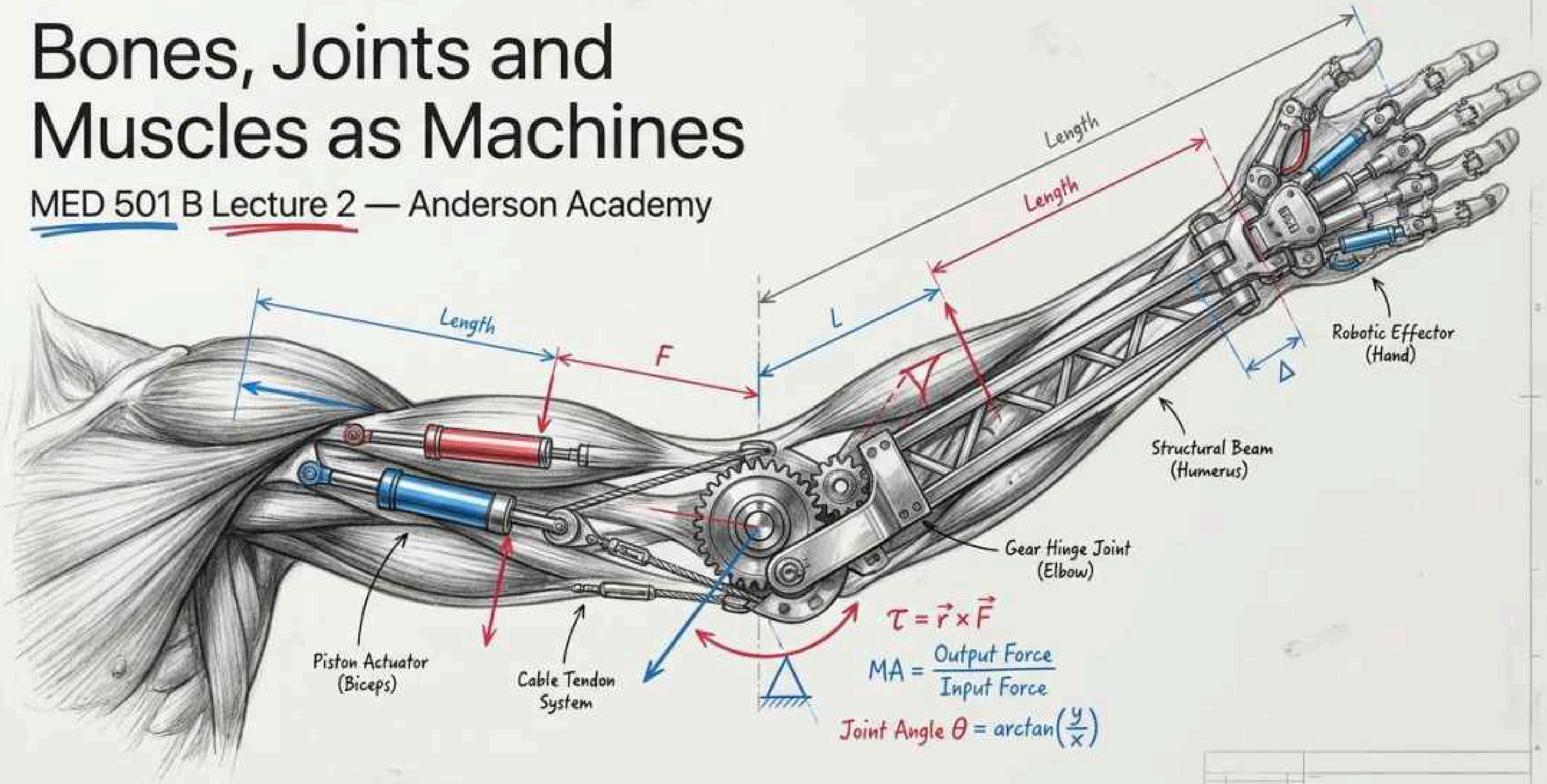
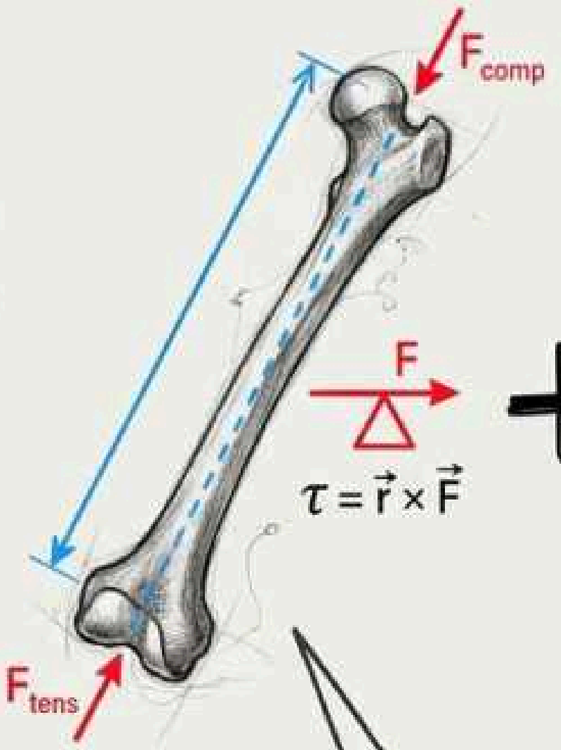
Bones, Joints and Muscles as Machines

MED 501 B Lecture 2 — Anderson Academy



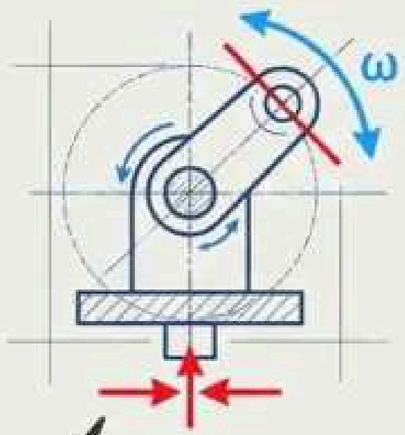
Questions or feedback: garyanderson@mail.grokbot.com | X: @garyanderson

The Biological Engine



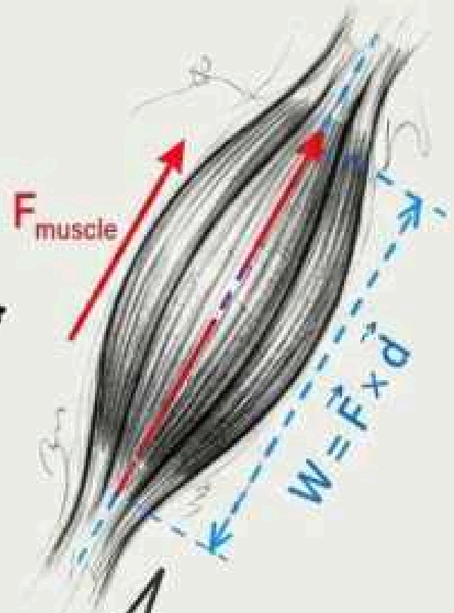
Bones = Levers

The body's structural frame.
Gives shape and protection.



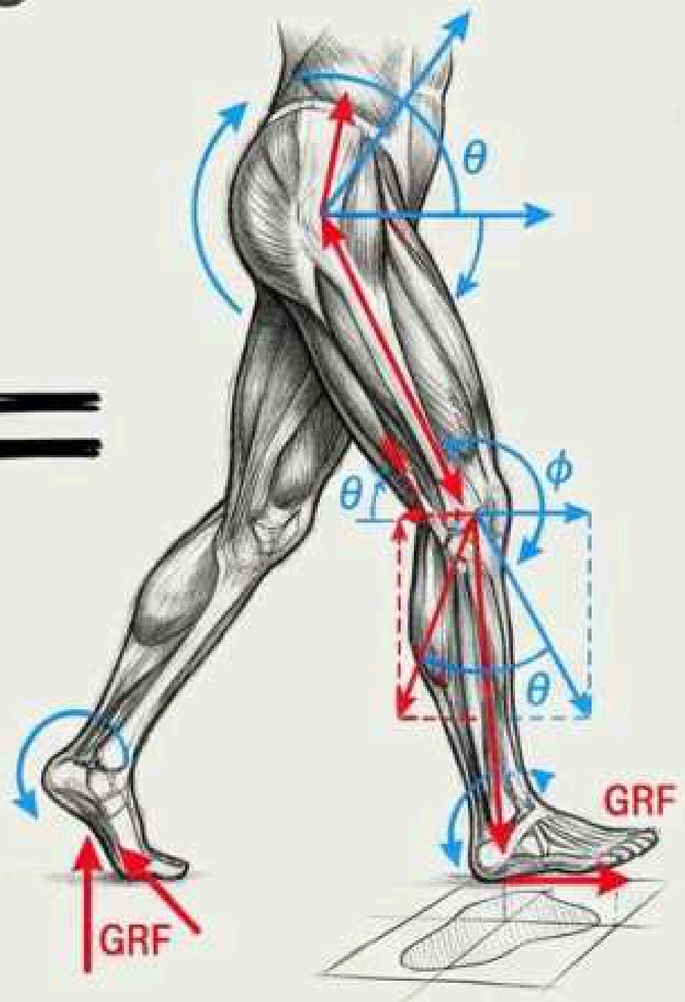
Joints = Hinges & Pivots

The mechanical linkages
between levers.



Muscles = Motors

The actuators that pull on
the levers to generate force.

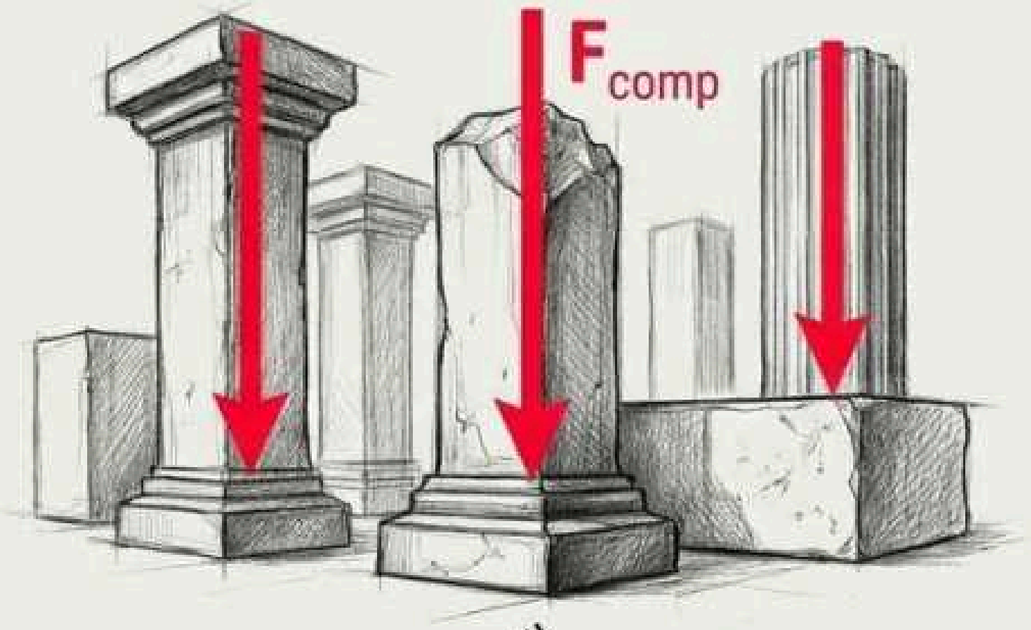


Functional anatomy is simply a matter of applied mechanics.

Bio-Materials: Concrete & Steel

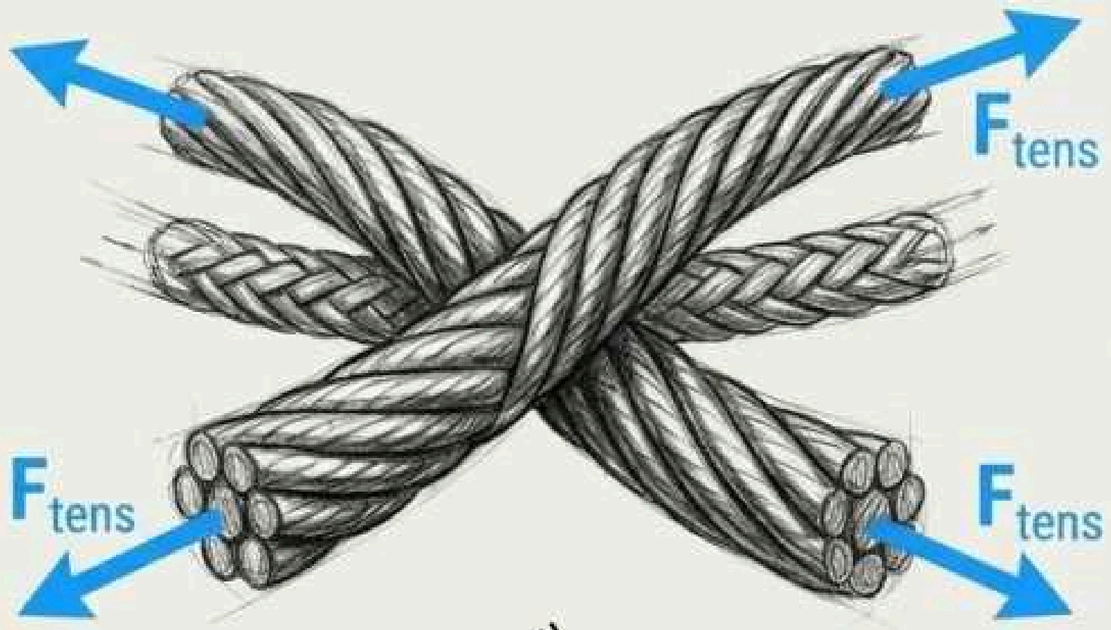
Living Tissue Blueprint: Bone contains blood vessels, nerves, and cells that constantly break it down and rebuild it.

Calcium Phosphate (Mineral)



Provides hardness; resists compression.

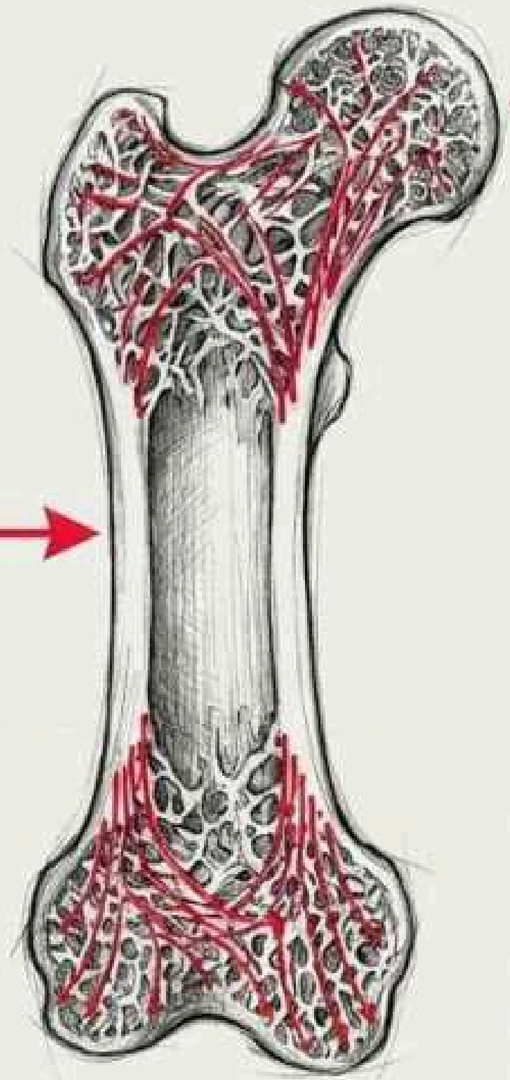
Collagen Fibres



Provides toughness; resists bending and pulling.

Architecture of Load

Compact Bone
A hollow tube of dense tissue. Delivers massive strength-to-weight ratio.



Spongy Bone
A lattice of tiny struts physically aligned along the exact lines of mechanical stress.

Wolff's Law

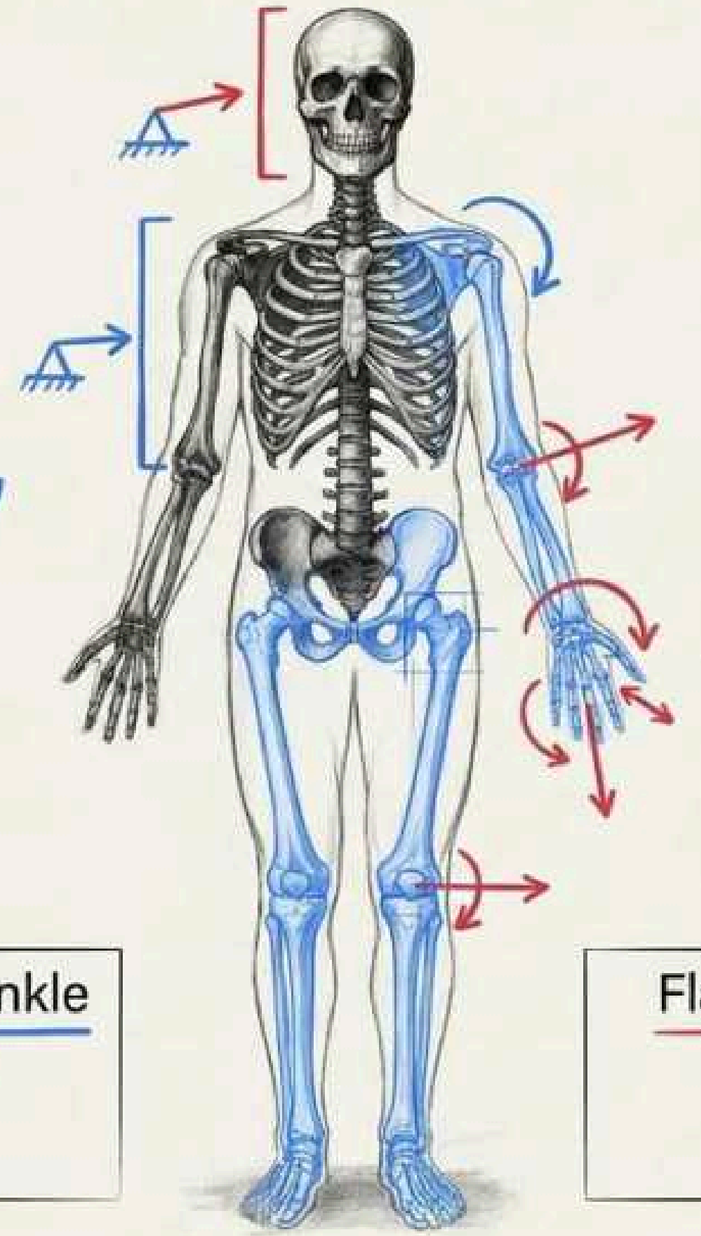
Bone remodels according to use. Exercise strengthens the lattice; inactivity or weightlessness weakens it.

Skeletal Taxonomy

Axial System (Protection)

Skull, spine, and rib cage.

Guards the brain, spinal cord, and chest organs.



Appendicular System (Movement)

Limbs and girdles.

Built for interaction and locomotion.

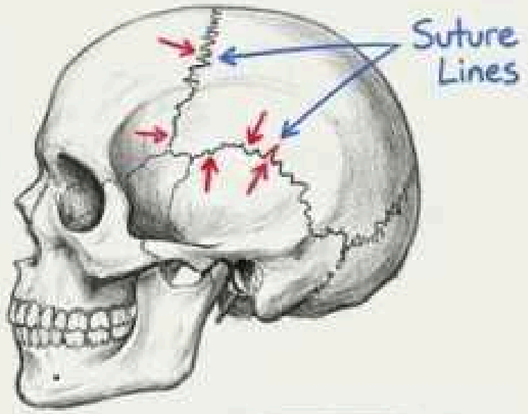
Shape Classification

Long: Limbs	Short: Wrist/Ankle	Flat: Skull/Ribs	Irregular: Vertebrae
			

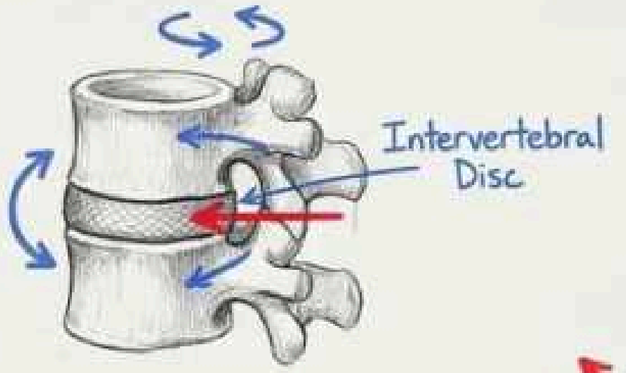
The Joint Trade-Off

¶ 2.5

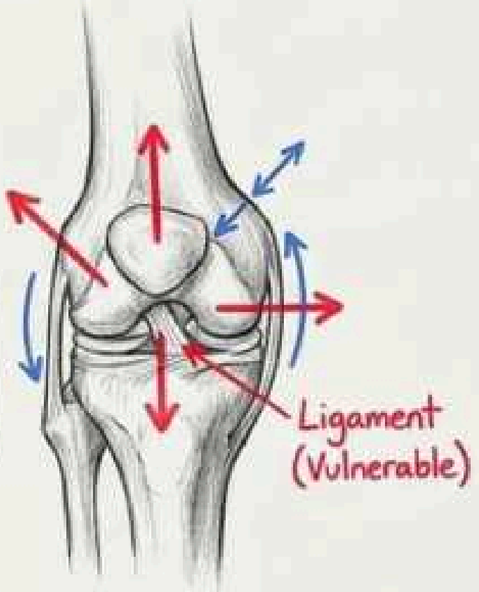
Fibrous Joints:
High stability, zero mobility.
Example: Sutures of the skull.



Cartilaginous Joints:
Moderate stability, moderate mobility.
Example: Bodies of the vertebrae.



Synovial Joints:
Low stability, high mobility.
Most easily injured.
Example: Knee and shoulder.

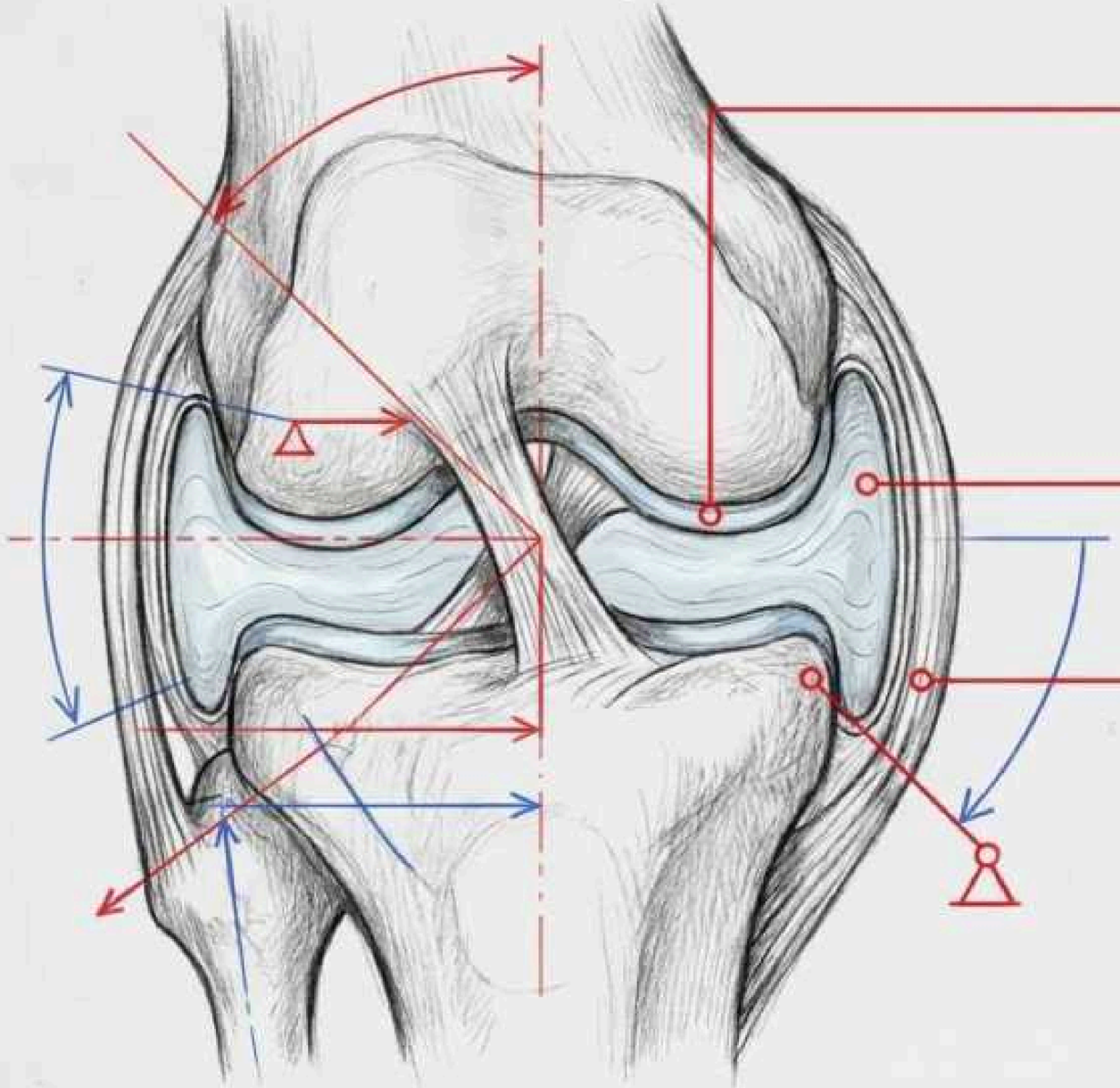


Stability

Mobility

Synovial Joint Blueprint

¶ 2.6



Articular Cartilage

Smooth surface covering bone ends.

Synovial Membrane & Fluid

Encloses the capsule; manufactures slippery fluid to lubricate and nourish cartilage.

Ligaments

Bands of tough connective tissue that hold bones together and physically limit unwanted motion.

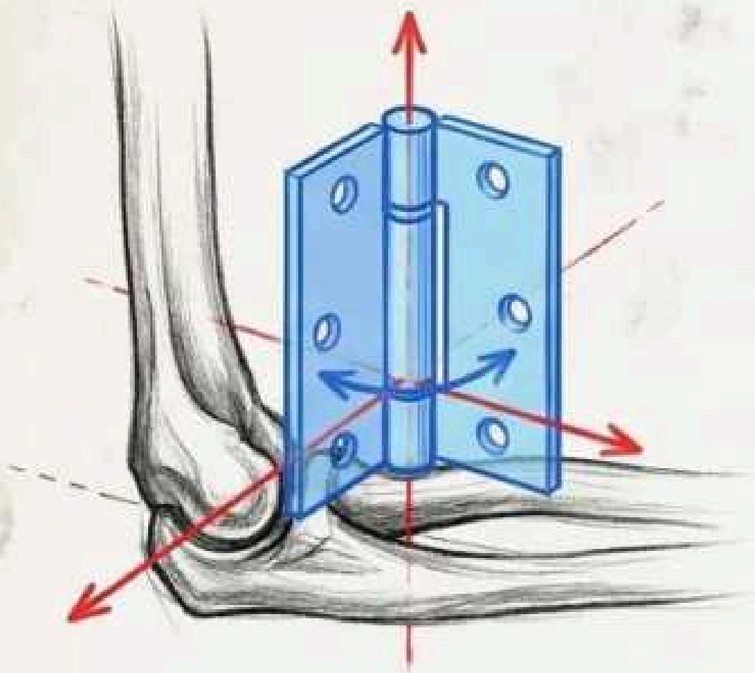
Failure Point: Osteoarthritis

Occurs when cartilage wears away with age; commonest cause of joint pain.

16:9 Leonardo Whiteboard

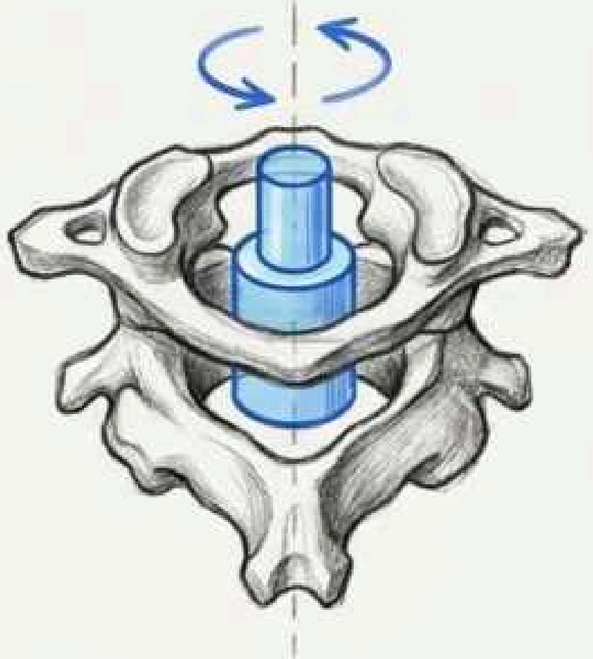
Geometry Dictates Motion

¶ 2.7



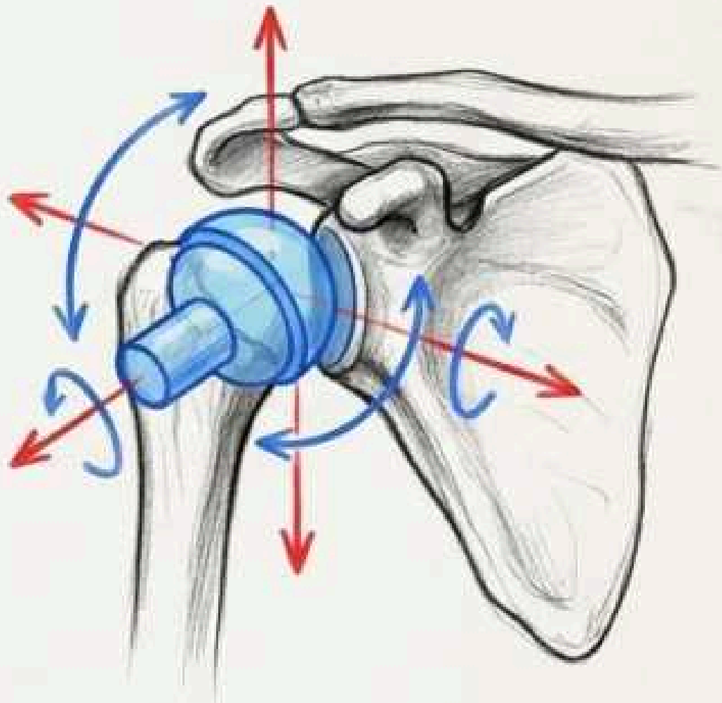
Hinge Joint (Elbow)

Bends and straightens in exactly one plane.



Pivot Joint (Neck)

Allows rotation (e.g., shaking the head).



Ball-and-Socket (Hip/Shoulder)

Movement in every direction.

Design Flaw: The shoulder's shallow socket permits massive range but dislocates far more easily than the deep, stable hip.

Biological Actuators



Anchor Points

Origin: The traditionally less movable attachment.

Insertion: The more movable attachment.

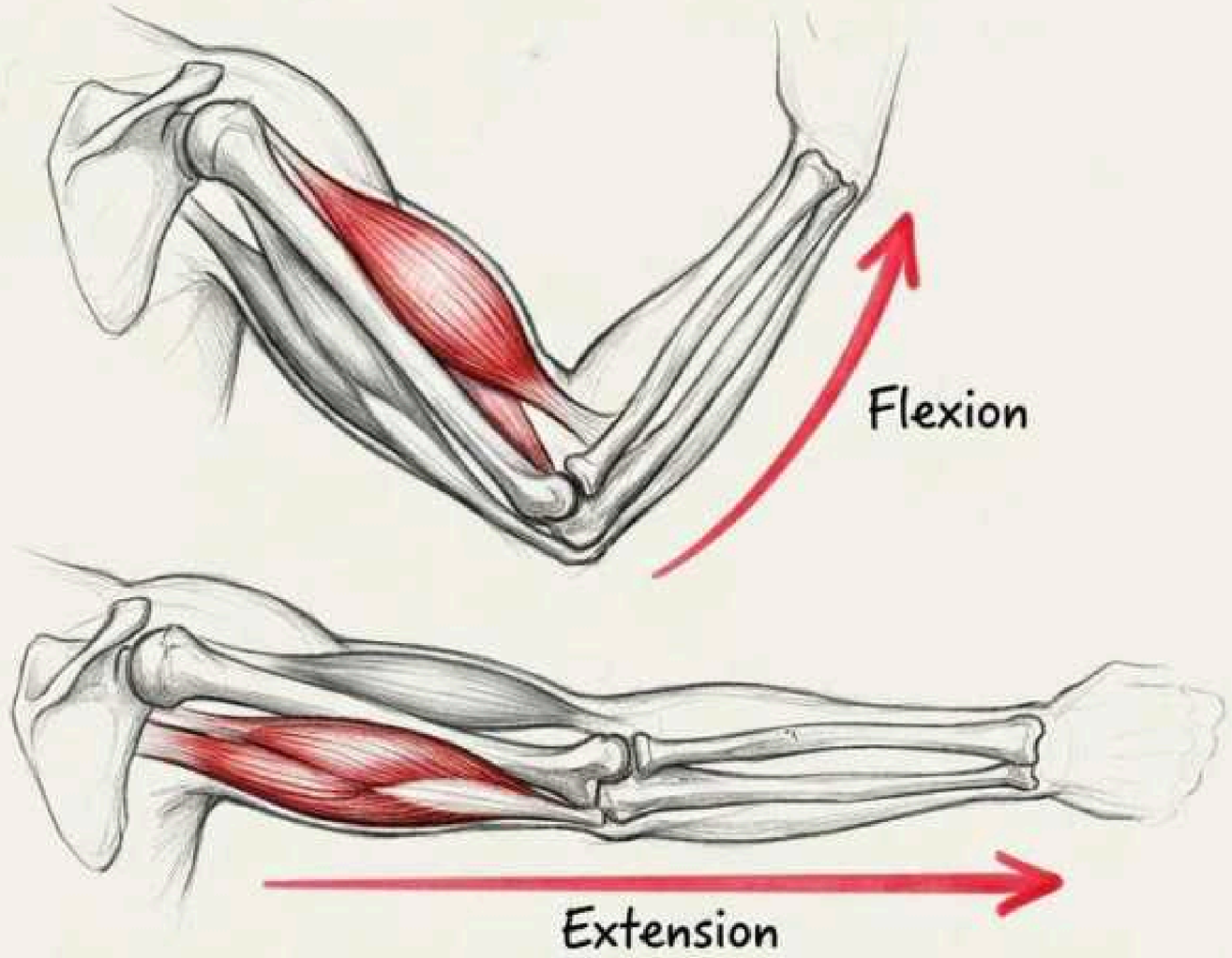
Mechanics

Muscles act solely by pulling their insertion point toward their origin point.

System Logic

Because they only pull, movements must be arranged in opposing pairs (Agonist vs. Antagonist).

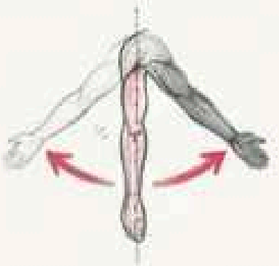
The Elbow Engine (Opposing Pairs)



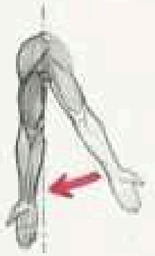
Agonist/Antagonist Logic: The biceps bends the elbow (flexion). The triceps straightens it (extension). The nervous system ensures one relaxes while the other contracts.

Spatial Glossary

Abduction: Moving a limb **away** from the midline.



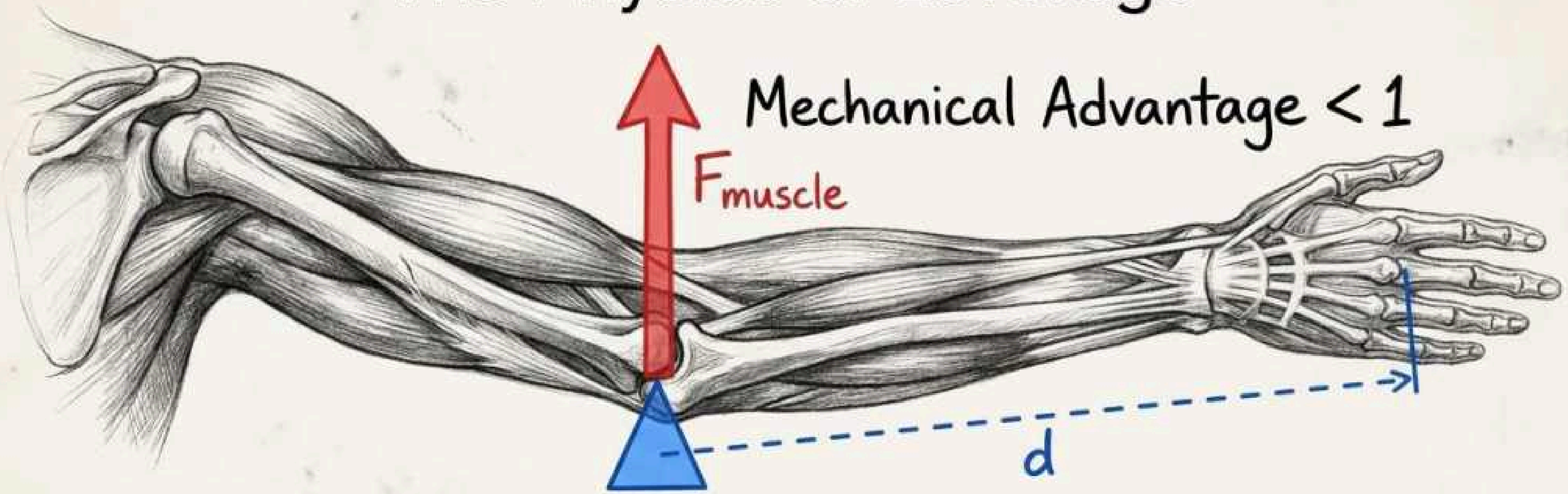
Adduction: Bringing a limb back toward the midline.



Rotation: Turning a limb around its long axis.



The Physics of Leverage

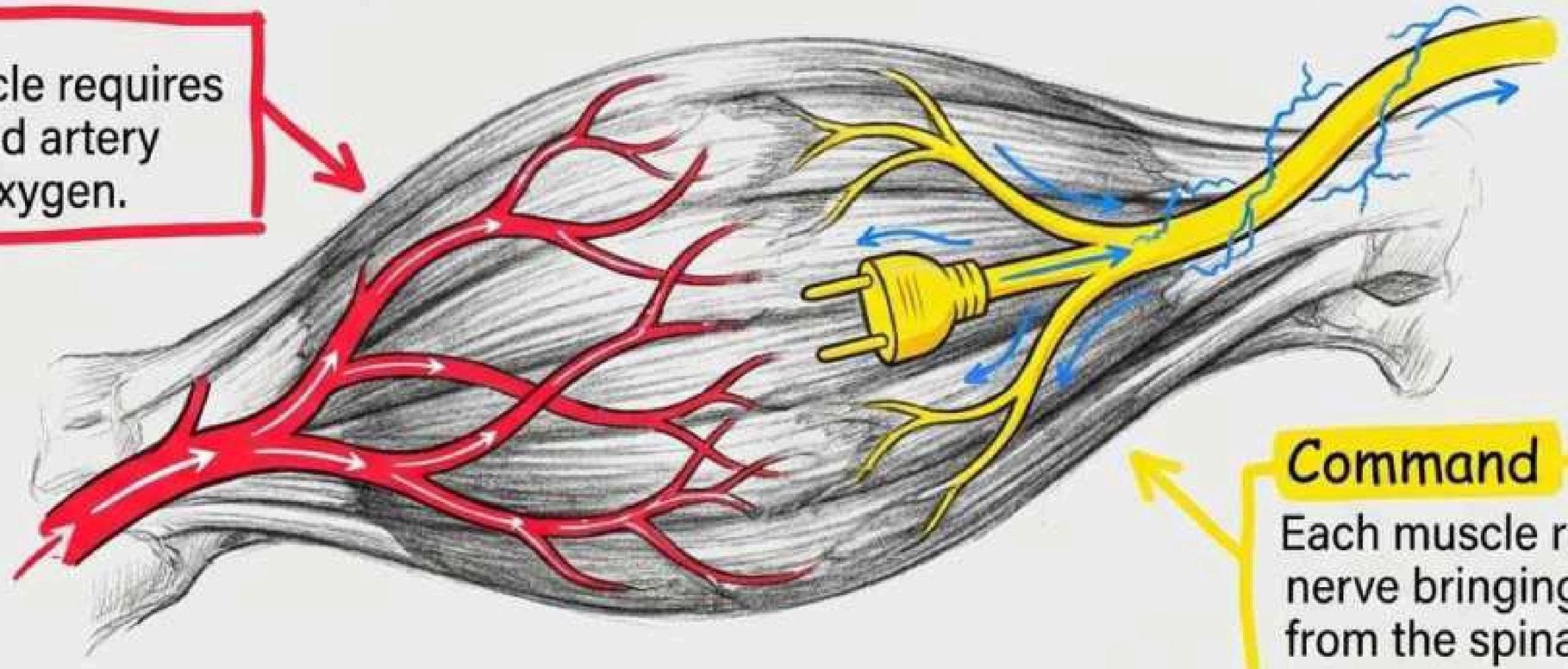


The Design Choice	The Trade-Off	Synthesis Insight
Most limb muscles attach very close to the joint they move.	**Costs Force:** The muscle must pull incredibly hard. **Gains Speed & Range:** A tiny shortening of the muscle produces a massive, rapid movement at the hand or foot.	The human body mathematically favors speed and range over raw force, perfectly optimizing us for throwing, running, and reaching.

Supply Lines & Control Signals

Fuel

Each muscle requires a dedicated artery bringing oxygen.



Command

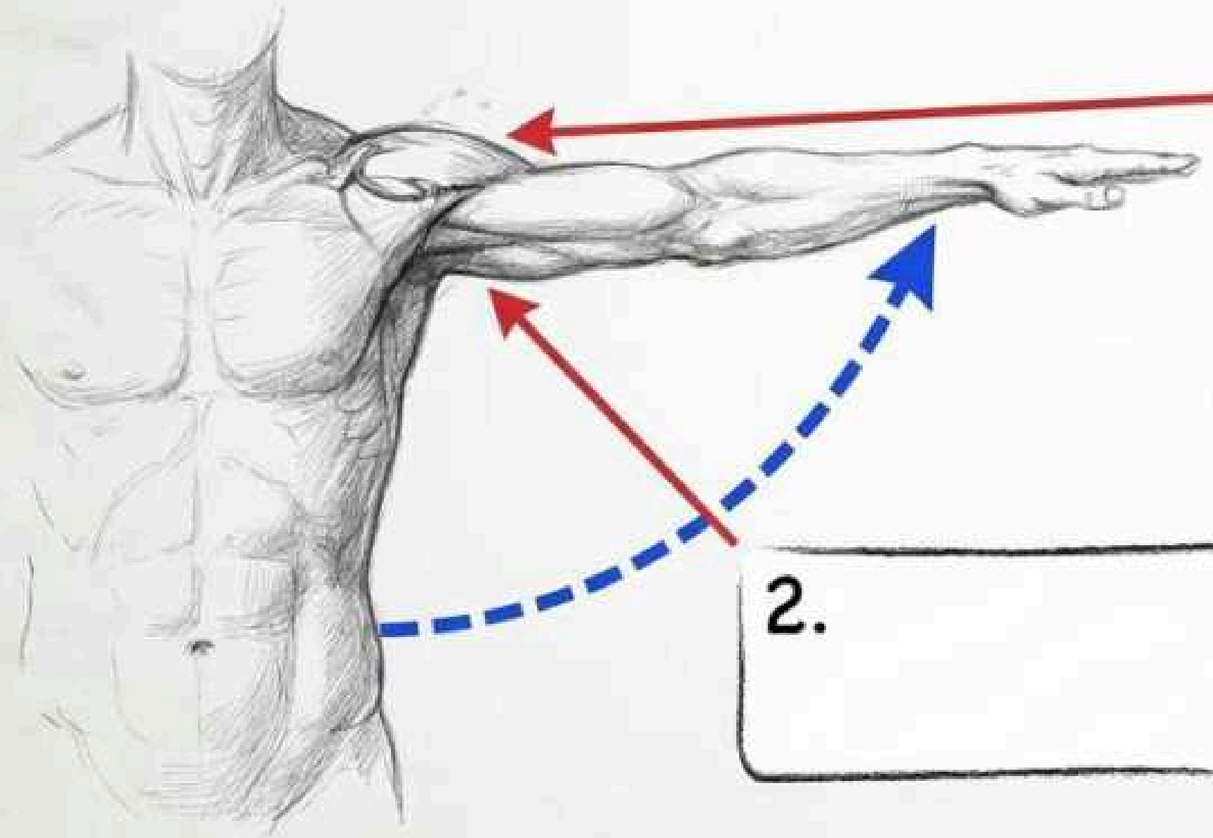
Each muscle requires a nerve bringing signals from the spinal cord.

System Failure

If the command nerve is cut, the muscle becomes paralyzed and slowly wastes away—even if the physical muscle tissue is entirely unhurt.

Applied Mechanics: Diagnostic Test

Stand up and raise your arm sideways to shoulder height. Which movement word describes this action?



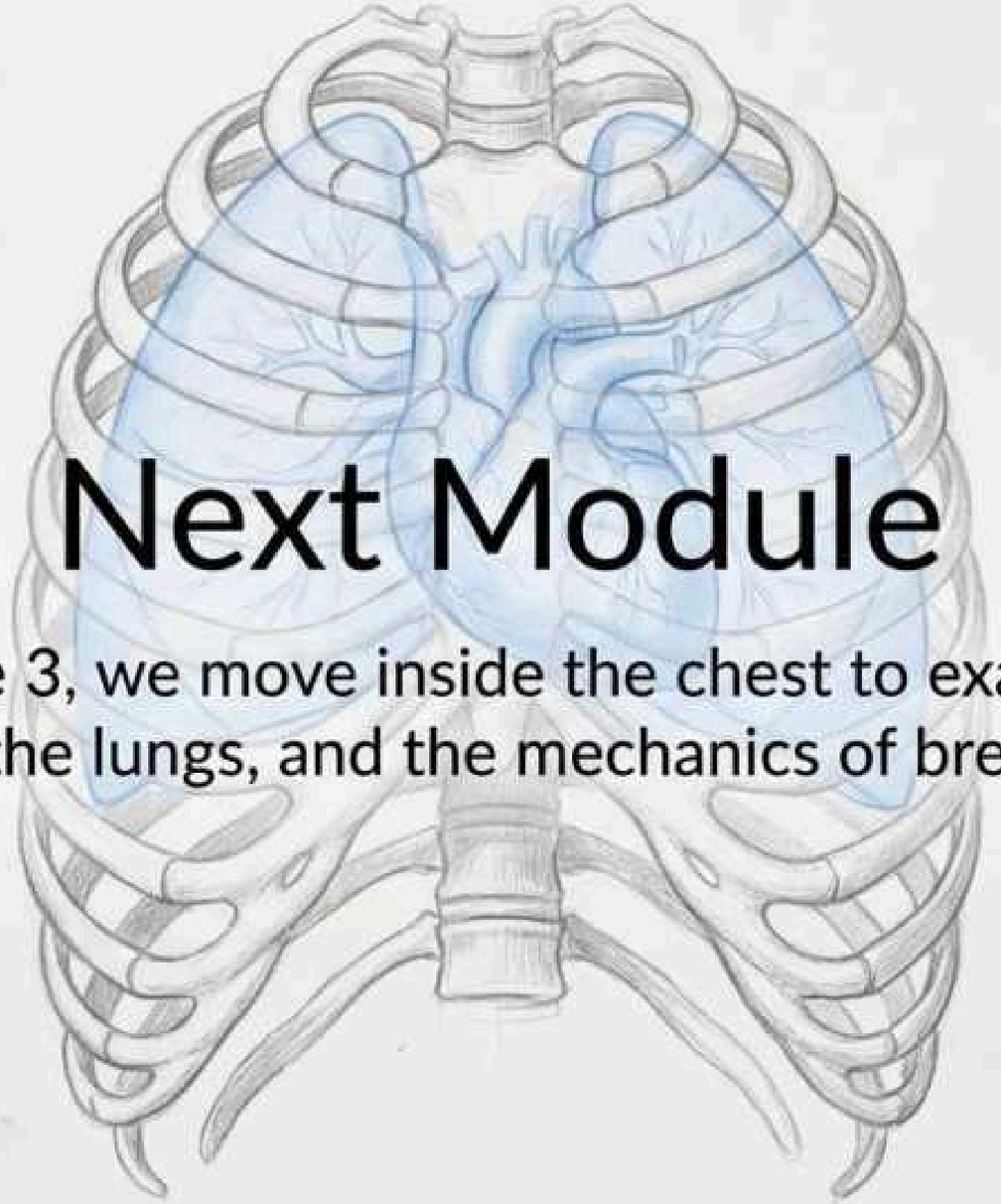
1.

2.

Which side of the shoulder must the muscle producing it lie on? Why can it not be on the other side?

Abduction

It must lie on the superior side to pull the lever Lmer upward. Muscles can pull, never push.



Next Module

In Lecture 3, we move inside the chest to examine the heart, the lungs, and the mechanics of breathing.