BIO 004 · HUMAN ANATOMY · SOLANO COMMUNITY COLLEGE

Week 4 Course Notes.

Muscles · Lymphatic · Blood

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BIO 004 · WEEK 4

Contents

Muscle Structure & Sarcomeres

Muscle Structure and Sarcomeres

A reference for the muscle structure video and lab. This page covers the structure of a skeletal muscle from its connective tissue coverings, down through the muscle fiber, to the sarcomere and its myofilaments. The contraction mechanism belongs to physiology and is not covered here.

BY THE END

1. Name the connective tissue coverings of a skeletal muscle and trace how they connect to the tendon.
2. Order the levels of muscle organization, from the whole muscle down to the myofilament.
3. Identify the parts of a muscle fiber, including the T tubules, sarcoplasmic reticulum, and triad.
4. Diagram a sarcomere, name its bands, lines, and zones, and state which filaments lie in each.

Skeletal Muscle, an Overview

A skeletal muscle is an organ. It is built of muscle tissue plus connective tissue, blood vessels, and nerves, and it is wrapped, bundled, and anchored at every level of its structure.

Skeletal muscle	a voluntary, striated muscle organ, usually attached to bone, that produces movement when it contracts
Muscle fiber	a single skeletal muscle cell, long and cylindrical, with many nuclei
Origin	the attachment of a muscle to the more stationary bone
Insertion	the attachment of a muscle to the more movable bone, the bone that is pulled toward the origin
Belly	the thick, fleshy middle region of the muscle between its attachments

Attachments and Action

A muscle crosses at least one joint and attaches to the articulating bones. When it contracts, one bone stays put and the other moves.

Origin	the tendon's attachment to the stationary bone, usually the proximal one
Insertion	the tendon's attachment to the movable bone, usually the distal one, pulled toward the origin
Action	the movement the muscle produces when it contracts

How Muscles Work Together

Skeletal muscles are arranged in opposing pairs across a joint, and each contraction has muscles playing different roles.

Agonist (prime mover)	the muscle that contracts to produce the action
Antagonist	the opposing muscle that stretches and yields to the prime mover
Synergist	a muscle that aids the action or prevents unwanted movement
Fixator	a muscle that stabilizes the origin so the prime mover acts efficiently
Compartment	a group of muscles, vessels, and nerves with a common function, such as the flexor and extensor compartments

How Skeletal Muscles Are Named

A muscle's name usually encodes one or more of these features. Learn the clues and the name tells you the muscle.

NAMING CLUE	EXAMPLES IN THE NAME
Direction of fibers	rectus, transverse, oblique
Size	maximus, minimus, longus, brevis, vastus
Shape	deltoid, trapezius, serratus, rhomboid, orbicularis
Action	flexor, extensor, abductor, adductor, levator, pronator, supinator
Number of origins	biceps, triceps, quadriceps

NAMING CLUE	EXAMPLES IN THE NAME
Location	temporalis, over the temporal bone
Origin and insertion	sternocleidomastoid, sternum and clavicle to the mastoid process

The Three Muscle Tissue Types

All three are muscle, but their structure differs. Compare them by location, appearance, control, and cell features.

TYPE	LOCATION	STRIATIONS AND CONTROL	CELL FEATURES
Skeletal	attached to the skeleton	striated, voluntary	long cylindrical fibers, many nuclei pushed to the edge
Cardiac	the heart wall	striated, involuntary	branching fibers, one central nucleus, joined by intercalated discs (desmosomes for adhesion, gap junctions for electrical coupling)
Smooth	walls of hollow organs and vessels	non-striated, involuntary	spindle-shaped cells, one central nucleus

Connective Tissue Coverings

Three connective tissue sheaths wrap the muscle at three scales. They are continuous with each other and with the tendon, so a fiber's pull is carried all the way to the bone. Compare the three sheaths.

SHEATH	WHAT IT WRAPS	TISSUE
Epimysium	the entire muscle, the outermost layer	dense irregular connective tissue
Perimysium	each fascicle, a bundle of muscle fibers	dense irregular connective tissue
Endomysium	each individual muscle fiber	a fine sheath of areolar connective tissue with reticular fibers

Superficial fascia	the subcutaneous layer of areolar and adipose tissue between the skin and the muscles
Deep fascia	a sheet of dense connective tissue that wraps muscles, separates them, and binds those with a common action into functional groups

Tendon	a cord of dense regular connective tissue, the merged continuation of all three sheaths, that attaches a muscle to bone
Aponeurosis	a broad, flat sheet of tendon-like connective tissue, an attachment used where a muscle is wide

Levels of Organization

A skeletal muscle is a set of structures nested inside one another. Follow them in order, from the whole organ down to the protein strands.

1. **Muscle** the whole organ, wrapped in epimysium
2. **Fascicle** a visible bundle of muscle fibers, wrapped in perimysium
3. **Muscle fiber** a single muscle cell, wrapped in endomysium
4. **Myofibril** a long contractile rod running the length of the fiber; hundreds to thousands fill each fiber
5. **Myofilament** the thick and thin protein strands within a myofibril; their ordered overlap forms the sarcomere

The Muscle Fiber

The muscle fiber is the muscle cell. Its parts carry the names of ordinary cell structures with the prefix sarco, from the Greek for flesh.

Sarcolemma	the plasma membrane of the muscle fiber
Sarcoplasm	the cytoplasm of the muscle fiber
Myonuclei	the many nuclei of the fiber, flattened against the inner sarcolemma; a muscle fiber is multinucleated

Myofibrils	the contractile rods that fill most of the sarcoplasm
Transverse (T) tubules	narrow tunnels of the sarcolemma that dive inward, carrying the surface signal deep into the fiber

Sarcoplasmic reticulum	the smooth endoplasmic reticulum of the muscle fiber, a network of tubules wrapping each myofibril, it stores calcium ions
Terminal cisternae	the enlarged end sacs of the sarcoplasmic reticulum, set on either side of a T tubule
Triad	the structural unit of one T tubule flanked by two terminal cisternae
Mitochondria	packed in rows between the myofibrils, they supply the ATP that contraction demands
Myoglobin	a red, oxygen-binding pigment in the sarcoplasm that stores oxygen and gives muscle its color
Glycogen	granules of stored carbohydrate fuel held in the sarcoplasm

Myofilaments, Thick and Thin

Two kinds of protein filament fill each myofibril. Compare them by their main protein and structure.

MYOFILAMENT	MAIN PROTEIN	STRUCTURE	ANCHORED AT
Thick filament	myosin	a bundle of myosin molecules; each molecule has a long tail and a pair of heads, and the heads project outward as cross bridges	the M line
Thin filament	actin	two twisted strands of actin subunits; each subunit carries a myosin-binding site	the Z disc

Tropomyosin	a rod-shaped regulatory protein that lies end to end along the thin filament
Troponin	a three-part regulatory protein bound at intervals to tropomyosin on the thin filament

The Sarcomere

The sarcomere is the contractile unit of muscle, the segment of a myofibril from one Z disc to the next. Its bands and zones are named for how the overlapping filaments look under the microscope. Compare the regions.

REGION	WHAT IT IS	FILAMENTS PRESENT
Z disc	the protein plate at each end of the sarcomere, its border	anchors the thin filaments
A band	the dark band, as wide as the thick filaments are long	thick filaments across its full width, with thin filaments overlapping at each edge
I band	the light band; a Z disc runs through its center, so one I band is shared by two sarcomeres	thin filaments only
H zone	the lighter region in the center of the A band	thick filaments only
M line	the protein line in the center of the H zone	anchors the thick filaments to one another
Zone of overlap	the region at each end of the A band	both thick and thin filaments, interleaved

Striations	the stripes of skeletal muscle, the alternating dark A bands and light I bands of thousands of aligned sarcomeres

Structural Proteins of the Sarcomere

Besides the contractile proteins, a set of structural proteins holds the sarcomere in register and links it to the cell membrane. Compare them by location and role.

PROTEIN	LOCATION	ROLE
Titin	spans from the Z disc to the M line	anchors the thick filament, gives the sarcomere elastic recoil, and keeps it from overstretching
Nebulin	runs the length of the thin filament	anchors the thin filament and sets its length
Alpha-actinin	the Z disc	binds the thin filaments and titin to the Z disc
Myomesin	the M line	binds the thick filaments together at the M line

PROTEIN	LOCATION	ROLE
Dystrophin	links the thin filaments to the sarcolemma	transfers the force of contraction from the sarcomere out to the connective tissue; faulty in muscular dystrophy

Structure explains the injury

The three connective tissue sheaths are continuous with one another and with the **tendon**, so the pull of every fiber reaches the bone. This continuity also explains injury. A muscle **strain** tears fibers and endomysium within the belly, while a **tendon** rupture separates the muscle from the bone entirely, and the two heal on very different timelines.

Muscular dystrophy is a group of inherited diseases of muscle structure. In Duchenne muscular dystrophy the gene for **dystrophin** is faulty, so the link between the sarcomere and the sarcolemma fails, the fiber damages itself with ordinary use, and weakness is progressive.

The **triad**, one T tubule flanked by two terminal cisternae, is the structural meeting point where a surface signal reaches the calcium store of the sarcoplasmic reticulum. Its tight, repeating arrangement is what lets an entire fiber respond almost at once.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Trace the structural ladder of skeletal muscle, from the whole muscle down to the myofilaments.
2. Name the parts of a sarcomere and what each one contributes.
3. Compare the three muscle tissue types by striations, control, and location.
4. Explain how the banding pattern of a sarcomere produces the striations you see on a slide.

Fascicle Arrangement & Lever Systems

Muscle Arrangement of Fascicles and Lever Systems

A reference for the fascicle arrangement and lever systems video and lab. This page covers how the fascicles of a muscle are arranged, how muscles are named, how they work in groups, and the bone-and-joint lever systems they act on.

BY THE END

1. Identify the patterns of fascicle arrangement and give an example muscle for each.
2. Explain how fascicle architecture trades range of motion against power.
3. Name the criteria used to name muscles, and classify the roles muscles play in a movement.
4. Identify the parts of a lever and classify first-, second-, and third-class levers in the body.

From Fascicles to Movement, an Overview

A skeletal muscle moves a bone by pulling across a joint. How its fascicles are arranged, what it is named, the team it works in, and the lever it acts on all shape the movement it produces.

Fascicle — a bundle of muscle fibers wrapped in perimysium, the unit whose arrangement gives a muscle its shape

Origin — the attachment of a muscle to the more stationary bone

Insertion — the attachment of a muscle to the more movable bone, pulled toward the origin

Action — the movement a muscle produces when it contracts and pulls the insertion toward the origin

Fascicle Arrangement Patterns

The fascicles of a muscle run in a set pattern, and that pattern gives the muscle its overall shape. Compare the patterns by how the fascicles lie and an example muscle.

PATTERN	FASCICLE ARRANGEMENT	EXAMPLE MUSCLE
Parallel	fascicles run parallel to the long axis of the muscle	sartorius, rectus abdominis
Fusiform	fascicles run parallel, but the muscle has a thick central belly that tapers to a tendon at each end	biceps brachii
Circular	fascicles arranged in concentric rings around an opening, forming a sphincter	orbicularis oris, orbicularis oculi
Convergent	a broad origin whose fascicles converge onto a single tendon, giving a triangular or fan shape	pectoralis major
Pennate	short fascicles attach at an angle to a central tendon, like the barbs of a feather; unipennate has fascicles on one side, bipennate on both, multipennate on a branched tendon	unipennate, extensor digitorum; bipennate, rectus femoris; multipennate, deltoid

Architecture, Power, and Range

Fascicle architecture is a trade-off. A muscle can be built for a wide range of motion or for power, but not for both at once. Compare the two extremes.

ARCHITECTURE	FASCICLE LENGTH AND NUMBER	RANGE OF MOTION	POWER
Parallel and fusiform	long fascicles, fewer of them per unit of muscle	larger range of motion, the muscle shortens by a greater distance	less power, fewer fibers pull on the tendon
Pennate	short fascicles, many of them packed at an angle per unit of muscle	smaller range of motion, the angled fascicles shorten by a shorter distance	greater power, many more fibers pull on the tendon

Range of shortening — a muscle fiber can shorten to roughly two-thirds of its resting length, so a muscle with longer fascicles moves its insertion farther

How Muscles Are Named

A muscle's name is a description. Most names combine two or more of these criteria, so the name itself tells you where the muscle is, what it looks like, or what it does. Compare the criteria.

NAMING CRITERION	WHAT IT DESCRIBES	EXAMPLES
Direction of fascicles	how the fascicles run relative to the body's midline	rectus, straight; oblique, at an angle; transversus, across
Relative size	the size of the muscle compared with its neighbors	maximus, minimus, longus, brevis
Shape	the overall geometric shape of the muscle	deltoid, triangular; trapezius, trapezoid; rhomboid
Location	the bone or body region the muscle is near	tibialis anterior, frontalis, intercostals
Number of origins	how many heads, or origin tendons, the muscle has	biceps, two; triceps, three; quadriceps, four
Origin and insertion	the muscle's two attachment points	sternocleidomastoid, from the sternum and clavicle to the mastoid process
Action	the movement the muscle produces	flexor, extensor, abductor, adductor, levator

Muscles Working in Groups

Almost no movement is the work of one muscle. Muscles act in teams, and the same muscle can play different roles in different movements. Compare the four roles.

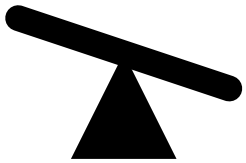
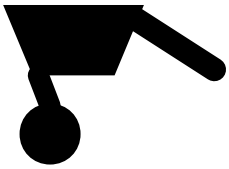
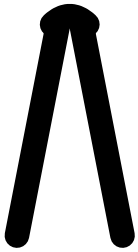
ROLE	FUNCTION IN THE MOVEMENT	EXAMPLE
Agonist	the prime mover, the muscle chiefly responsible for producing a given movement	biceps brachii during elbow flexion
Antagonist	opposes the agonist, relaxing and lengthening as the agonist contracts; it can slow or reverse the movement	triceps brachii during elbow flexion
Synergist	assists the agonist, adding force or preventing an unwanted movement	brachialis assisting elbow flexion
Fixator	a synergist that holds the origin bone steady so the agonist can act efficiently on the insertion bone	scapular muscles steadying the scapula during arm movements

Lever Systems

When a muscle pulls on a bone, the bone acts as a lever and the joint as its pivot. Every body movement is a lever at work.

Lever	a rigid bar that moves around a fixed point; in the body, a bone is the lever
Fulcrum	the fixed point the lever turns around; in the body, a joint is the fulcrum
Effort	the force applied to move the lever; in the body, the pull of a contracting muscle
Load	the resistance moved by the lever; in the body, the weight of the body part plus anything it carries
Mechanical advantage	when the effort acts farther from the fulcrum than the load, so a small effort moves a large load
Mechanical disadvantage	when the effort acts closer to the fulcrum than the load, so a large effort is needed, but the load moves fast and far

Levers are sorted into three classes by the order of the fulcrum, effort, and load along the bar. Compare them.

LEVER CLASS	ARRANGEMENT ALONG THE LEVER	EXAMPLE IN THE BODY
First-class lever 	the fulcrum lies between the effort and the load; think of a seesaw	nodding the head: the posterior neck muscles, the atlanto-occipital joint, and the weight of the face
Second-class lever 	the load lies between the fulcrum and the effort; think of a wheelbarrow	standing on tiptoe: the ball of the foot, the body's weight, and the calf muscles pulling up the heel
Third-class lever 	the effort lies between the fulcrum and the load; think of tweezers; the most common lever in the body	flexing the elbow: the elbow joint, the biceps pull, and the weight held in the hand

Architecture reads off the body

Fascicle architecture is visible in the clinic. A **pennate** muscle like the deltoid packs many short fascicles around a tendon for power, while a **parallel** muscle like the sartorius trades power for a long, sweeping range. A surgeon planning a tendon transfer matches the architecture to the job the muscle must take over.

Muscle **names** are a working vocabulary. Reading "flexor carpi radialis" tells a clinician the action (flexor), the region (carpi, the wrist), and the position (radialis, the radial side) before the muscle is ever seen, which is why the naming criteria are worth learning as a system.

Most body movements run on **third-class levers**, which work at a mechanical disadvantage: the muscle must generate a large force, but it buys speed and a wide range of motion. That trade-off is why a small change in where a tendon inserts can noticeably change a joint's strength and speed.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the three connective tissue wrappings of a muscle, from the single fiber out to the whole muscle.
2. Explain how fascicle arrangement, parallel, pennate, or circular, affects what a muscle can do.
3. Trace the connective tissue from inside the muscle to the tendon that attaches it to bone.
4. Compare a muscle built for power with one built for range of motion, by fascicle pattern.

The Lymphatic System

The Lymphatic System

A reference for the lymphatic system video and lab. This page covers lymph and the pathway it follows, the lymphatic vessels, lymph nodes, the lymphatic organs, and common disorders of the system.

BY THE END

1. Define lymph and trace the pathway it follows back to the blood.
2. Describe the structure of lymphatic vessels and a lymph node.
3. Sort the lymphatic organs into primary and secondary.
4. Name common disorders of the lymphatic system.

The Lymphatic System, an Overview

The lymphatic system is a one-way drainage network. It collects fluid that leaks out of the blood capillaries, filters it, and returns it to the bloodstream, while also housing the body's defenses.

Lymphatic system	a network of vessels, tissues, and organs that drains tissue fluid and defends the body
Interstitial fluid	the fluid in the spaces between cells, filtered out of the blood capillaries
Lymph	the interstitial fluid once it has entered the lymphatic vessels; a clear, watery fluid
Three functions	draining excess interstitial fluid back to the blood, absorbing dietary fats from the small intestine, and housing the immune defenses
A one-way system	lymphatic vessels carry lymph in one direction only, toward the heart; the system has no pump of its own

The Pathway of Lymph

Lymph travels a fixed route from the tissue spaces back to the bloodstream, growing into larger and larger vessels along the way. Follow it in order.

1. **Lymphatic capillaries** blind-ended tubes that take up excess interstitial fluid from the tissue spaces
2. **Lymphatic collecting vessels** larger vessels, with valves, that carry the lymph onward
3. **Lymph nodes** the lymph is filtered as it passes through nodes spaced along the vessels
4. **Lymphatic trunks** collecting vessels merge into large trunks, each draining a major region of the body
5. **Lymphatic ducts** the trunks empty into two ducts: the right lymphatic duct and the larger thoracic duct
6. **Subclavian veins** the ducts return the lymph to the bloodstream where the subclavian and internal jugular veins meet

Lymphatic Vessels

Lymphatic vessels resemble veins, but they begin as blind-ended capillaries and they move fluid without a pump.

Lymphatic capillaries	the smallest lymphatic vessels, blind-ended and more permeable than blood capillaries
Overlapping endothelial cells	the cells of a lymphatic capillary overlap as one-way flap valves, letting fluid in but not back out
Lacteals	specialized lymphatic capillaries in the lining of the small intestine that absorb dietary fat
Lymphatic valves	one-way valves in the collecting vessels that keep lymph moving in a single direction
How lymph moves	with no pump, lymph is pushed along by the squeeze of nearby skeletal muscles and by breathing movements
Right lymphatic duct	the smaller duct, draining lymph from the upper right quadrant of the body
Thoracic duct	the larger duct, draining the rest of the body; it begins at a sac called the cisterna chyli

Lymph Nodes

Lymph nodes are the filters of the system. Hundreds of them lie along the lymphatic vessels, cleaning the lymph before it returns to the blood.

Lymph node	a small, bean-shaped organ that filters lymph and houses immune cells
Capsule	the dense connective tissue covering of a node
Cortex	the outer region of a node, packed with lymphocytes in rounded clusters
Medulla	the inner region of a node
Afferent vessels	the lymphatic vessels that carry lymph into a node
Efferent vessels	the lymphatic vessels that carry filtered lymph out of a node, leaving at the hilum
Node clusters	nodes are especially concentrated in the cervical, axillary, and inguinal regions

The Lymphatic Organs

The lymphatic organs are sorted into primary organs, where lymphocytes form and mature, and secondary organs, where lymphocytes meet and respond to invaders. Compare them.

ORGAN	GROUP	LOCATION	ROLE
Red bone marrow	primary	the spongy bone of the axial skeleton and limb girdles	where all lymphocytes form, and where B cells mature
Thymus	primary	the mediastinum, behind the sternum	where T cells mature
Lymph nodes	secondary	clustered along the lymphatic vessels	filter the lymph
Spleen	secondary	the upper left abdomen, behind the stomach	filters the blood
Tonsils	secondary	a ring around the entrance to the throat	guard against inhaled and swallowed pathogens
MALT	secondary	the mucous membranes of the digestive, respiratory, and other tracts	guards the body's mucosal surfaces

The Spleen, Thymus, and Tonsils

Three of the lymphatic organs are worth a closer look at their structure.

The spleen

Spleen	the largest lymphatic organ, in the upper left abdomen behind the stomach
White pulp	the lymphocyte-rich tissue of the spleen that carries out its immune functions
Red pulp	the tissue of the spleen that filters the blood and removes worn-out erythrocytes

The thymus and tonsils

Thymus	the primary organ where T cells mature; large in childhood and shrinking after puberty
Tonsils	a ring of lymphatic tissue guarding the throat, including the palatine, lingual, and pharyngeal tonsils
Pharyngeal tonsil	the single tonsil on the posterior wall of the nasopharynx, also called the adenoid

Disorders of the Lymphatic System

When drainage fails or the lymphatic tissue is diseased, the problems show up as swelling or as changes in the nodes and organs. Compare the common ones.

DISORDER	STRUCTURE AFFECTED	WHAT IT IS
Edema	the interstitial space	swelling from excess interstitial fluid when lymphatic drainage cannot keep up
Lymphedema	the lymphatic vessels	long-term tissue swelling from blocked or missing lymphatic vessels, sometimes after lymph node removal
Lymphadenopathy	the lymph nodes	enlarged lymph nodes, often a sign the nodes are fighting an infection
Lymphoma	lymphatic tissue	a cancer arising in lymphatic tissue, including Hodgkin and non-Hodgkin lymphoma
Splenomegaly	the spleen	an enlarged spleen, which can follow an infection or a blood disorder
Tonsillitis	the tonsils	inflammation of the tonsils, common in childhood

The system a clinician reads through the skin

Swollen glands are **lymphadenopathy**: lymph nodes enlarge as they trap and fight pathogens, which is why a clinician feels for tender nodes in the neck, armpit, and groin during an exam.

Because lymph passes through nodes in order, the lymphatic system also maps how some cancers spread. The first node a region drains into is the sentinel node, and checking it tells a surgeon whether a cancer has begun to travel. Removing many nodes can block drainage and leave lasting **lymphedema** in the limb.

The **spleen** sits just under the lower left ribs. Its soft tissue is easily torn, so a blow to that area can rupture the spleen and cause heavy internal bleeding, since the organ filters a large volume of blood.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Trace the path of lymph from a tissue back to the bloodstream, naming the major vessels.
2. Compare a lymph node and the spleen by structure and the job each one does.
3. Explain why the lymphatic system has no central pump, and how lymph still moves.
4. Name the primary and secondary lymphoid organs and what happens at each.

Blood

Blood, Composition, Formation, and Disorders

A reference for the blood video and lab. This page covers the composition of blood, plasma and the formed elements, how blood cells are formed, and common blood disorders. The focus is on structure and the named components.

BY THE END

1. Describe the composition of blood: plasma and the formed elements.
2. Identify the structure of erythrocytes, the five leukocytes, and platelets.
3. Explain where and how blood cells are formed.
4. Name common blood disorders and the component each one affects.

Blood, an Overview

Blood is a connective tissue, the body's only liquid tissue. Like every connective tissue it is cells suspended in a matrix; here the matrix, plasma, is a fluid.

Blood	a fluid connective tissue that transports materials throughout the body
Plasma	the liquid extracellular matrix of blood, roughly 55 percent of blood volume
Formed elements	the cells and cell fragments suspended in the plasma, roughly 45 percent of blood volume
Hematocrit	the percentage of blood volume made up of erythrocytes
Buffy coat	the thin pale layer of leukocytes and platelets between the plasma and the erythrocytes in a spun sample
Functions of blood	transport of gases, nutrients, wastes, and hormones; regulation of temperature and pH; protection through clotting and immune defense

Plasma

Plasma is about 92 percent water. The rest is dissolved solutes, and the plasma proteins are the most abundant of them. Compare the three main proteins.

PLASMA PROTEIN	MADE BY	ROLE
Albumin	the liver	the most abundant plasma protein; maintains the osmotic pressure that holds water in the blood, and carries some substances
Globulins	the liver and plasma cells	include the antibodies of immune defense and several transport proteins
Fibrinogen	the liver	the clotting protein; it converts to fibrin threads that form the framework of a clot

Water	about 92 percent of plasma, the solvent that carries every other component
Serum	plasma with the clotting proteins removed, the fluid left after blood has clotted
Other solutes	electrolytes, nutrients, dissolved gases, hormones, and wastes carried in the plasma

The Formed Elements

The formed elements are the cellular part of blood. There are three kinds, and only one of them is a complete cell type with a nucleus. Compare them.

FORMED ELEMENT	ALSO CALLED	DESCRIPTION	RELATIVE NUMBER
Erythrocytes	red blood cells	biconcave discs without a nucleus, packed with hemoglobin	by far the most numerous
Leukocytes	white blood cells	complete nucleated cells that defend the body	the least numerous
Platelets	thrombocytes	small cell fragments, not whole cells, that act in clotting	intermediate in number

Erythrocytes

Erythrocytes, the red blood cells, carry oxygen. Almost every feature of their structure is a compromise made to fit more hemoglobin into the cell.

Erythrocyte	a red blood cell, the oxygen carrier of the blood	**Hemoglobin**	the red, iron-containing protein that fills the erythrocyte and binds oxygen for transport
Biconcave disc	the erythrocyte's shape, a disc thinner at its center, which gives a large surface area for gas exchange	**Flexible plasma membrane**	lets the disc bend and fold to squeeze single file through the narrowest capillaries
No nucleus	a mature erythrocyte has ejected its nucleus and most organelles, leaving more room for hemoglobin	**Lifespan**	about 120 days, after which worn cells are broken down by the spleen and liver

Leukocytes

Leukocytes, the white blood cells, defend the body. They sort into granulocytes, which have visible cytoplasmic granules, and agranulocytes, which do not. Compare the five types.

LEUKOCYTE	GROUP	APPEARANCE	DEFENSE ROLE
Neutrophil	granulocyte	a multi-lobed nucleus and fine pale granules; the most numerous leukocyte	the first responder to infection, engulfs and digests bacteria
Eosinophil	granulocyte	a two-lobed nucleus and coarse red-orange granules	attacks parasites and moderates allergic reactions
Basophil	granulocyte	a lobed nucleus hidden by large dark granules; the rarest leukocyte	releases histamine and other mediators in inflammation
Lymphocyte	agranulocyte	a large round nucleus filling almost the whole cell	the core of specific immunity, includes the T cells and B cells
Monocyte	agranulocyte	the largest leukocyte, with a kidney-shaped nucleus	leaves the blood and matures into a macrophage that engulfs debris and pathogens

Platelets and Blood Formation

Platelets are not whole cells, and all the formed elements trace back to one stem cell in the red bone marrow. The formation of blood cells is called hematopoiesis (hemopoiesis).

Platelets

Platelet	also called a thrombocyte, a small membrane-bound fragment of cytoplasm, not a complete cell	**Role in clotting**	platelets gather and stick at a vessel injury, forming a plug and helping the clotting proteins build a clot
Megakaryocyte	the giant bone marrow cell whose cytoplasm breaks into thousands of platelets		

Hematopoiesis, the formation of blood cells

Hematopoiesis	the formation of the blood's formed elements	**Myeloid line**	the line that gives rise to erythrocytes, platelets, and all the leukocytes except lymphocytes
Red bone marrow	the site of hematopoiesis in adults, found in the spongy bone of the axial skeleton and the proximal limb bones	**Lymphoid line**	the line that gives rise to the lymphocytes
Hemocytoblast	the hematopoietic stem cell that every formed element arises from		

Blood Disorders

Most blood disorders are a problem of one formed element or one plasma protein, too few, too many, or abnormal. Compare them by the component each one affects.

DISORDER	COMPONENT AFFECTED	WHAT IT IS
Anemia	erythrocytes	too few erythrocytes or too little hemoglobin, so the blood carries less oxygen
Sickle cell disease	erythrocytes and hemoglobin	an inherited abnormal hemoglobin distorts erythrocytes into a sickle shape that jams capillaries
Polycythemia	erythrocytes	an excess of erythrocytes that thickens the blood and slows its flow
Leukemia	leukocytes	a cancer of white blood cell formation that crowds the marrow with abnormal leukocytes
Leukopenia	leukocytes	an abnormally low white blood cell count, which weakens the body's defense
Thrombocytopenia	platelets	an abnormally low platelet count, which raises the risk of bleeding
Hemophilia	clotting proteins	an inherited deficiency of a clotting factor, so blood clots too slowly

One tube of blood, a whole status report

Because blood is a tissue that can be sampled with a needle, a single tube reports on the whole body. Spinning it gives the **hematocrit**, the fraction of red cells; a complete blood count tallies each formed element. A low red cell count points to **anemia**, a high white cell count toward infection or **leukemia**.

The structure of the erythrocyte explains its diseases. In **sickle cell disease** a single abnormal hemoglobin makes the cell rigid and curved, so it cannot fold through a capillary and blocks it instead, causing pain and tissue damage downstream.

Because **hematopoiesis** happens in red bone marrow, a marrow sample drawn from the iliac crest or the sternum is how the blood-forming tissue itself is examined when a count is abnormal.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the formed elements of blood and the job of each.
2. Explain what makes blood a connective tissue, and identify its fluid matrix.
3. Where are blood cells made? Name the tissue responsible and where it is found.
4. Explain how the structure of a red blood cell suits oxygen transport.