUGH A MICROSCOPE

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CURRICULUM

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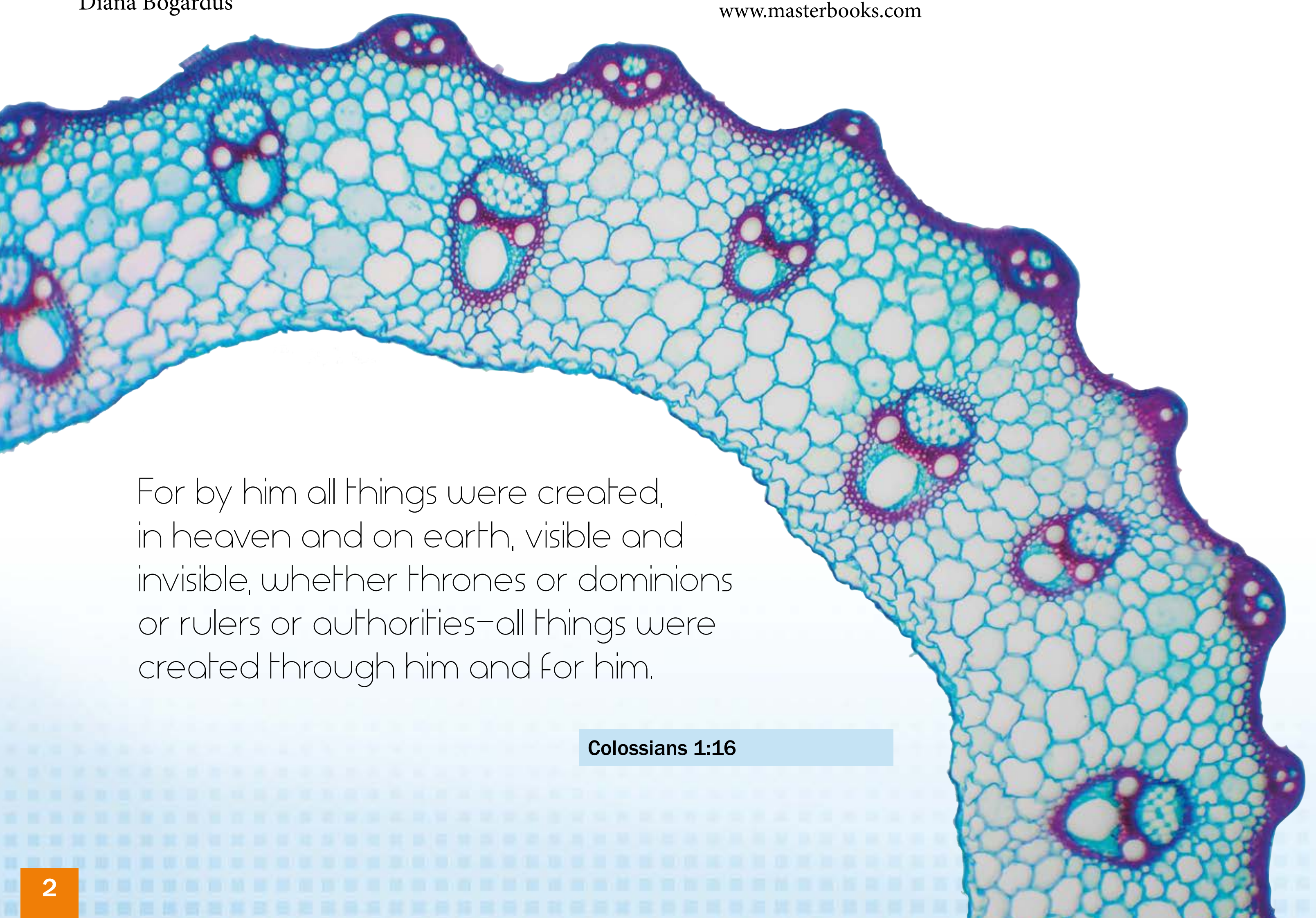
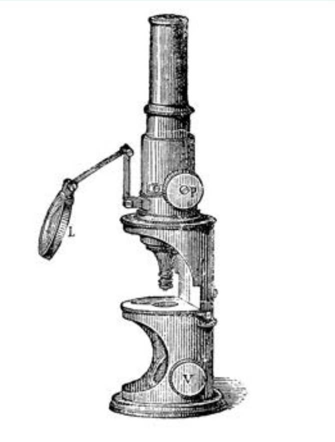
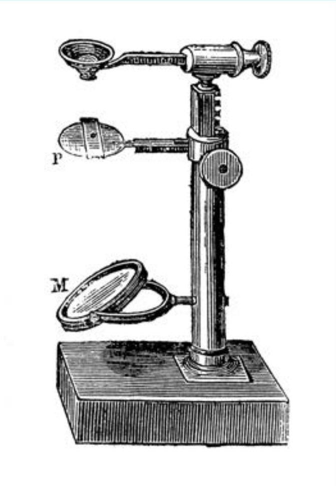


For by him all things were created, in heaven and on earth, visible and invisible, whether thrones or dominions or rulers or authorities—all things were created through him and for him.

Colossians 1:16



Antique microscopes



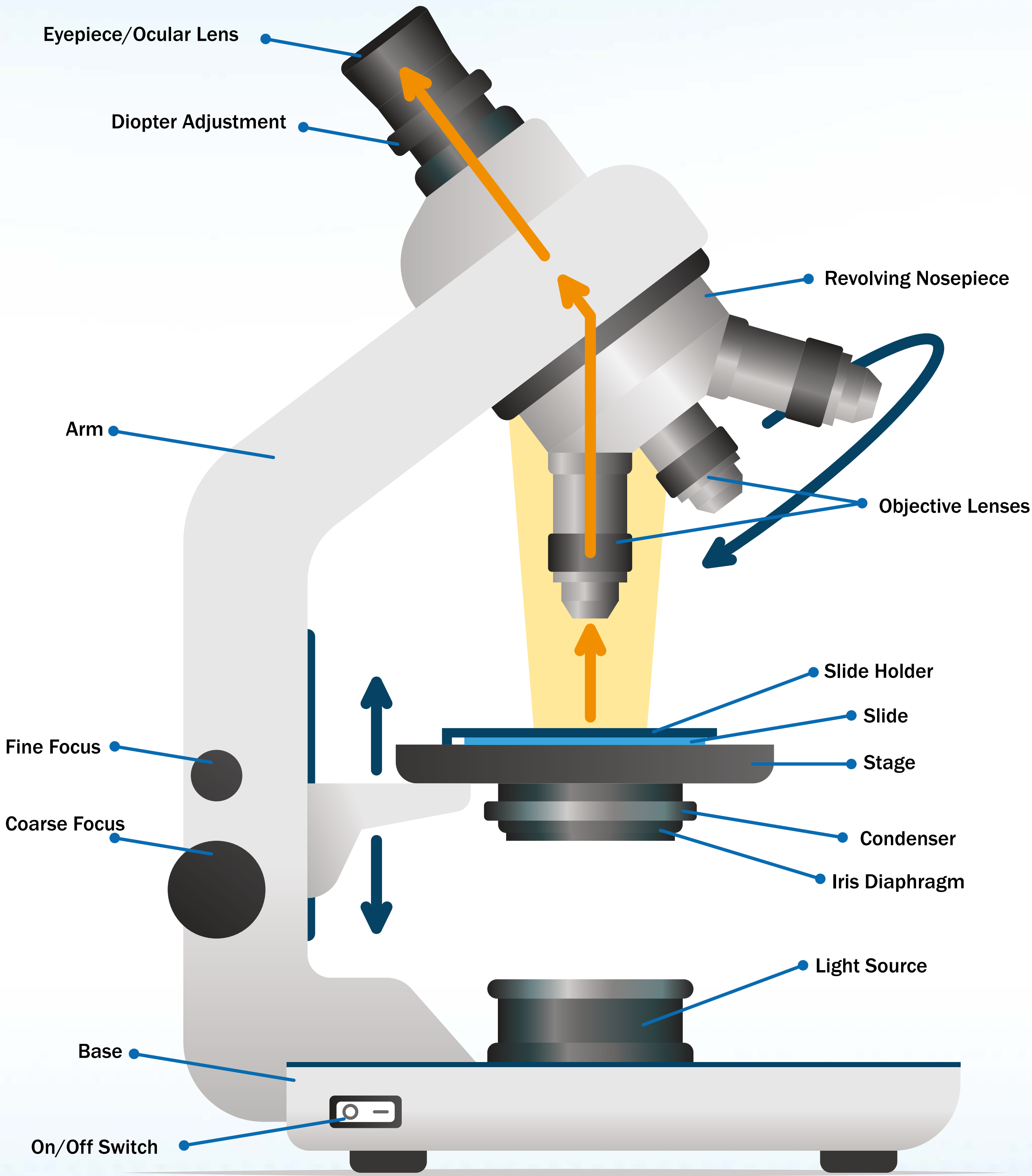
For thousands of years, people have marveled at the world God created, but it wasn't until the invention of the microscope in the 13th century that we would finally see the how detailed and beautiful His unseen creations were.

The first forms of microscope were simple magnifying glasses and eyeglasses. Early compound microscopes are the first that we would recognize as a microscope today, with an objective lens near the specimen being viewed and a separate eyepiece lens. Simple mirrors and separate light sources provided illumination.

By the 20th century, other methods of illuminating the specimen were developed. Köhler illumination is particularly useful because it results in an even illumination of the sample with no visible details of the light source. Advances in optics also allowed for binocular microscopes with two eyepieces and the attachment of cameras.

Currently, specialized microscopes use electrons, scanning probes, fluorescence, and x-rays to produce images far beyond what can normally be seen. Computer colorization of the images helps scientists see fine details as they study them.

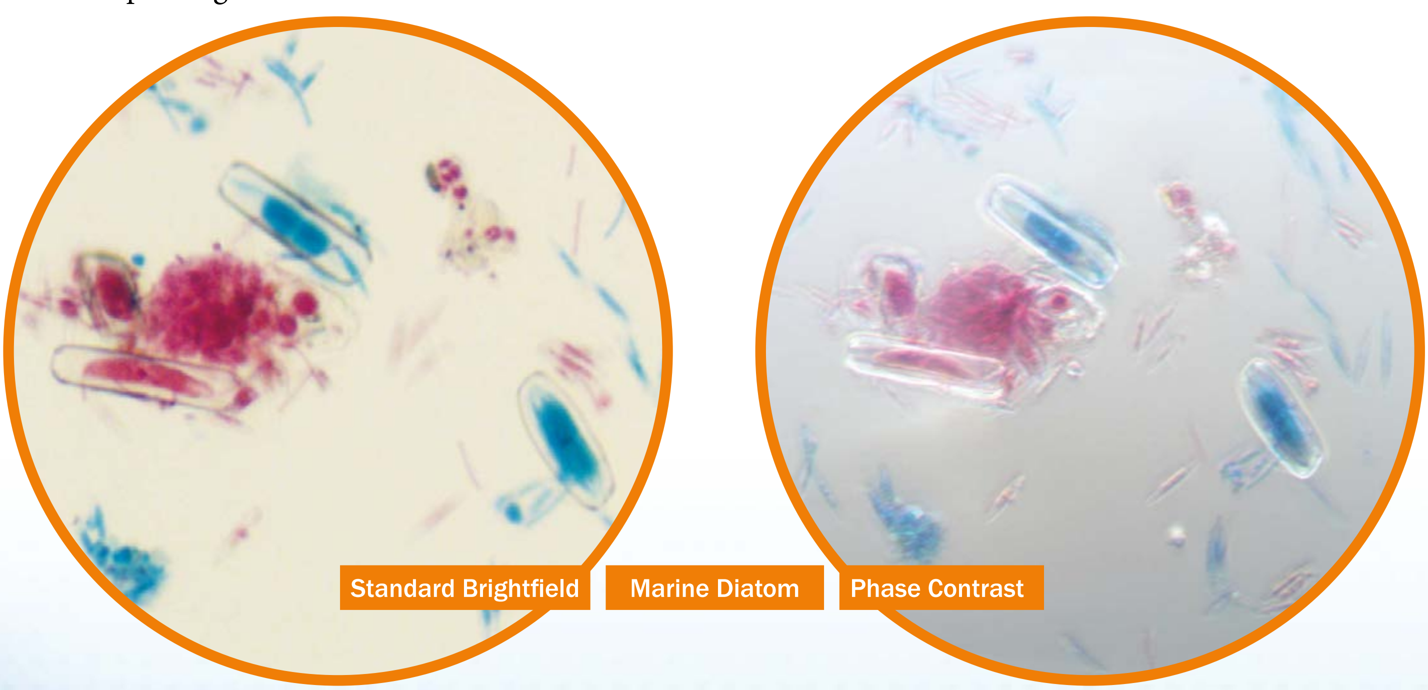
In spite of all the advancements throughout the years, light microscopes are still similar to the original microscopes with light sources, objective lenses, and eyepieces. Most basic microscopes today will share many common parts, as shown below:



Even simple light microscopes have many available options for illuminating specimens depending on the sample. The examples below were taken of the same slide of colored threads at a low magnification (40x).

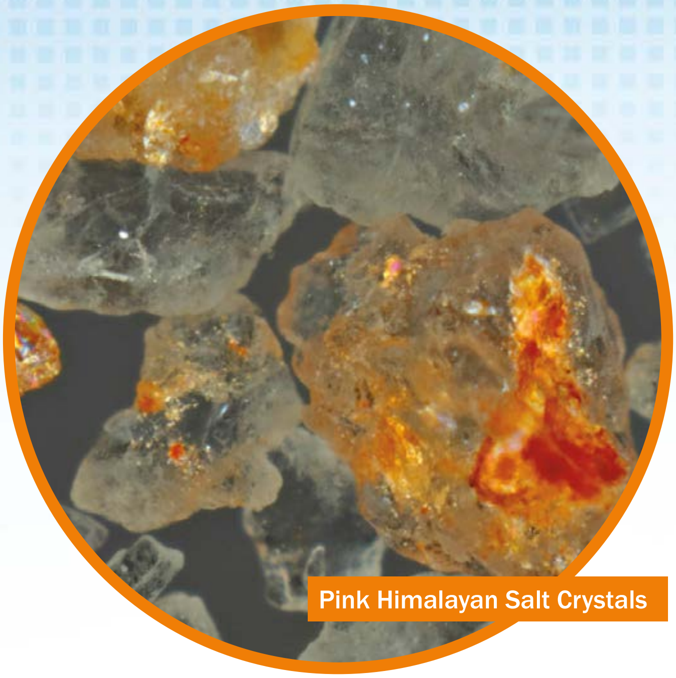
This sample is using a typical brightfield backlit setup with the lamp underneath the specimen and no special attachments. Thicker samples might be illuminated from the top, but most thin slices or small specimens are adequately lit using a light source under the microscope's stage.

These samples were illuminated using phase contrast and darkfield techniques, which involve lighting the sample from the edges with specific patterns of light in order to highlight details that are not clearly visible. These techniques require some additional attachments or filters on the condenser, but are vital for the study of samples with subtle details or minimal contrast against the containing **medium**. Marine diatoms are an excellent example of this, with transparent **cell walls** nearly indistinguishable from the water they live in.



The images of marine diatoms above illustrate the difference between brightfield and phase contrast microscopy. The samples are shown at equivalent sizes: the first image is a standard brightfield image, while the second is using phase contrast to highlight the details of the diatoms' cell walls.

Salt Crystals



Pink Himalayan Salt Crystals

Himalayan Rock Salt

Kala Namak (India)

Alaea Red Salt (Hawaii)

Gerand Salt

Herb Salt

Black Pearl Salt (Hawaii)

Himalayan Salt

Common Salt

Atlantic Sea Salt

The salts shown above are all comprised of sodium chloride with variations in added compounds, both naturally occurring and added during processing. The difference in coloration is easily visible without assistance, but a microscope is necessary to study differences in crystal structures caused by the rate of formation and analyze distinctions like those between salt crystals that appear white because of mineral deposits and ones that are full of tiny air bubbles.


Brown Zircon


Blue Zircon

These microscopy techniques are used for studying other crystals as well. Many minerals form crystalline structures, from gemstones to salts.

A microscope is used for studying a crystal's optical properties and understanding its growth patterns, locating defects and identifying impurities. These imperfections frequently result in color variations, like over 80 minerals and trace elements contributing to Pink Himalayan Salt's distinctive color.

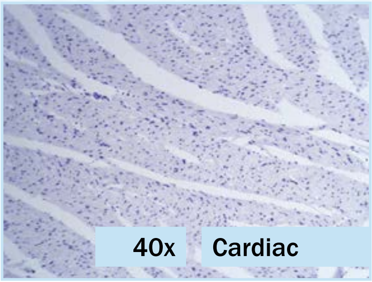
In cases where the color is caused by damaged crystalline structure, it can sometimes be altered by heating the crystal or removed when faceting it. An example of this is when natural brown zircon is heat treated to alter its color and then cut to remove surface defects.

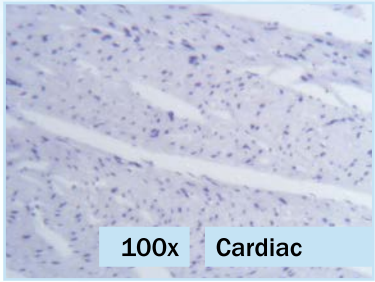

Faceted Blue Zircon

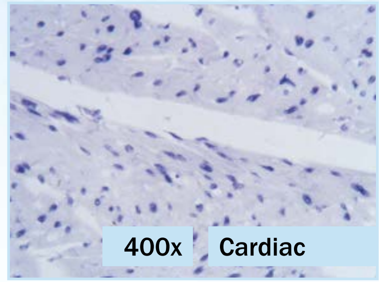
KINGDOM	SAMPLES	

ANIMALS

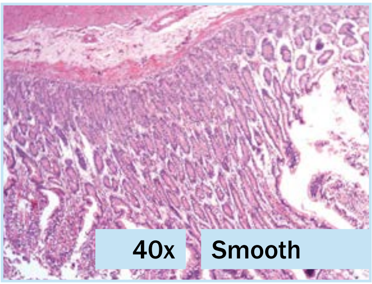
Animals have three different types of muscle: cardiac, smooth, and skeletal. Samples of these are shown below in various magnifications.

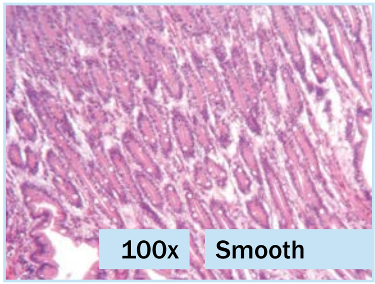


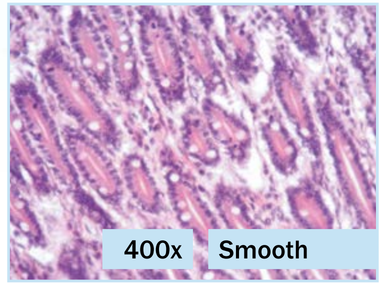




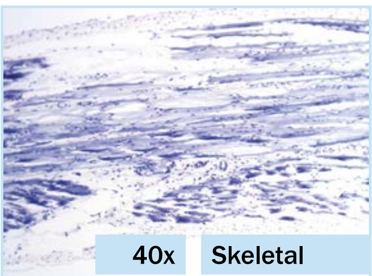
Cardiac muscle is a **striated** involuntary muscle type found in the walls of the heart.

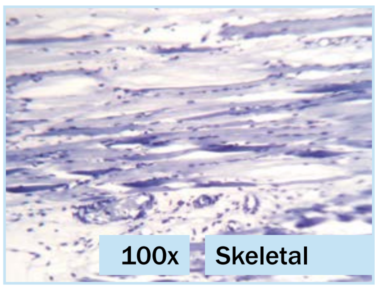


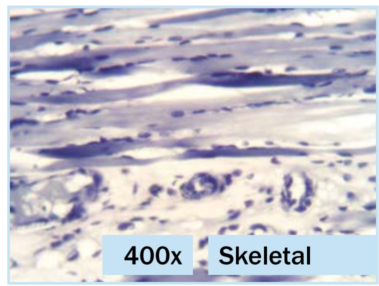




Smooth muscle fibers are also involuntary, and are found in the walls of internal organs other than the heart.

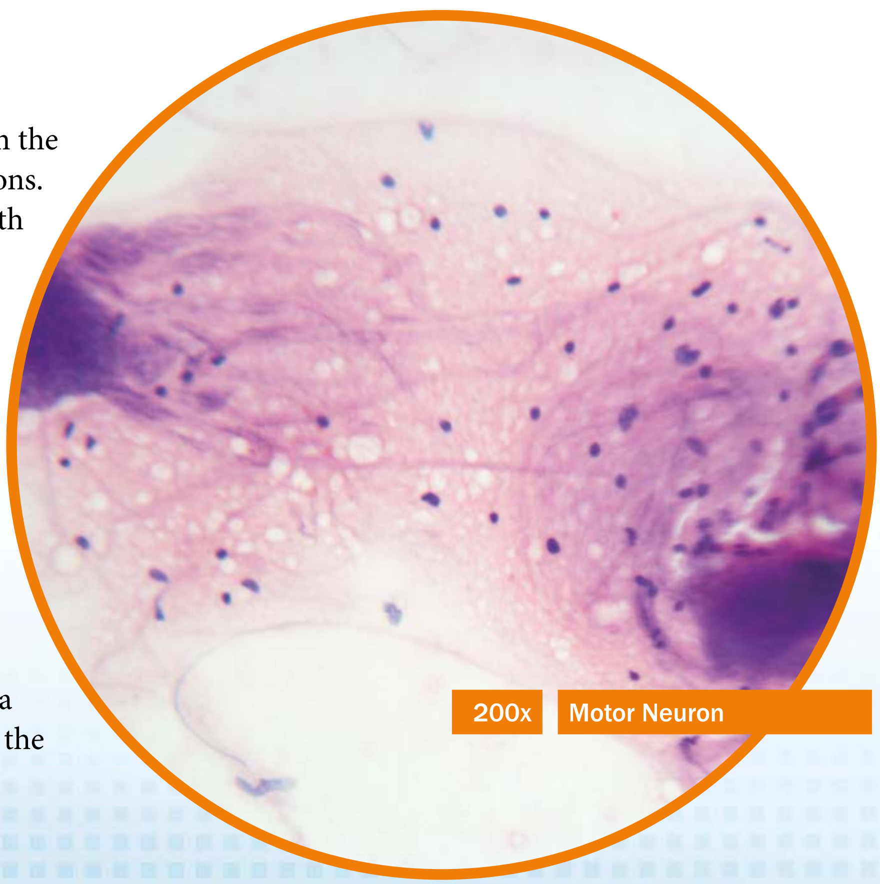






Skeletal muscle fibers are striated voluntary muscles. They have banding similar to cardiac muscle visible in the individual fibers.

Muscles of all types receive signals from the brain via nerve cells called motor neurons. These are too small to be easily seen with without magnification, but are easily visible under a microscope. Motor neurons are divided into two groups: upper motor neurons that connect directly to the brain and transmit signals to the spinal cord and lower motor neurons that connect the spinal cord to individual muscle fibers. Both upper and lower motor neurons consist of several dendrites to receive signals from other neurons and propagate them into the cell body, and a single axon, the nerve fiber that carries the received signal through the body.

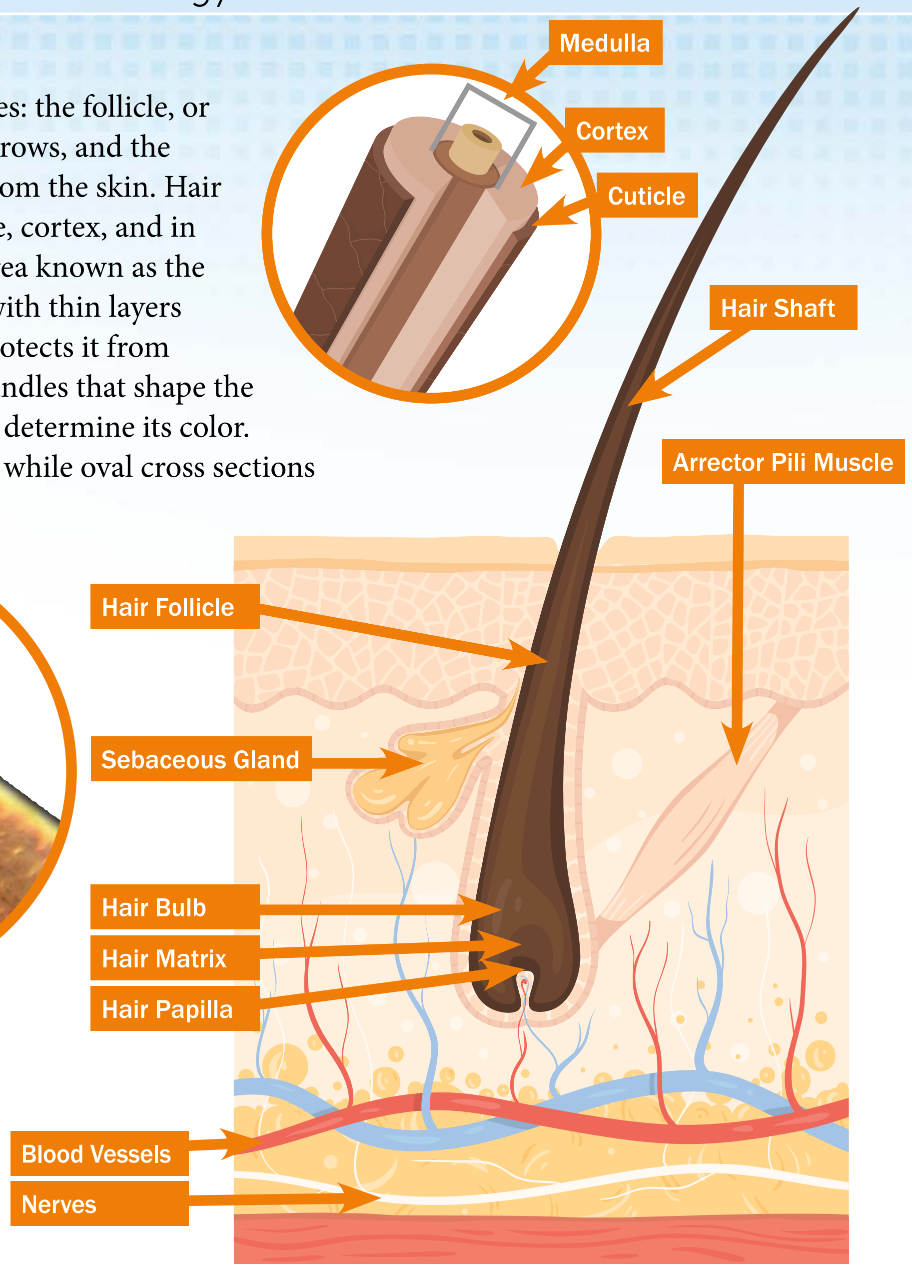


Covering the muscles, nerves, and other internal organs is the integumentary system, comprising skin, hair, scales, feathers, and nails. This system is a body's first line of defense against infection and physical damage. While skin itself is easily visible on most animals, finer structural details can only be studied under magnification, such as the hair follicles below. Other structures like fish scales and individual hairs are also easier to study under magnification.

Skin with Hair Follicle

Parrotfish Scales

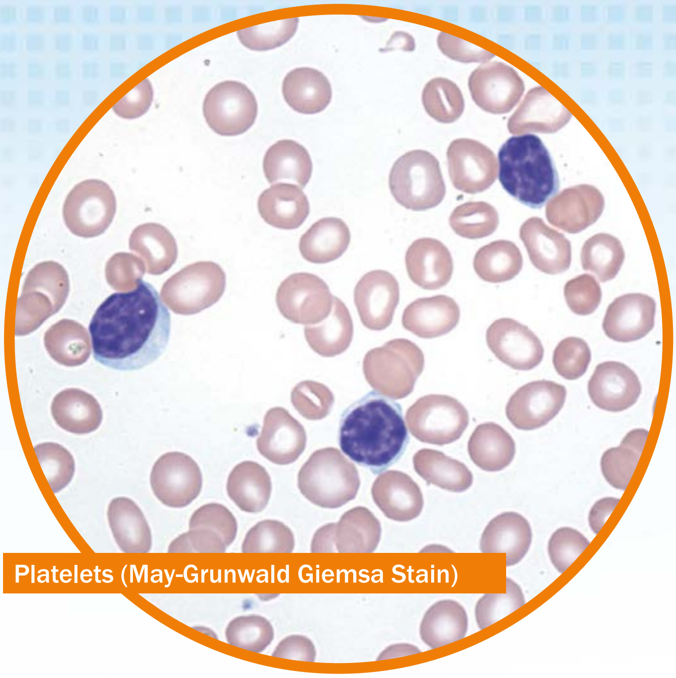
Hair is divided into two major structures: the follicle, or bulb, which is the portion of hair that grows, and the shaft, or visible strand that protrudes from the skin. Hair shafts are divided into zones: the cuticle, cortex, and in thicker hairs an unstructured central area known as the medulla. The cuticle encloses the hair with thin layers of cells overlapping like shingles and protects it from damage. The cortex contains keratin bundles that shape the type of hair and melanin pigments that determine its color. Rounder cortices form straighter hairs, while oval cross sections form wavier or curly hairs.



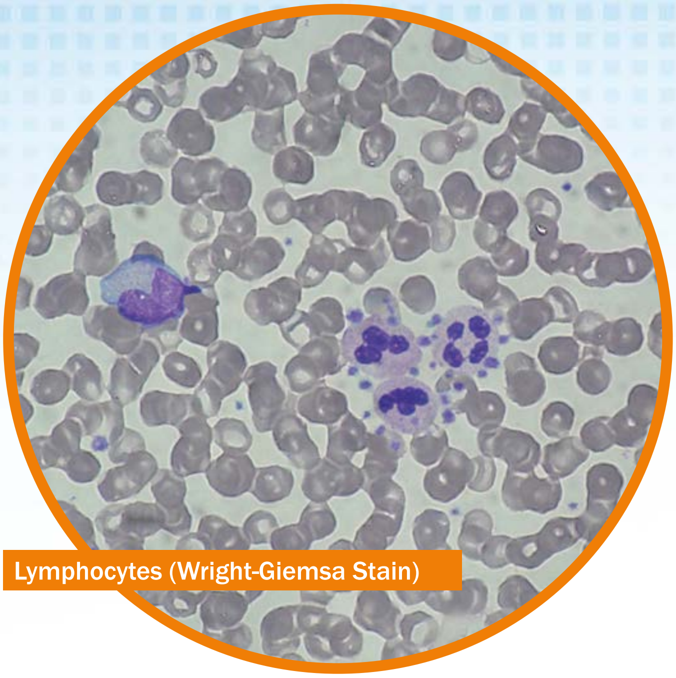

Human Hairs with Follicles

Hair provides many animals with protection from both UV radiation in sunlight and extremes of temperature. The arrector pili muscle is a tiny involuntary muscle that attaches to each hair follicle individually, causing the hair to rise up, increasing trapped air among the erect hairs, which improves the insulating ability of fur. In some animals, like porcupines, the spines are special hairs which also stand erect and form a defensive barrier.


125x Porcupine Quill (SEM)



Platelets (May-Grunwald Giemsa Stain)

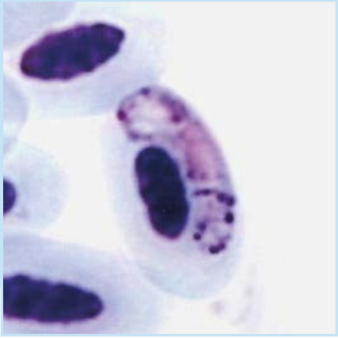


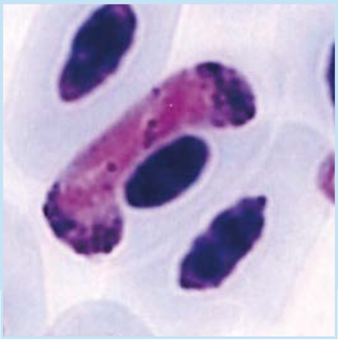
Lymphocytes (Wright-Giemsa Stain)

All members of the animal kingdom use blood for oxygen and nutrient transport throughout their bodies. One of the challenges of studying blood through a microscope is how to differentiate different cells or even organisms in the blood. An auxiliary technique for microscopic observation developed to help accomplish this is called staining.

Many different staining compounds exist with various behaviors, but all of them rely on the principle that certain cells or compounds will retain a specific dye better than other cells. This means that a staining compound that is absorbed by a **cell wall** will mark bacteria with a thick, exposed cell wall, but not bacteria with a thinner cell wall and outer membrane. This is referred to as Gram staining, and can identify whether a particular bacteria sample is likely to be generally antibiotic resistant.

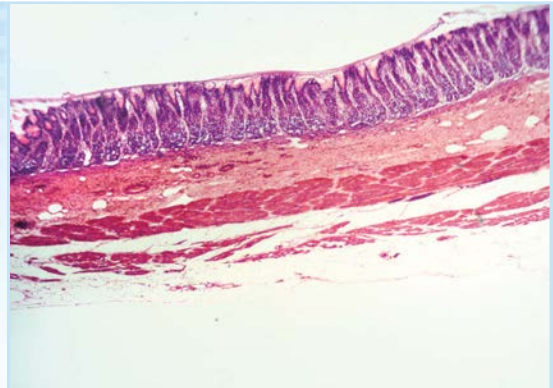
Various Stained & Unstained Samples

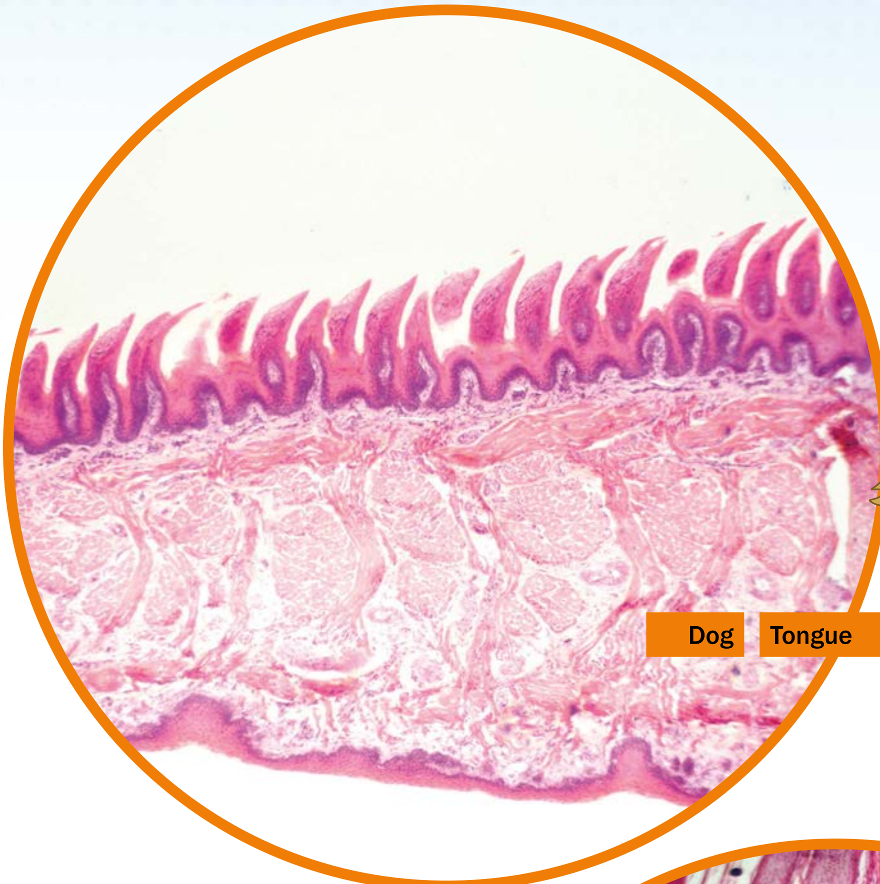


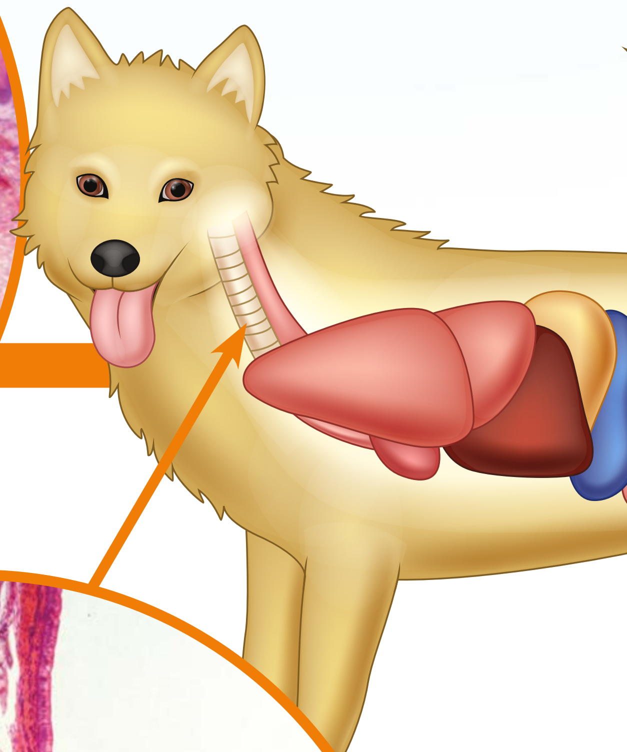


In blood samples, blends like a combination of the Wright and Giemsa stains are often used for differentiating cell types in a complete blood count, or the number of red and white blood cells, platelets, and their density in the blood. With this stain, red blood cells will appear pink, platelets a lighter pink and white blood cells will be various shades of blue. Other stains are used to identify foreign organisms in the blood such as bacteria and **parasites**. Some examples of these stains and the differences in how samples appear after staining are shown above.

Taste buds play an important role in what we decide to eat, and dogs have them too: although they only have about 1/6th as many of them as in a human being. Taste buds are located on raised protrusions on the tongue known as papillae.


Stomach (Cardiac Region)

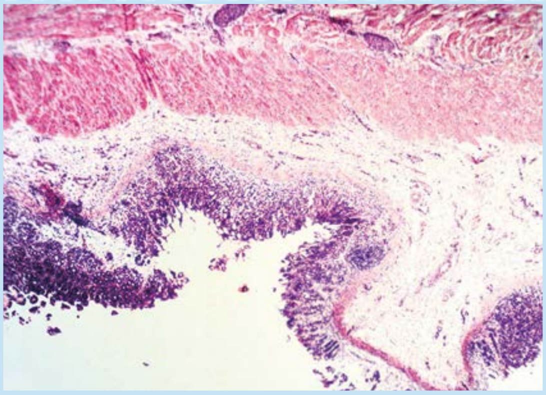




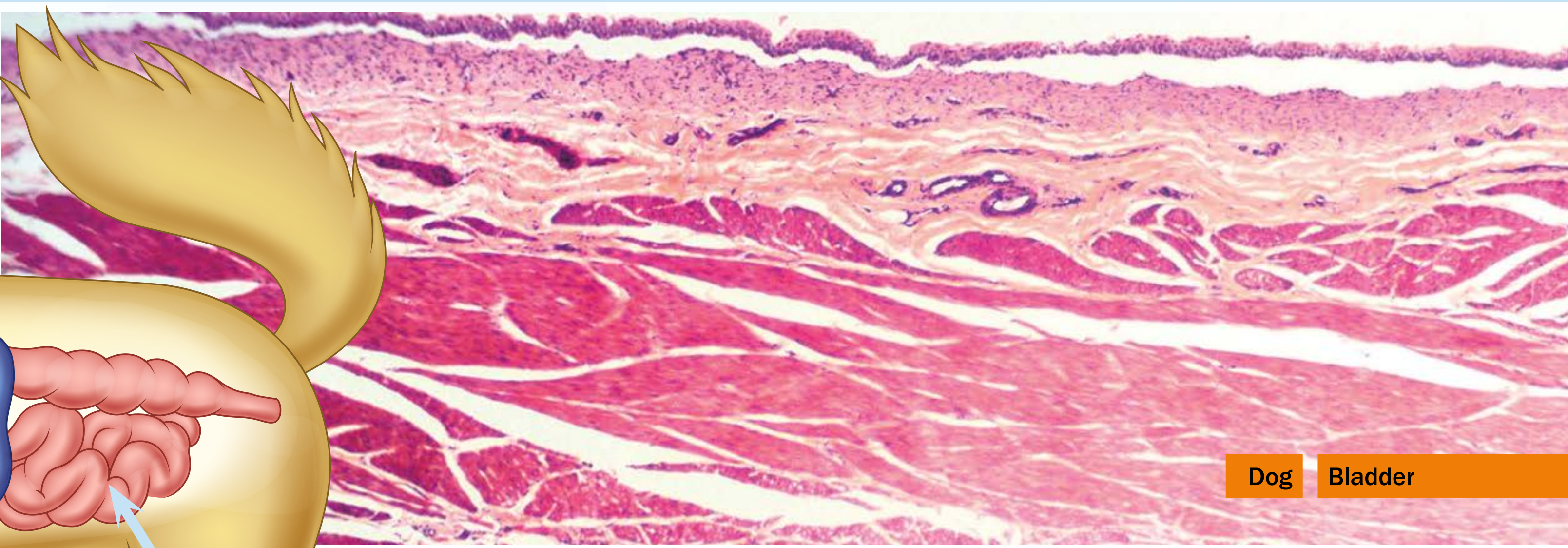
Connecting the mouth to the stomach is the esophagus, a tube with layers of involuntary smooth and **striated** muscle fibers and other tissues. Running parallel to the esophagus is the trachea, which consists of a thin, smooth cartilaginous tube with a number of rings made of thicker cartilage to keep it from collapsing. The cells lining the interior produce mucus to trap foreign particles and are ciliated to move the particles back up the trachea and away from the lungs.

The stomach is divided into three major areas with differing cell structures depending on their functions:

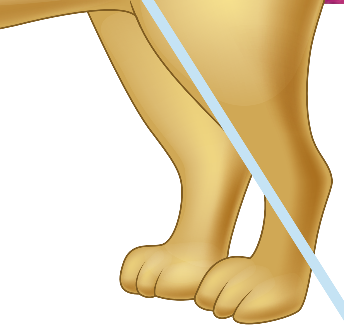
1. The cardiac region, which contains mucus secreting glands and is next to the esophagus.
2. The fundus region, where most of the mechanical action of breaking down food takes place.
3. The pyloric region, which secretes more mucus and the hormone gastrin, which aids digestion by increasing gastric contractions known as motility.



Stomach (Pyloric Region)



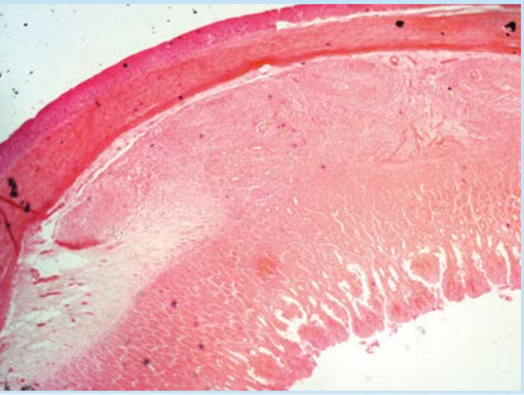
Dog Bladder



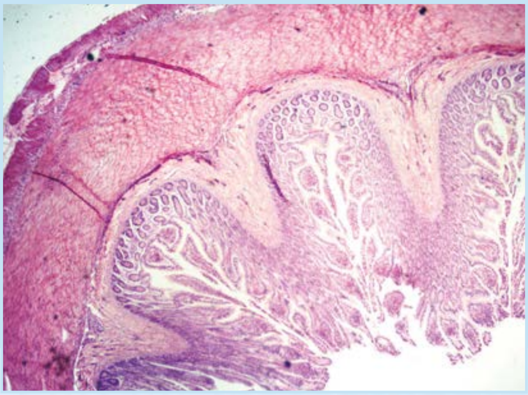
There are also three sections in the small intestine characterized by their functions and structure:

1. The duodenum is immediately after the stomach and is where most chemical digestion occurs. Very little nutrients are absorbed in this area.
2. The jejunum has much higher surface area with folds covered in small projections called villi. These aid in the absorption of carbohydrates and proteins.
3. The ilium is the final and usually longest portion. Here is where other vitamins, salts, and any remaining nutrients are absorbed prior to waste products being collected in the large intestine. There are still a large number of villi in this portion of the intestine.

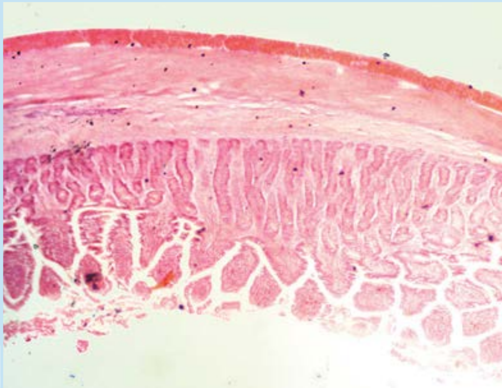
Duodenum

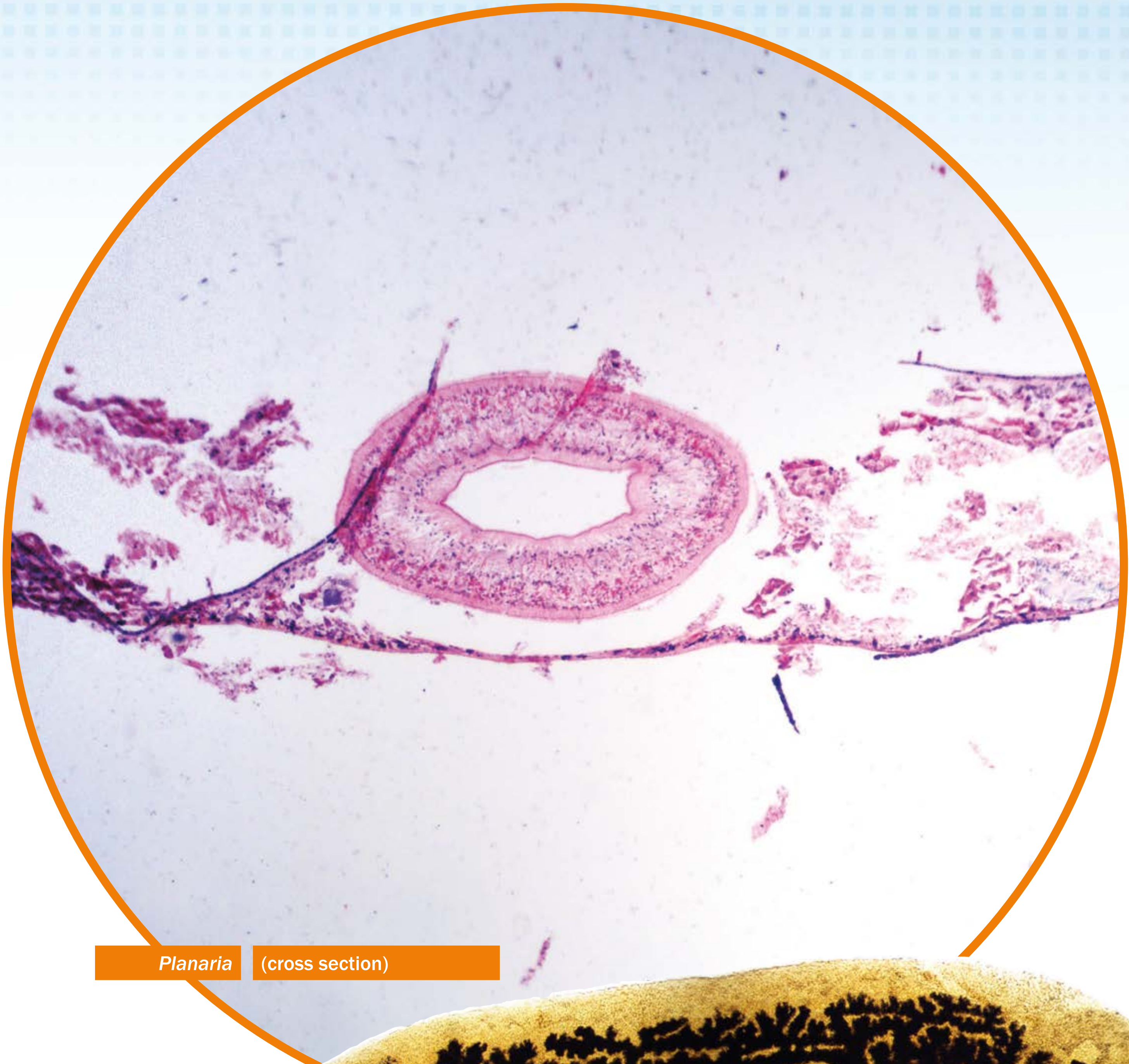


Jejunum



Ilium





Planaria (cross section)

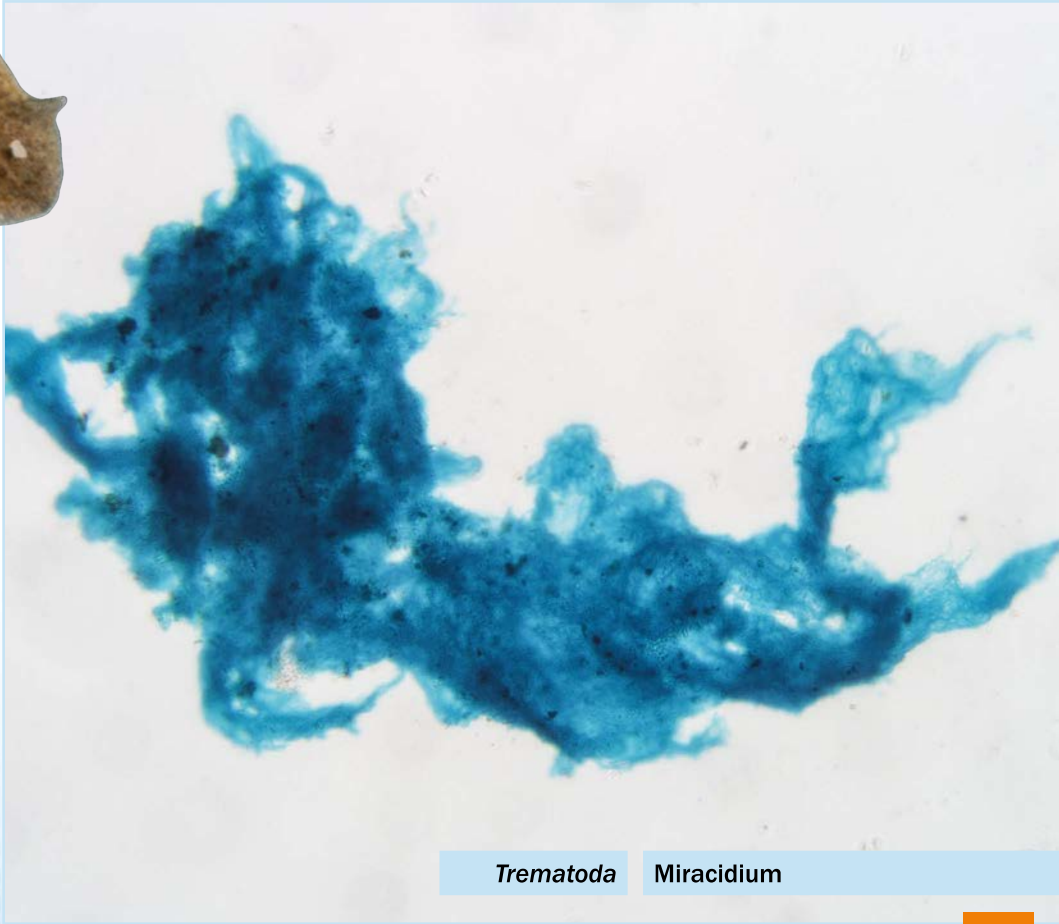
The term **flatworm** encompasses a wide variety of simple, bilaterally symmetrical invertebrates. **Free-living** flatworms such as planaria do not require a host and are generally predatory: feeding on smaller organisms such as mosquito **larvae**.

Other species fall under classifications such as trematoda and cercomeromorpha, which are **parasitic** organisms more commonly known as flukes and tapeworms.

Flukes have a very complex life cycle, infecting multiple different hosts during their parasitic lifecycle. Beginning from an egg, the young fluke hatches into a larval form known as a **miracidium**. If the egg hasn't been eaten by a suitable host organism before hatching, the miracidium must quickly find a host or it will starve before entering the next phases of life. These phases depend on the species, but include a variety of intermediate forms such as **sporocysts**, **rediae**, and **cercariae** before transforming into the adult form.

Blood Fluke | Eggs

Most trematodes require two hosts throughout their life cycle: typically the intermediate host is an invertebrate like a mollusc, and hosts the flatworm throughout the larval stages. The majority of adult forms are **hermaphroditic** and prefer vertebrate hosts where they reproduce sexually, although there are species of flatworms that grow to maturity in the initial host.



Trematoda | Miracidium

Frog Egg | Early Division (Cleavage)

Frog embryos start as a single-celled egg, but split into many smaller cells fairly rapidly through holoblastic cleavage (a process where the cell divides completely into smaller cells without increasing in mass). This process results in an embryo known as a morula, consisting of 16 to 64 cells.

Frog Egg | Blastula Period

By the 128-cell stage, the cells have formed a sphere with a defined hollow, or blastocoel, in the middle. This form is considered a blastula, and separates the cells so they can differentiate into different types.

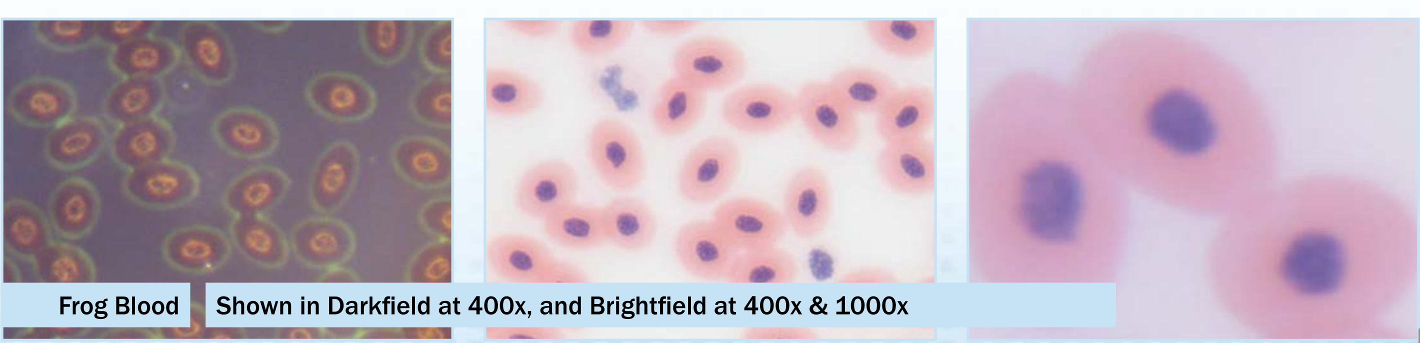
Frog Egg | Early Gastrulation

As the embryo continues to grow, the blastula folds in on itself in a process called gastrulation, forming several layers of cells in the process: the endoderm, ectoderm, and mesoderm. The endoderm will become the nervous system and skin, while the ectoderm forms muscle, connective tissue, and some internal organs. The mesoderm forms digestive organs, lungs, and other internal organs.

The development of the frog continues for 12 weeks, growing from a tadpole through the two and four-leg stages into a froglet with a stub of a tail. Finally, after a total of 16 weeks, the embryo has grown into a mature, tailless amphibian that is ready to reproduce.

Frog Skin 1000x

Frog blood is very similar to most other vertebrates' blood: it still carries oxygen in the hemoglobin molecule and has a "filled-in-donut" shape. Other creatures have a variety of oxygen-carrying molecules such as haemocyanin, haemorythrin, and chlorocruorin that make their blood different colors. Green blood isn't limited to science fiction!



Frog Blood Shown in Darkfield at 400x, and Brightfield at 400x & 1000x