Muscles

IB SEHS

STARTER – Group Activity

Decide whether the following statements are true or false:

1. There are over 1,000 muscles in your body.
2. Skeletal, or voluntary, muscles are the muscles you can control.
3. Ligaments connect muscles to bones.
4. Your heart is a muscle.
5. A muscle gets strained when it is stretched too much.
6. A sprain happens when a tendon is stretched too much.
7. Muscles that are not used can get smaller and weaker
8. You don't need more than 30 minutes of physical activity every day.
9. If something hurts when playing sports, you should play through the pain and it will go away.
10. A balanced diet:
    a) Emphasizes fruits, vegetables, whole grains, and fat-free or low-fat dairy products like milk, cheese, and yogurt.
    b) Includes protein from lean meats, poultry, seafood, beans, eggs, and nuts.
    c) Is low in solid fats, saturated fats, cholesterol, salt (sodium), added sugars, and refined grains.
    d) All of the above

Answers

1. There are over 1,000 muscles in your body. -***False.*** *There are over 600 muscles in the body.*

2. Skeletal, or voluntary, muscles are the muscles you can control. ***True.*** *You can control your skeletal muscles to walk, run, pick up things, play an instrument, throw a baseball, kick a soccer ball, push a lawnmower, or ride a bicycle*

3. Ligaments connect muscles to bones. ***False.*** *Ligaments connect bones to other bones. Tendons connect muscles to bones.*

4. Your heart is a muscle. ***True.*** *The heart is a special muscle called "cardiac muscle." It works constantly to pump blood through your body.*

5. A muscle gets strained when it is stretched too much. ***True.*** *Muscles can be strained by stretching them too much, as when you lift something that is too heavy.*

6. A sprain happens when a tendon is stretched too much. ***False.*** *Sprains happen when ligaments (which connect bones to bones) are stretched too much. A stretching injury to a tendon (which connects a muscle to a bone) is called a strain.*

7. Muscles that are not used can get smaller and weaker ***True.*** *If a muscle is not used, it will get smaller and weaker. This is known as atrophy.*

8. You don't need more than 30 minutes of physical activity every day. ***False.*** *You should get at least 60 minutes of exercise every day. It doesn't have to be a whole hour all at once, but it does need to be in at least 10-minute increments to count toward your 60 minutes of physical activity per day.*

9. If something hurts when playing sports, you should play through the pain and it will go away. ***False****. If something starts to hurt, stop playing or exercising. You might just need to rest the injured part, or you might need to see a doctor.*

10. A balanced diet:
    a) Emphasizes fruits, vegetables, whole grains, and fat-free or low-fat dairy products like milk, cheese, and yogurt.
    b) Includes protein from lean meats, poultry, seafood, beans, eggs, and nuts.
    c) Is low in solid fats, saturated fats, cholesterol, salt (sodium), added sugars, and refined grains.
    d) All of the above

Learning Objectives

Everyone should

Distinguish between the different types of muscle

Outline the general characteristics common to muscle tissue

Most will

Identify the location of skeletal muscles in various regions of the body

Some might

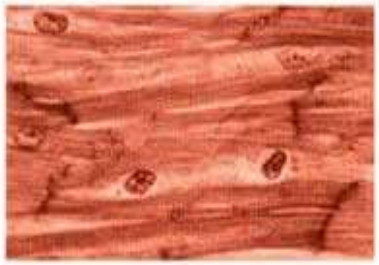
Explain the need for antogonistic pairs

Now complete the Types of Muscles section in your workbook!

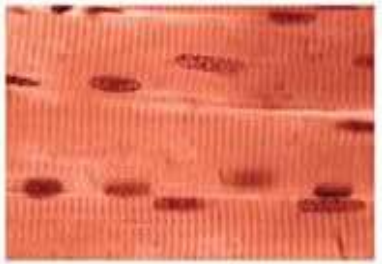
Types of Muscles

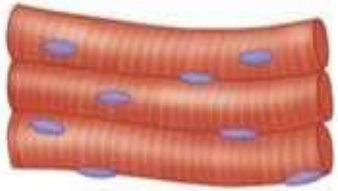
striated: appearance of light and dark stripes

Smooth muscle
- has narrow, tapered rod-shaped cells.
- has nonstriated, uninucleated fibers.
- occurs in walls of internal organs and blood vesselS.
- is involuntary.



Cardiac muscle
- has striated, tubular, branched, uninucleated fibers.
- occurs in walls of heart.
- is involuntary.





Skeletal muscle
- has striated, tubular, multinucleated fibers.
- is usually attached to skeleton.
- is voluntary.

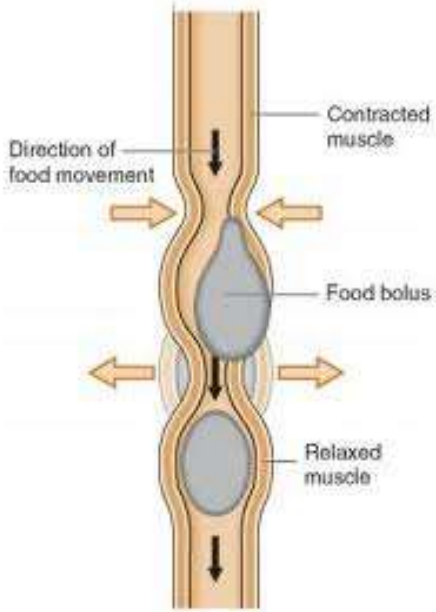
GROUP THOUGHT – What do we use our muscles for?

- Skeletal muscles contract exerting forces on the tendons
- Tendons then pull on the bones causing joint movement

- Generating body heat

- Postural muscles stabilise and maintain body positions

- Movement of substances within the body e.g. peristalsis



Now complete the Functions of Muscles section in your workbook!

Pairs activity – can you write a definition for the words below?

Contractility	ability to receive and respond to stimuli via generation of an electrical pulse which causes contraction of the muscle cells
Excitability	ability to shorten
Extensibility	ability to be stretched or extended
Elasticity	ability of a muscle fibre to recoil and resume its resting length

Now complete the Properties of Muscles section in your workbook!

Class thought…

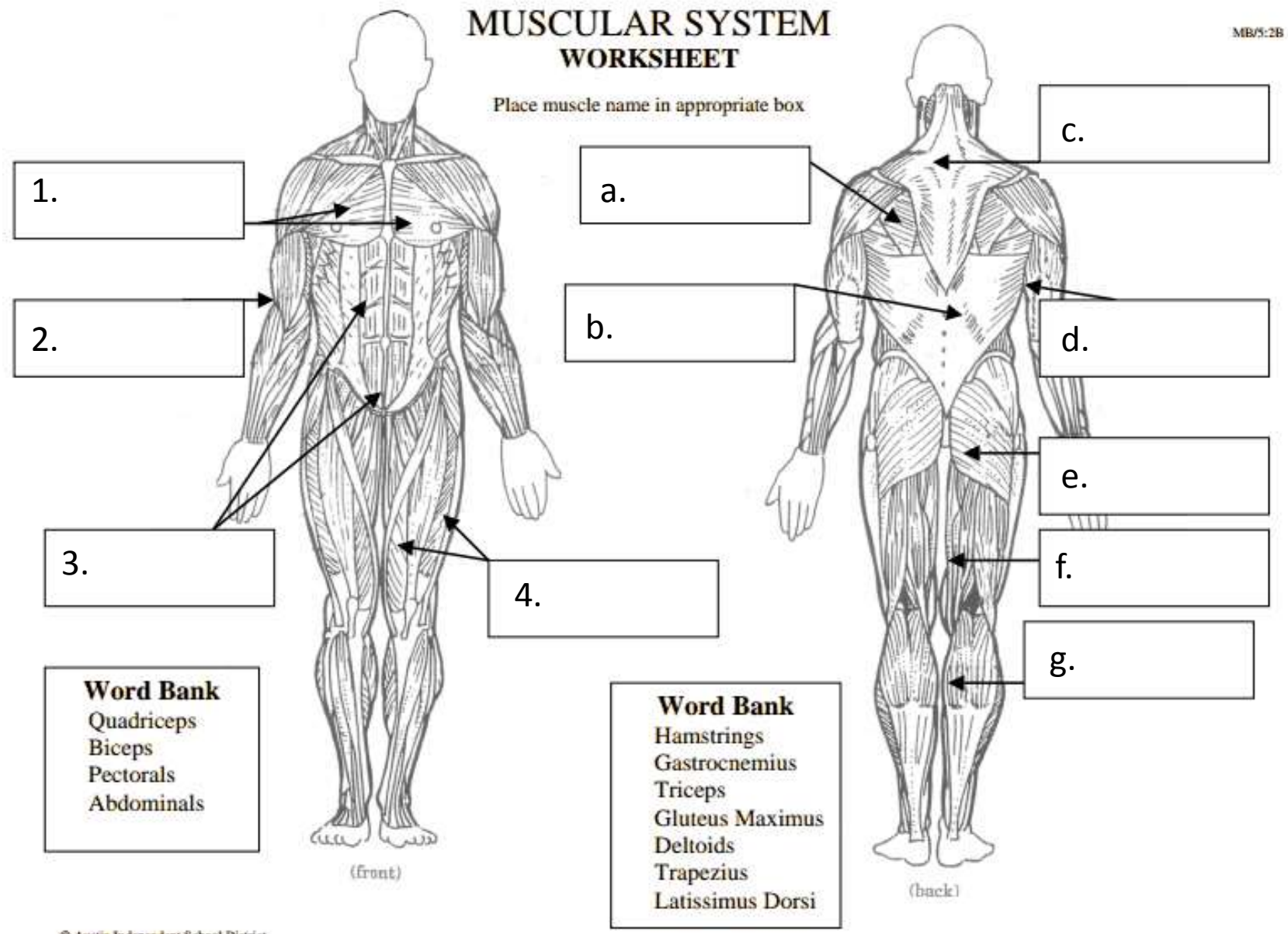
Why do you warm up before playing sport?

Individual Activity

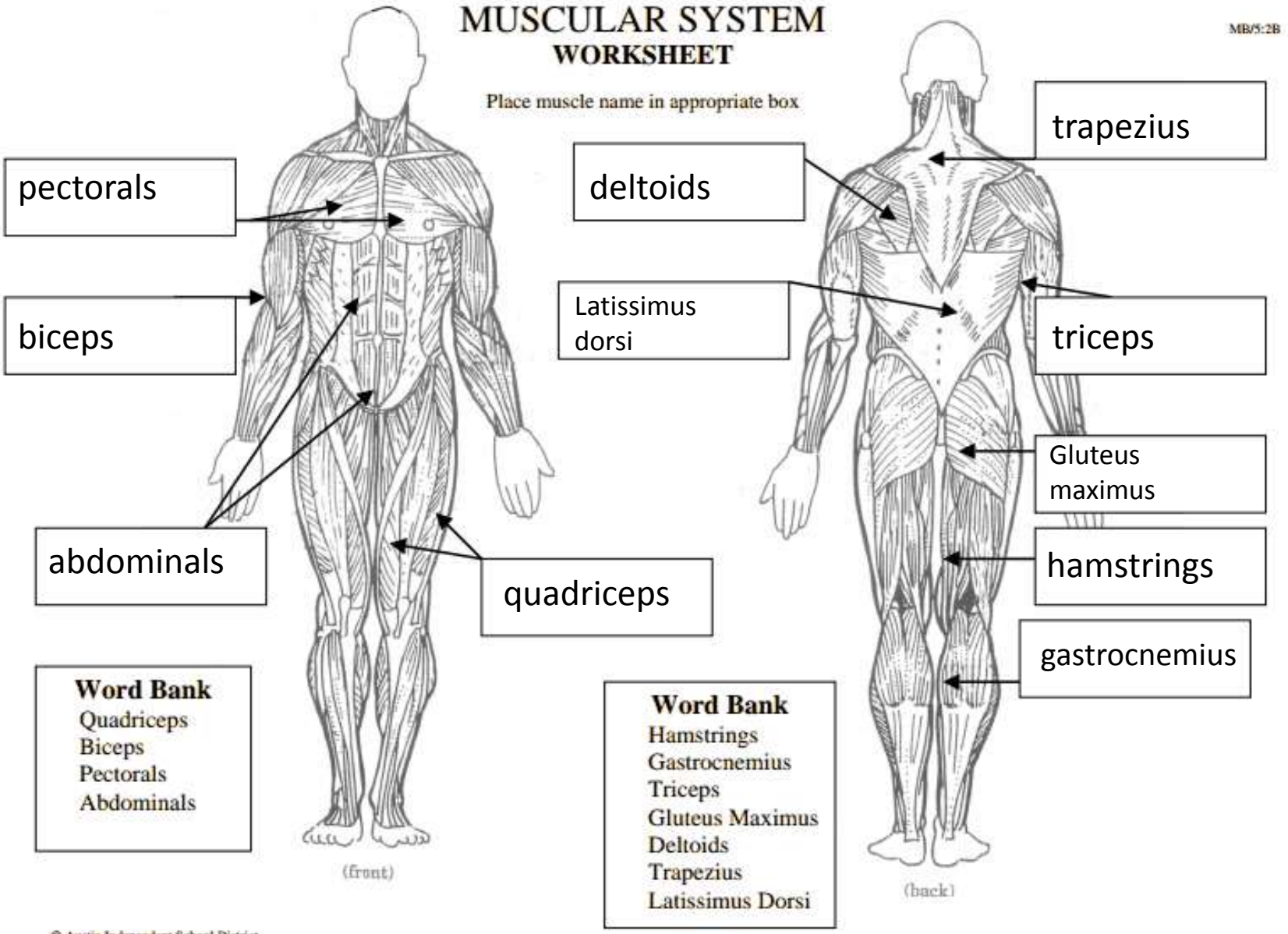
Carry out the investigation in your workbook

“The effect of temperature on muscle function”

STARTER– Which muscles do you already know?

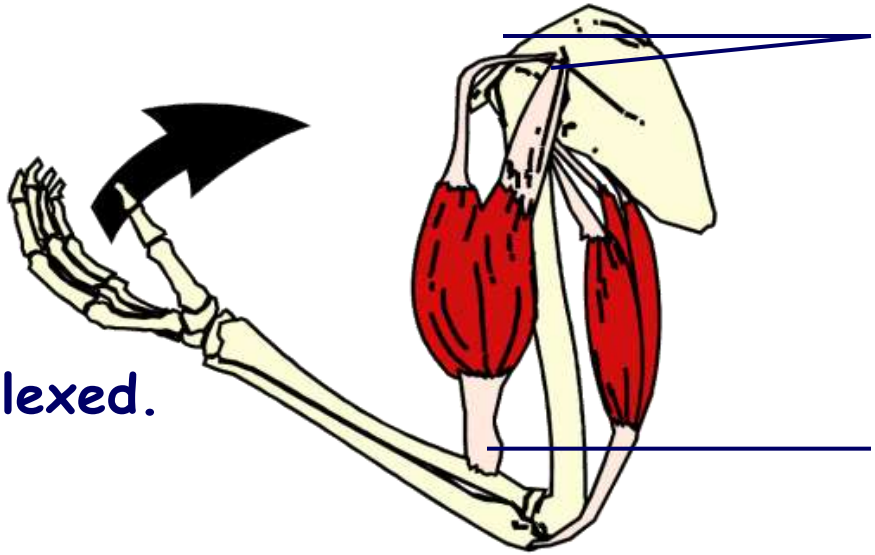


STARTER– Which muscles do you already know?



The Origin and Insertion

- When a muscle contracts, only one bone moves leaving the other stationary. The points at which the tendons are attached to the bone are known as the **origin** and the **insertion.**
- The **origin** is where the tendon of the muscle joins the **stationary** bone(s).
- The **insertion** is where the tendon of the muscle joins the **moving** bone(s).



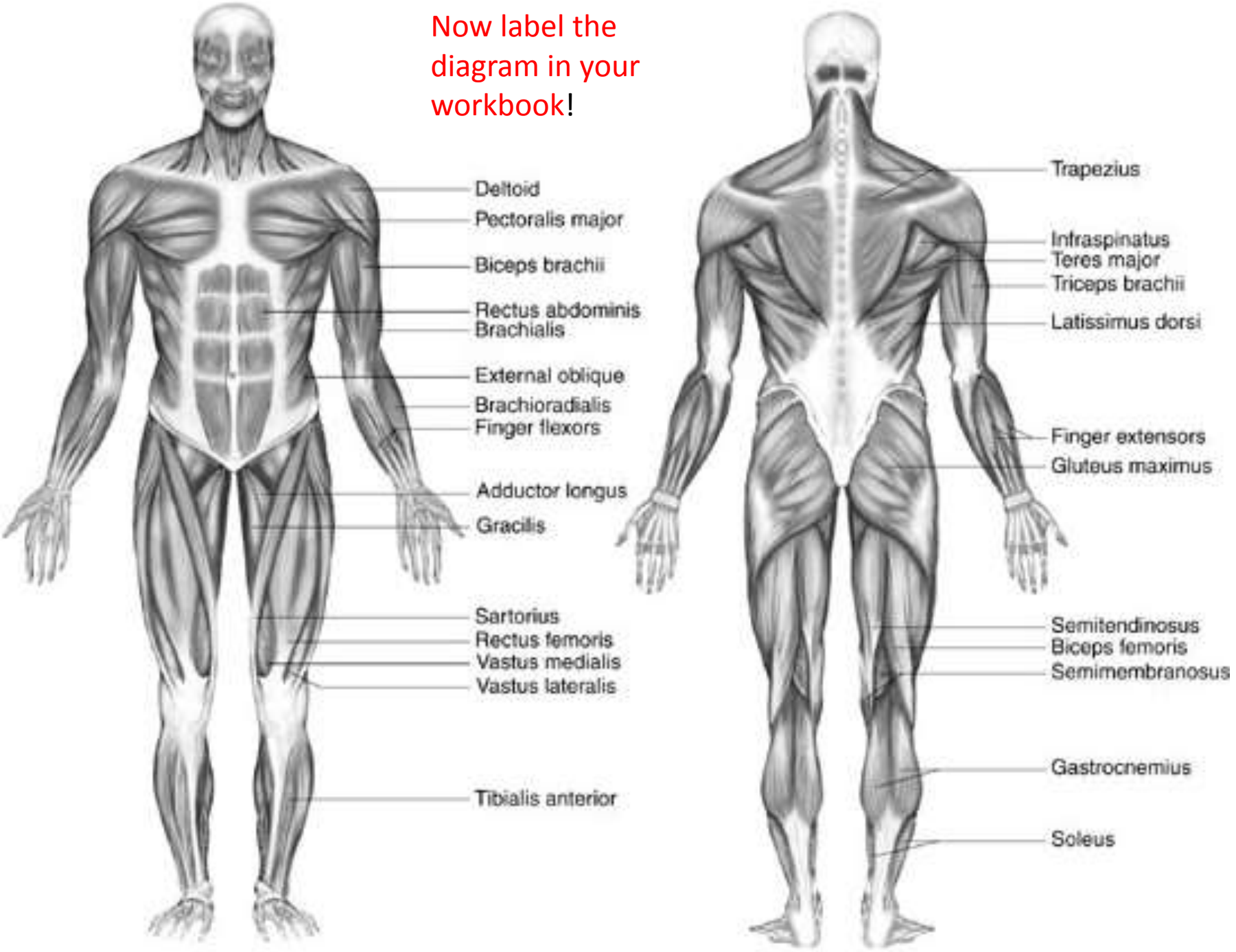
Now complete the section in your workbook!

The arm is being flexed.

The radius and ulna are the moving bones- **INSERTION**

The **humerus** and **scapula** are **stationary** bones- **ORIGIN**

Now label the diagram in your workbook!



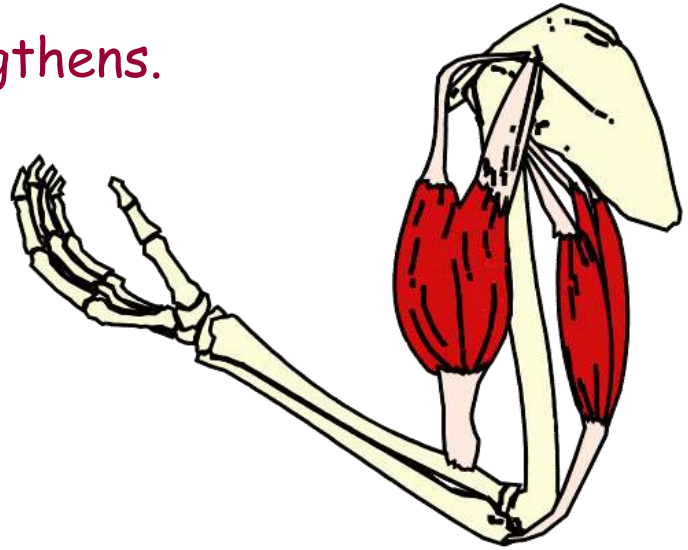
Antagonistic Muscles

- Skeletal muscles work across a **joint** and are attached to the bones by strong cords known as **tendons.**
- They work in **pairs**, each **contracting** or **relaxing** in turn to create movement.

- E.g Biceps brachii and triceps brachii = known as ANTAGONISTIC MUSCLE ACTION.

AS one muscle shortens the other one lengthens.

Movement of the arm at the elbow

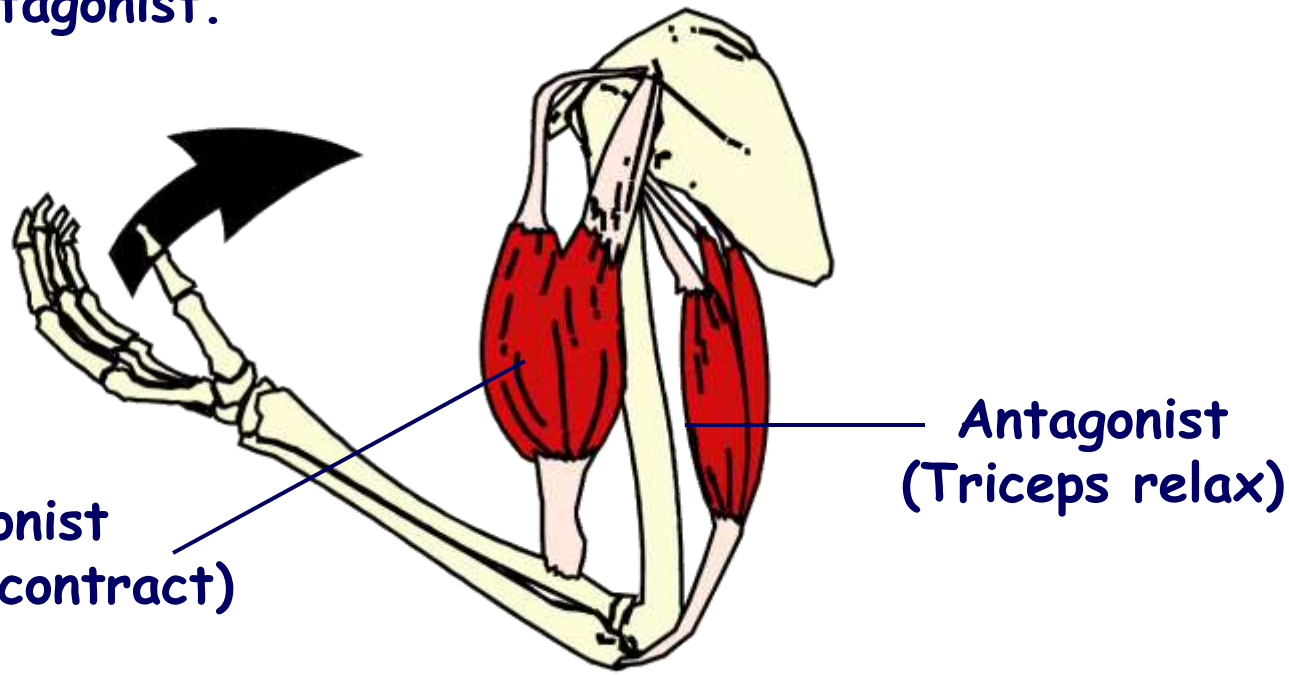


Now complete the How Muscles Work section in your workbook!

Flexion (Bending) of the Arm

- The muscle doing the work (contracting) and creating the movement is called the **agonist.**
- The muscle which is relaxing and letting the movement take place is called the **antagonist.**

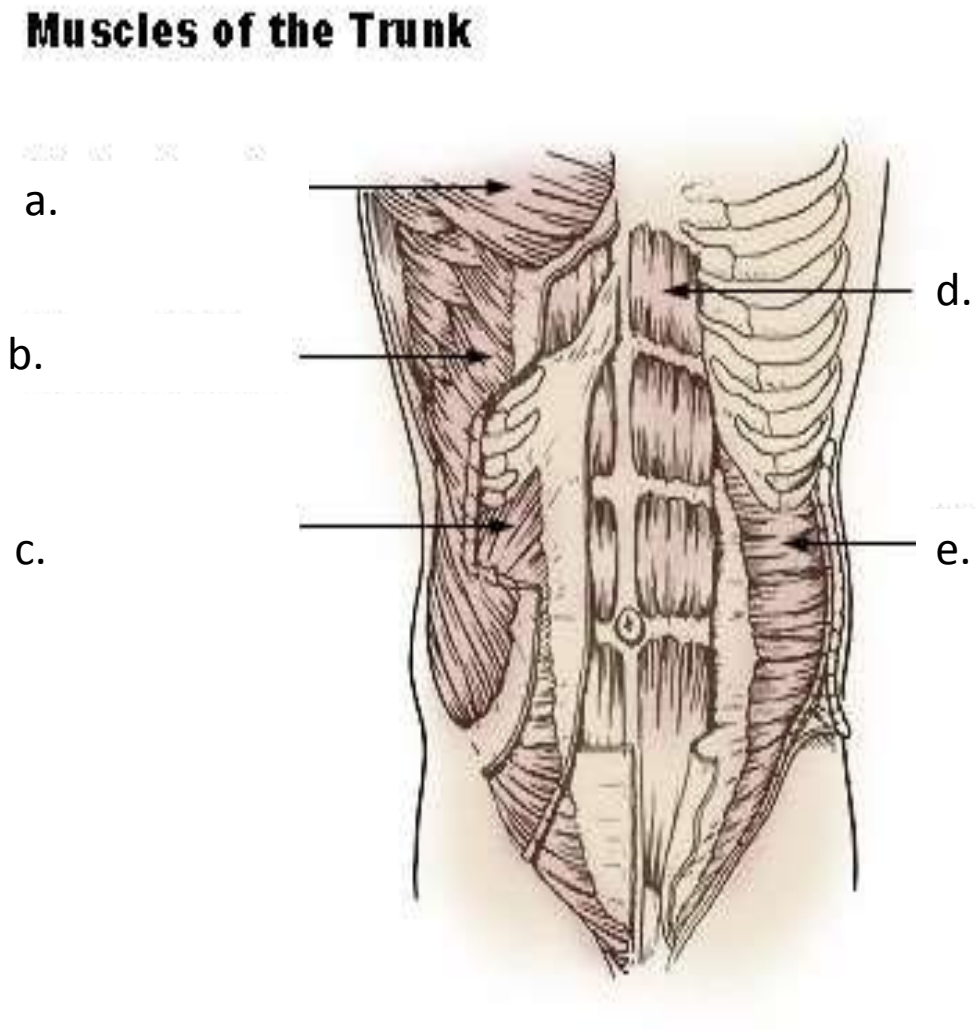
Now complete the How Muscles Work section in your workbook!



- Other muscles support the agnist in creating movement and these are called **synergists (neutraliser).**

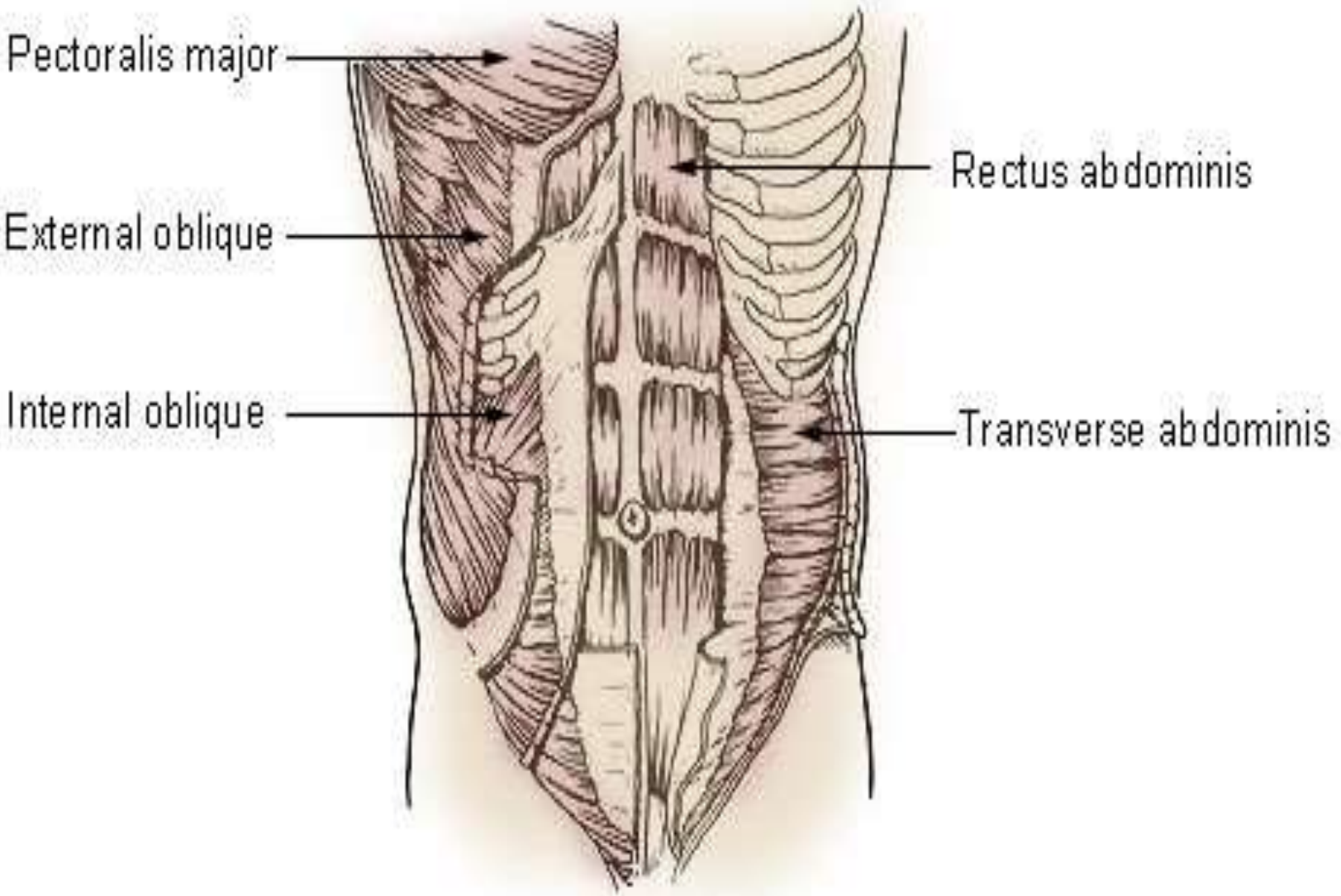
- **Fixator (stabliser)-the muscle that allows the agonist to work, stabilising the origin.**

STARTER – Label the diagram



- Transverse abdominus
- external oblique
- rectus abdominus
- internal oblique
- pectoralis major

Muscles of the Trunk



Learning Objectives

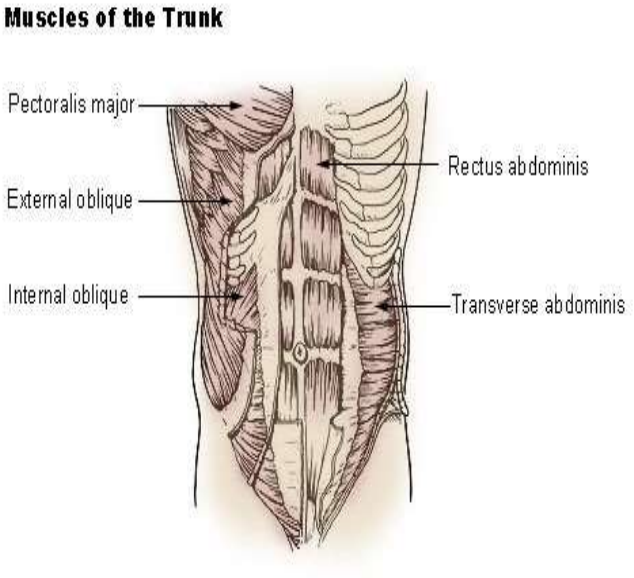
Everyone should

Identify the location of skeletal muscles in the trunk and upper extremities of the body

Most will

Describe strengthening exercises for the specific muscle groups mentioned

RECTUS ABDOMINIS



Flexion of the spine

ORIGIN: Pubis

INSERTION: Sternum and 5th – 7th ribs

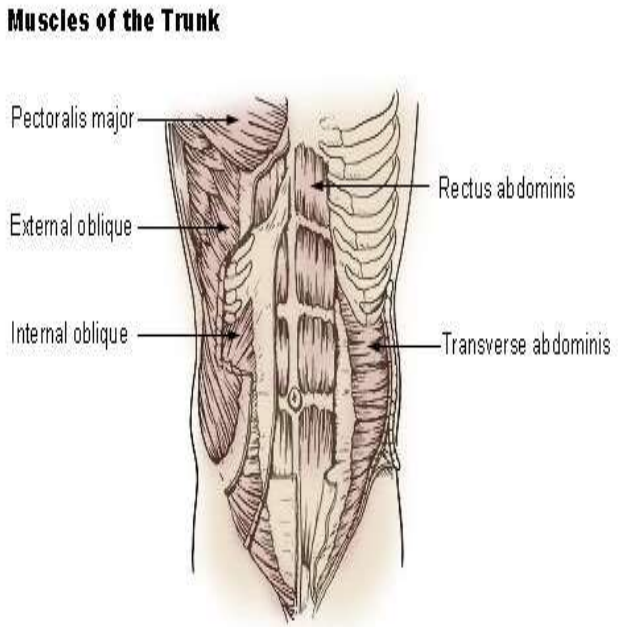
STRENGTHENING EXERCISE: Crunches

EXTERNAL OBLIQUES

MOVEMENT: Flexion

ORIGIN: Lower eight ribs

INSERTION: Ilium



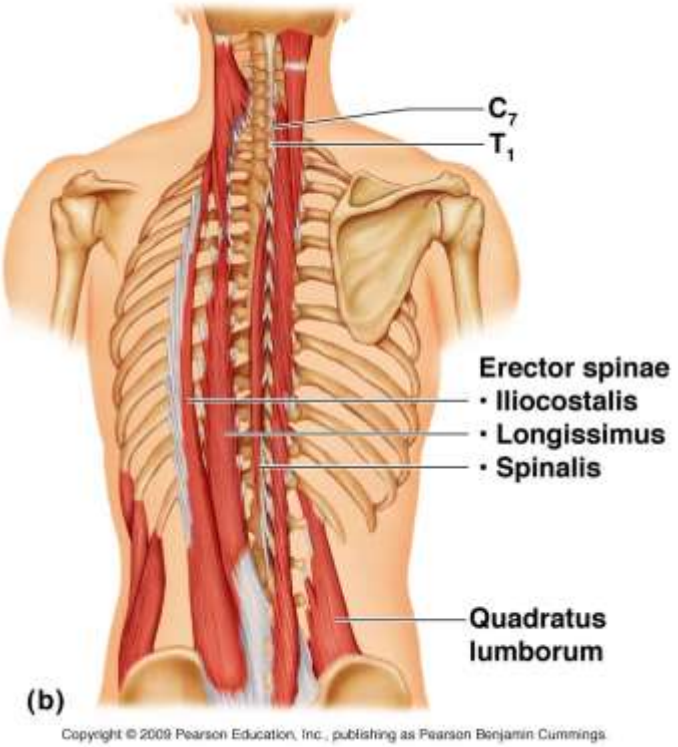
STRENGTHENING EXERCISE; Broomstick twists

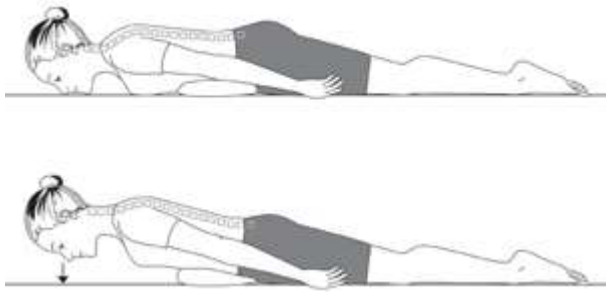
ERECTOR SPINAE

MOVEMENT: Extension

ORIGIN: ribs, vertebrae, ilium

INSERTION: ribs and vertebrae





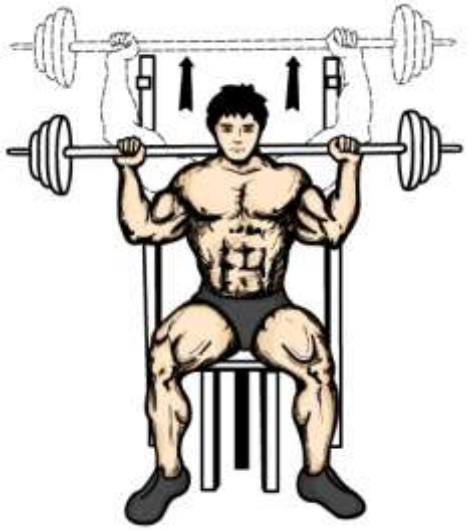
STRENGTHENING EXERCISE: Chest raises

DELTOID

ORIGIN; Clavicle and scapula

INSERTION: Lateral humerus

MOVEMENT: Flexion, extension and abduction of the shoulder



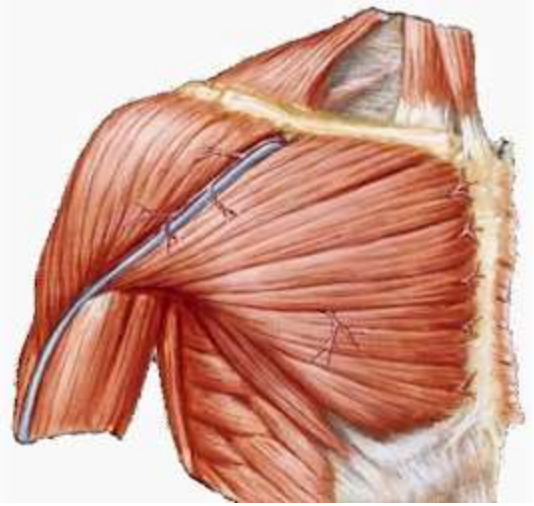
STRENGTHENING EXERCISE: Back press

PECTORALIS MAJOR

MOVEMENT- Flexion, Adduction of the shoulder

ORIGIN- Clavicle, sternum, anterior ribs

INSERTION- Humerus



STRENTHENING EXERCISE: Seated rows

BICEPS BRACHII

FLEXION

Origin: Scapula

Insertion: Radius and ulna

TRICEPS BRACHII

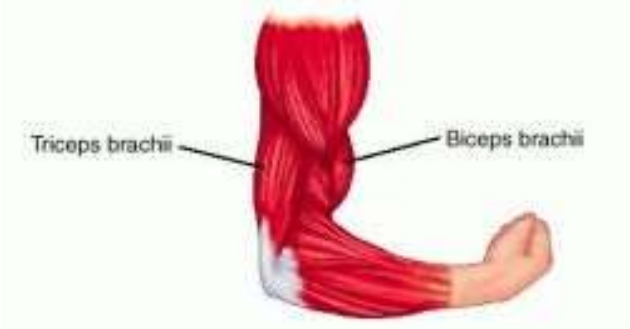
EXTENSION

Origin: Scapula and humerus

Insertion: Ulna

Agonist; Biceps

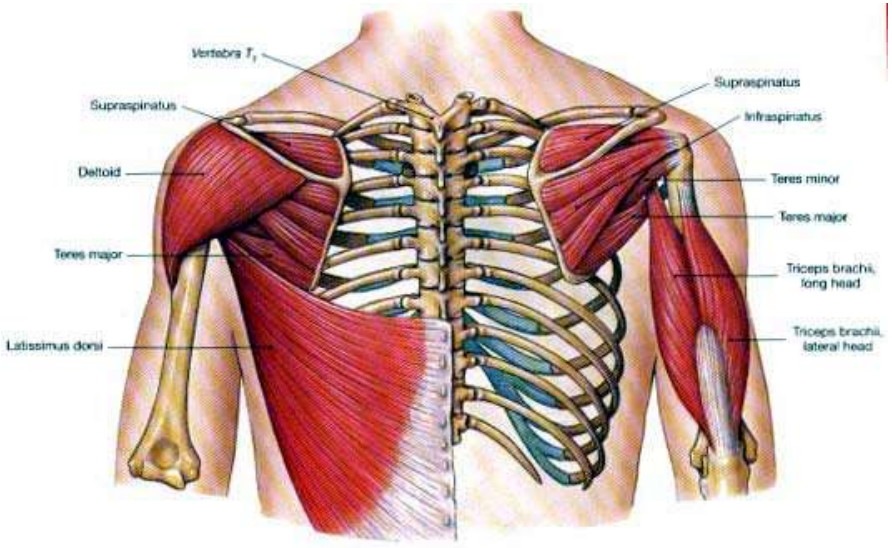
Antagonist; Triceps



Strengthening exercises:

Biceps curls and tricep extensions

LATISSIMUS DORSI



ORIGIN: sacrum, ileum, thoracic and lumbar vertebrae

INSERTION: Humerus

MOVEMENT: Adduction and extension of the shoulder

STRENGTHENING EXERCISE: Chin ups

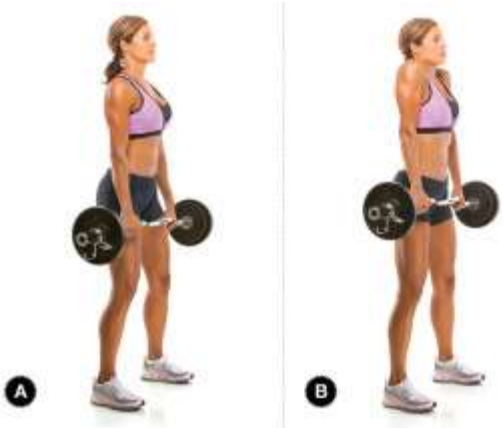
TRAPEZIUS

MOVEMENT- Extension of the shoulder

ORIGIN- cervical and thoracic vertebrae, base of skull

INSERTION- Clavicle and Scapula

STRENTHENING EXERCISE: Shrugs



STARTER –Chalk bodies!

- Draw around one of your group members using chalk (OUTSIDE!)
- Shade in and label all the muscles you can remember from last lesson!
- *HINT – it might be easier if you draw TWO outlines – anterior view and posterior view*

ILIOPSOAS

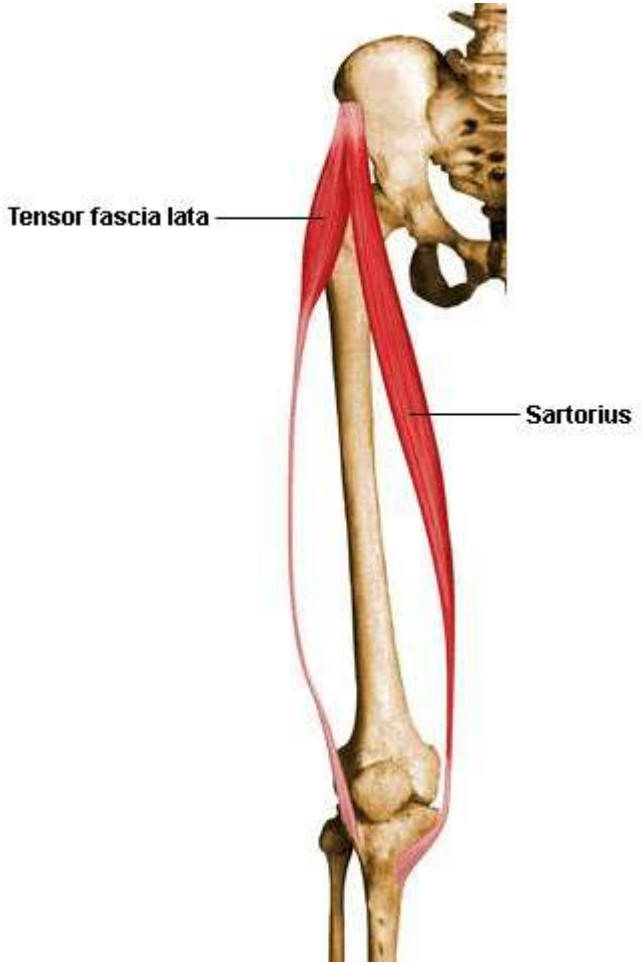
ORIGIN: Ilium and lumbar vertebrae

INSERTION: Inner femur

MOVEMENT: Flexion of hip

STRENGTHENING EXERCISE: Sit ups

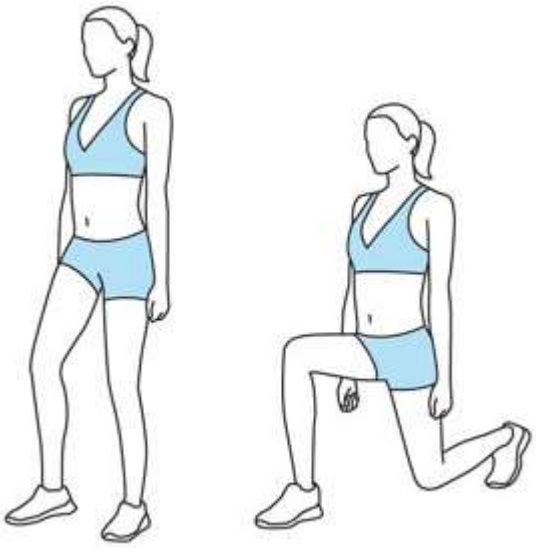
SARTORIUS



ORIGIN: Ilium

INSERTION: Medial tibia

MOVEMENT: Flexion, abduction and lateral rotation of hip

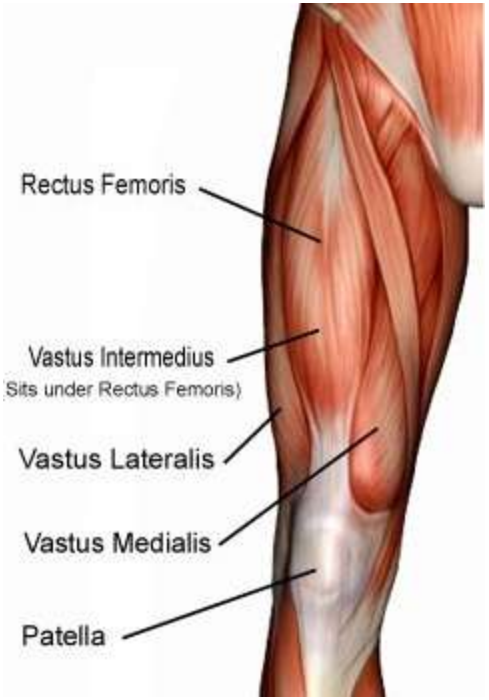


STRENGTHENING EXERCISE: Walking lunges

QUADRICEPS

Movement: Flexion, extension

Muscle	Origen
Rectus femoris	Ilium
Vastus lateralis	Femur
Vastus medialis	Femur
Vastus intermedius	Femur



Insertion: Tibia

Strengthening exercises:
Dumbbell squats

GLUTEUS MAXIMUS

MOVEMENT: Extension and rotation of th

ORIGIN: posterior ilum,
sacrum and coccyx

INSERTION: Femur

Strengthening exercises: one legged dead lifts

TIBIALIS ANTERIOR

Movement: Dorsiflexion and planarflexior

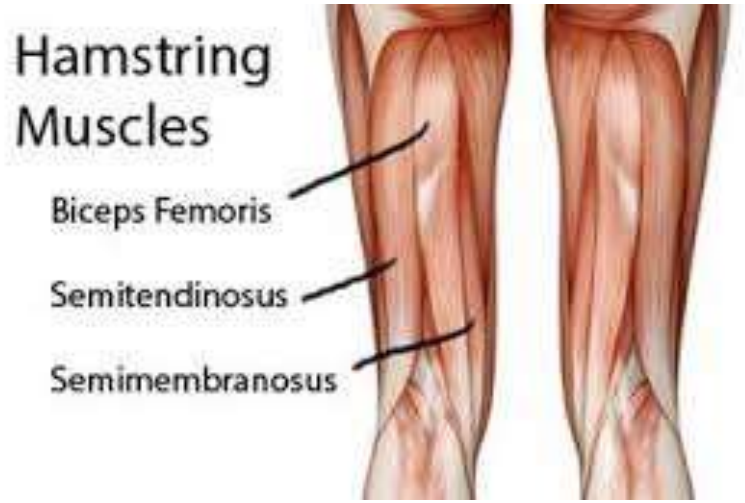
Muscles: Tibialis anterior

Origin: Lateral tibia

Insertion: 1st metatarsal and 1st cuneiform

Strengthening exercises: Toe raises

HAMSTRINGS



Movement: Flexion, extension

Muscle	Origen	Insertion
Biceps femoris	Ischium, femur	Fibula, lateral tibia
Semitendinosus	Ischium	Medial tibia
Semimembranosus	Ischium	Medial tibia

Strengthening exercises:
Leg curls

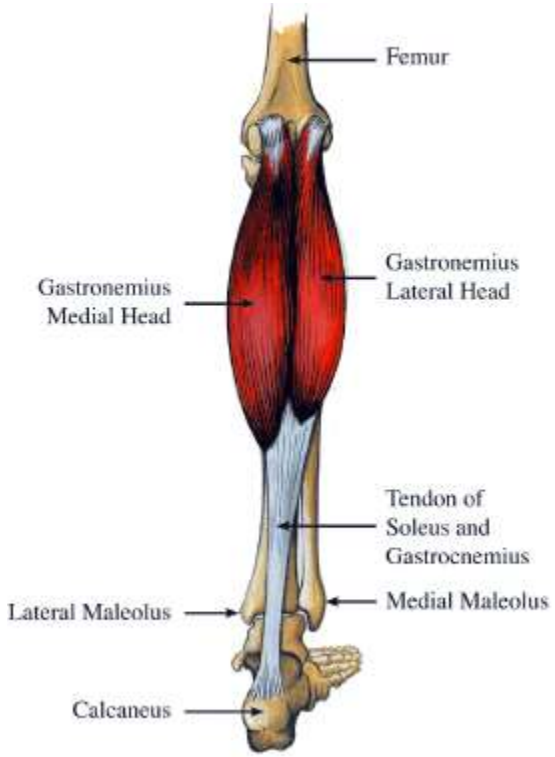
GASTROCNEMIUS

Movement:
Dorsiflexion and plantarflexion

Origin: Posterior femur

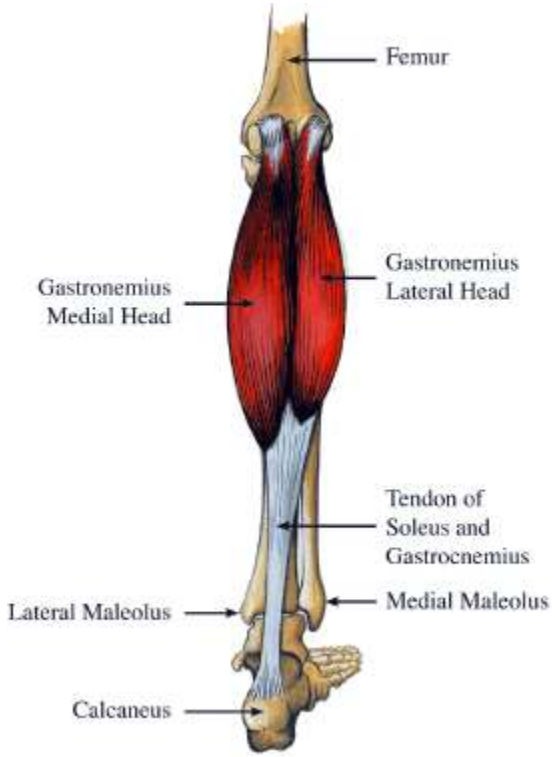
Insertion: Calcaneus via Achilles tendon

Strengthening exercises: Calf raises



SOLEUS

Movement:
Dorsiflexion and plantarflexion



Origin: Posterior tibia and fibula

Insertion: Calcaneus via Achilles tendon

Strengthening exercises: Seated calf raise

Next lesson you will get a pop quiz on muscles that will count for a classowrk grade for this bimester…….

STARTER –Muscles Pop Quiz!

A – frontalis

B – trapezius

C – deltoid

D – pectoralis major

E – triceps brachii

F – biceps brachii

G – latissimus dorsi

H – abdominal muscles

I – gluteus maximus

J – sartorius

K - biceps femoris

L – rectis femoris

M – gastrocnemius

N – achilles tendon

Learning Objectives

Everyone should

List the structures within muscle

Most will

Label a diagram of muscle with its structures

Some might

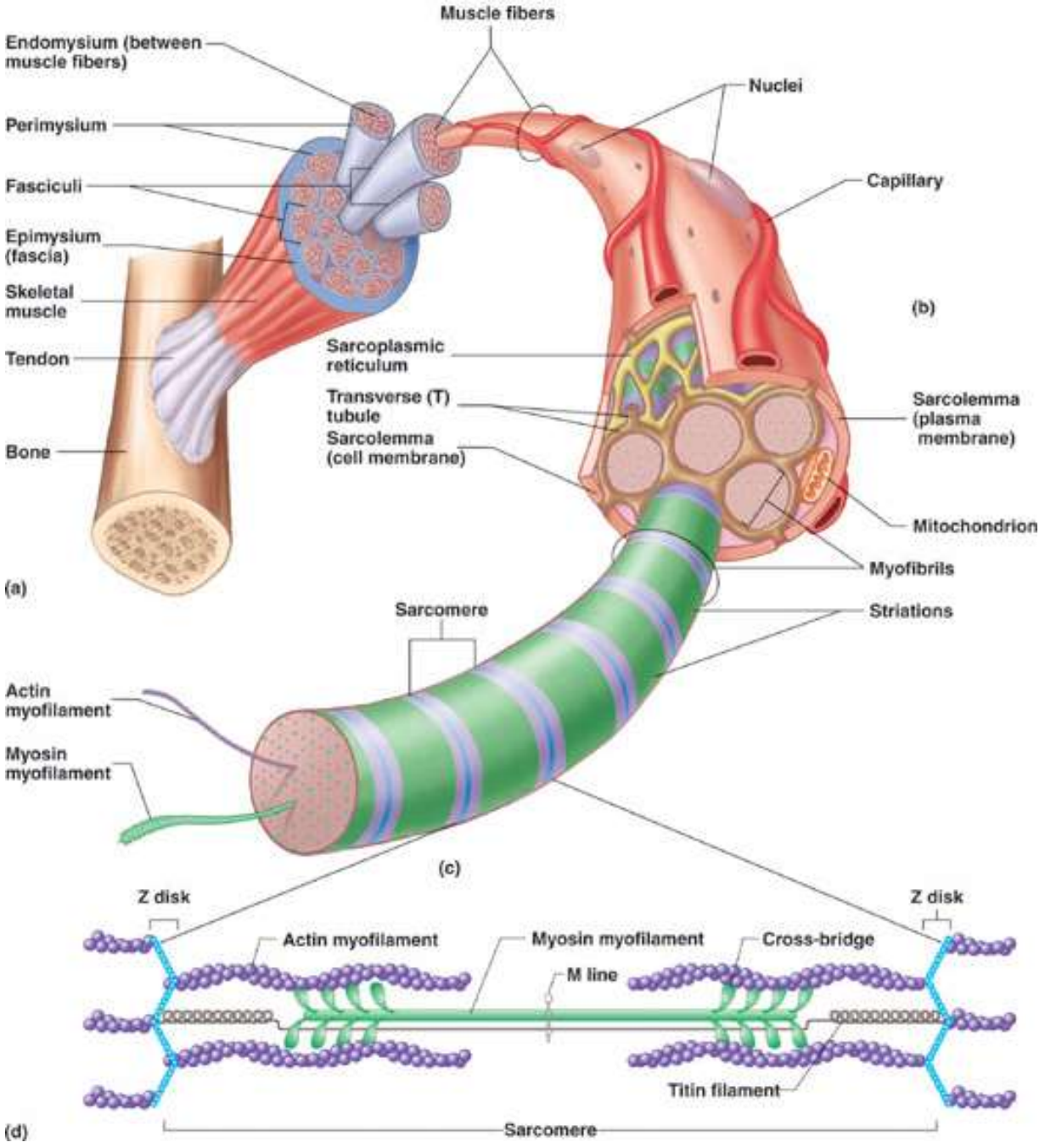
Annotate a diagram of muscle

GROUP ACTIVITY

Can you make a flow diagram to show the different **LEVELS** of skeletal muscle structure?

Start with …Skeletal muscle
End with……actin and myosin

Skeletal muscle
↓
Fasiculli
↓
Muscle fibre
↓
Myofibril
↓
Sarcomere
↓
Myofilaments
↓
Actin and myosin



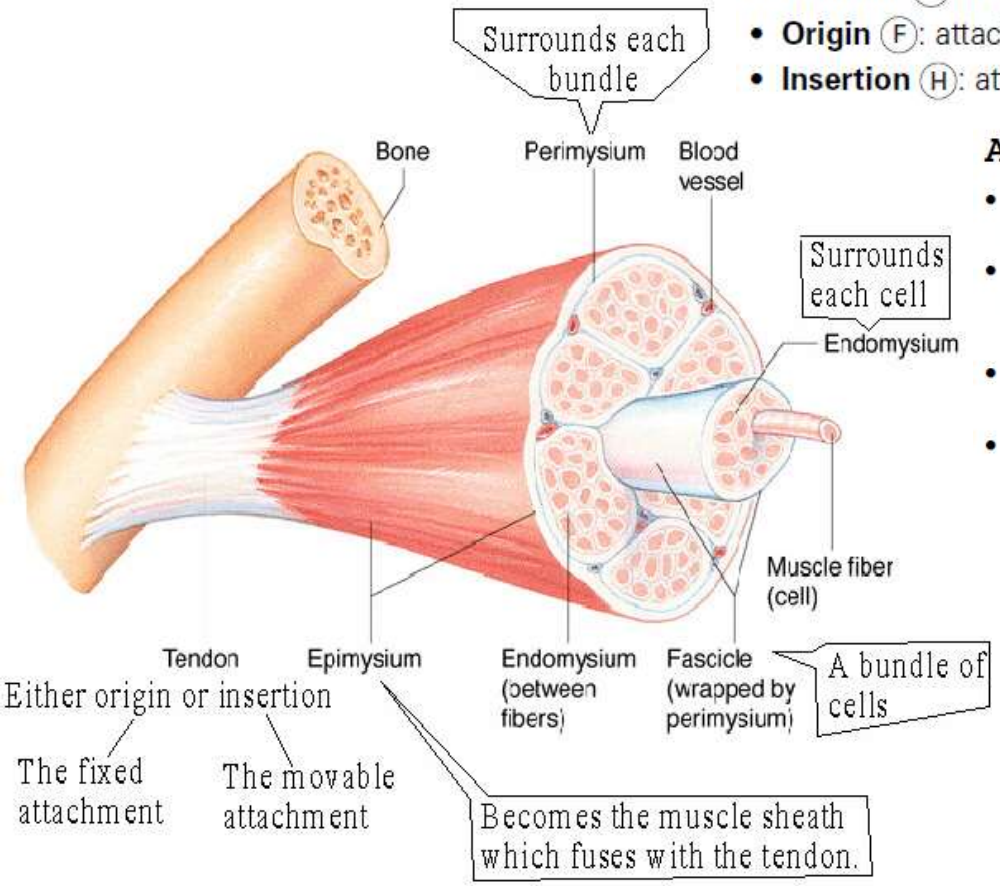
epi - upon or on
peri - around
endo - within
myo - muscle

Muscle Tissue

- **Smooth muscle** (A): walls of hollow organs, blood vessels, and respiratory passages
- **Cardiac muscle** (B): wall of heart (see Coloring Exercise 8-6)
- **Skeletal muscle** (C): makes up muscles under voluntary control; moves bones and face, compresses abdominal organs
  - Several muscle cell precursors fuse to form a single muscle cell, containing multiple nuclei
- Muscle cells are also called fibers

Skeletal Muscle: Attachments to Bones

- **Tendons** (D) attach skeletal muscle **body** (E) to bones
- **Origin** (F): attachment to less moveable bone (e.g., **scapula** (G))
- **Insertion** (H): attachment to more moveable bone (e.g., **radius** (I))



Anatomy of a Skeletal Muscle

- Muscle enveloped by a membrane, the **epimysium** (J)
  - The **tendon** (D) is a continuation of the epimysium
- Skeletal muscle body divided into **fascicles** (K)
  - Each fascicle surrounded by membrane; the **perimysium** (L)
  - **Blood vessels** (M) travel between fascicles
- Each fascicle made up of individual **muscle cells** (C)
  - Each muscle cell surrounded by **endomysium** (N) membrane
- Remember, you already colored a longitudinal view of skeletal muscle fibers in the top figure

Now annotate the diagram in your work book

Individual activity – colouring exercise

COLORING INSTRUCTIONS

Color each structure and its name at the same time, using the same color. On the top figure:

1. Color the nuclei black in each figure.
2. Color the muscle cells for each muscle type (Ⓐ to Ⓒ).

COLORING INSTRUCTIONS

On the middle figure:

1. Color the bones (Ⓖ, Ⓘ), tendons Ⓓ, and the muscle body Ⓔ. Use light colors for the bones (Ⓖ, Ⓘ) and the muscle body.
2. Using two dark colors, draw circles at the origins Ⓕ and insertion Ⓗ of the muscle.

COLORING INSTRUCTIONS

On the bottom figure:

1. Color the bone Ⓘ, tendon Ⓓ, and epimysium Ⓙ.
2. Color the perimysium Ⓛ around the extruded fascicle and in the cross section.
3. Color the fascicle Ⓚ that is labeled in the cross section, and one additional fascicle.
4. Color the endomysium Ⓝ around the extruded muscle fiber. Outline some muscle fibers in the cross-section with the same color, because the endomysium surrounds all fibers.
5. Color the ends of some muscle fibers Ⓒ and the blood vessels Ⓜ.

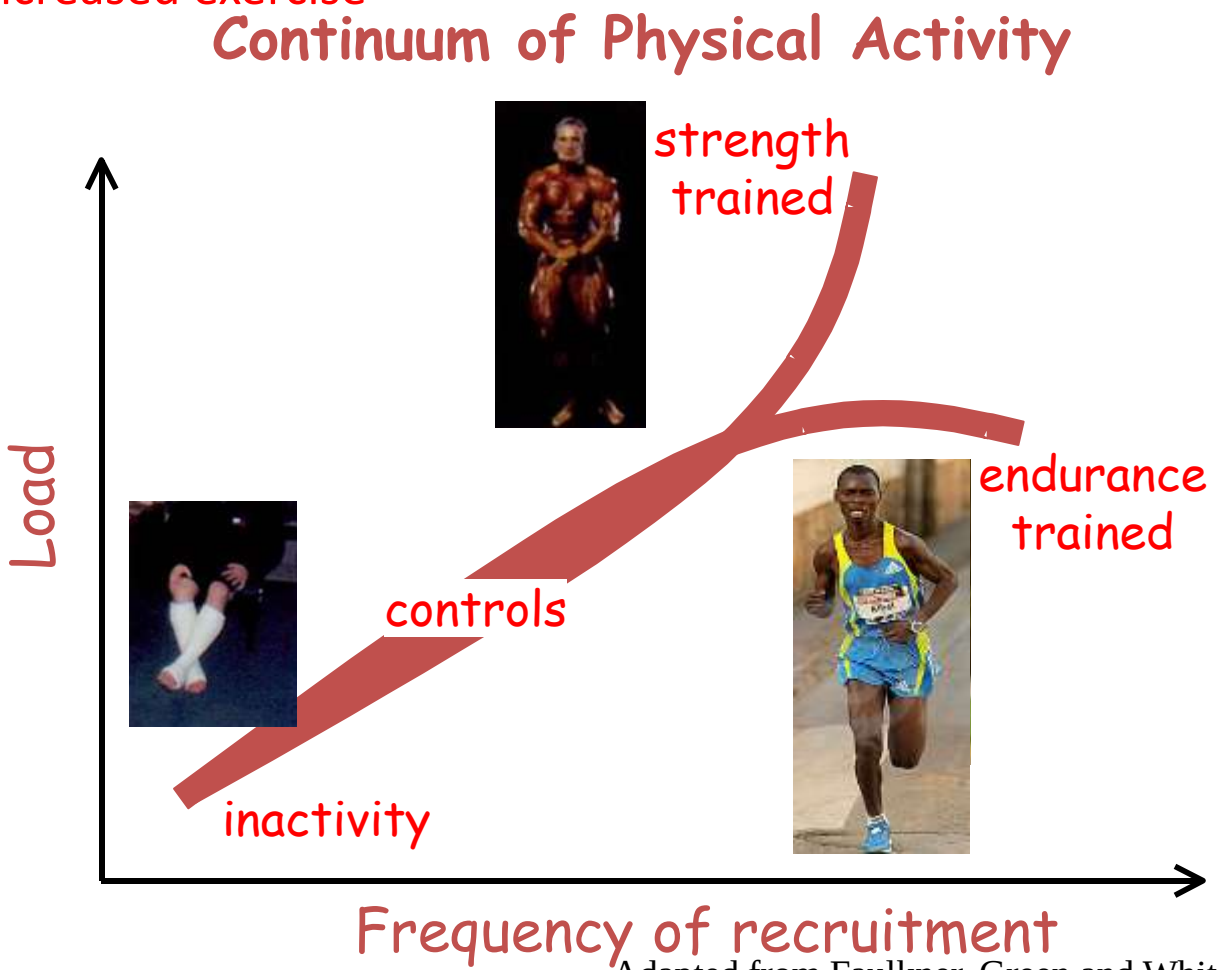
Muscle is plastic!

Muscle "adapts" to meet the habitual level of demand placed on it, i.e. level of physical activity. This results in muscular **hypertrophy** which is a result in a increase of **myofibrils** as a result of increased exercise

Level of physical activity determined by the frequency of **recruit-ment** and the **load.**

Increase muscle use
– endurance training
– strength training
(cannot be optimally trained for both strength and endurance)

Decrease muscle use
– prolonged bed rest
– limb casting
– denervation
– space flight.

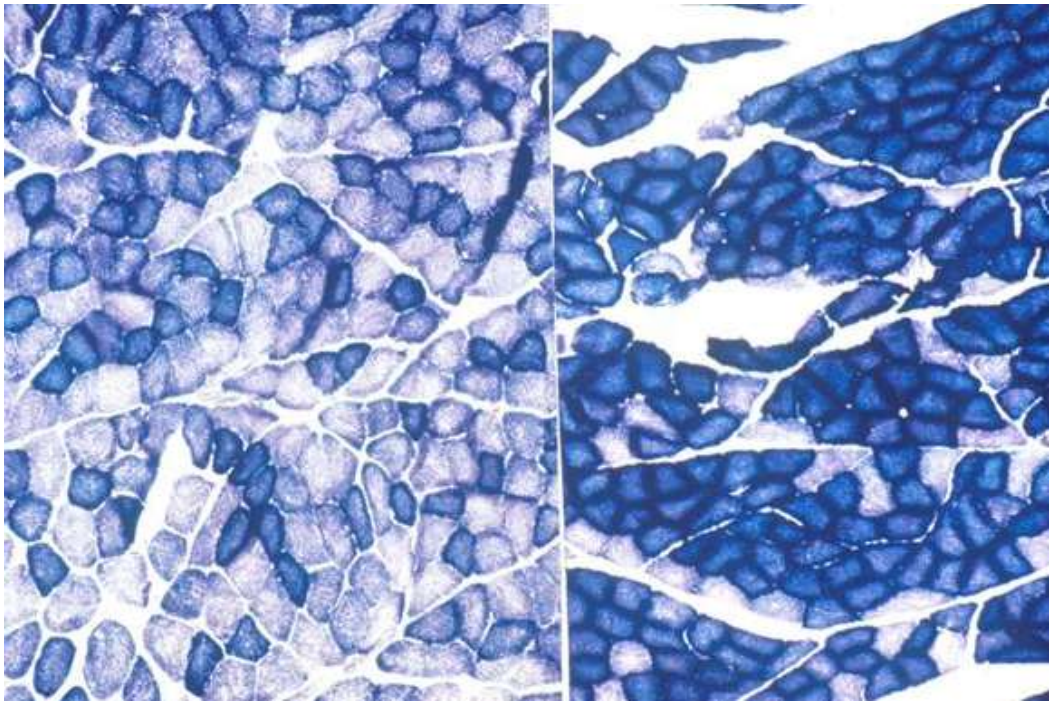


Adapted from Faulkner, Green and White
In: *Physical Activity, Fitness, and Health*, Ed. Bouchard, Shephard and Stephens
Human Kinetics Publishers, 1994

Endurance training

Little hypertrophy but major biochemical adaptations within muscle fibers.

Increased numbers of mitochondria; concentration and activities of oxidative enzymes (e.g. succinate dehydrogenase, see below).



Control

12-weeks
treadmill running

Succinate dehy-
drogenase (SDH)
activity:
Low activity light
High activity dark

Images courtesy of John Faulkner and Timothy White

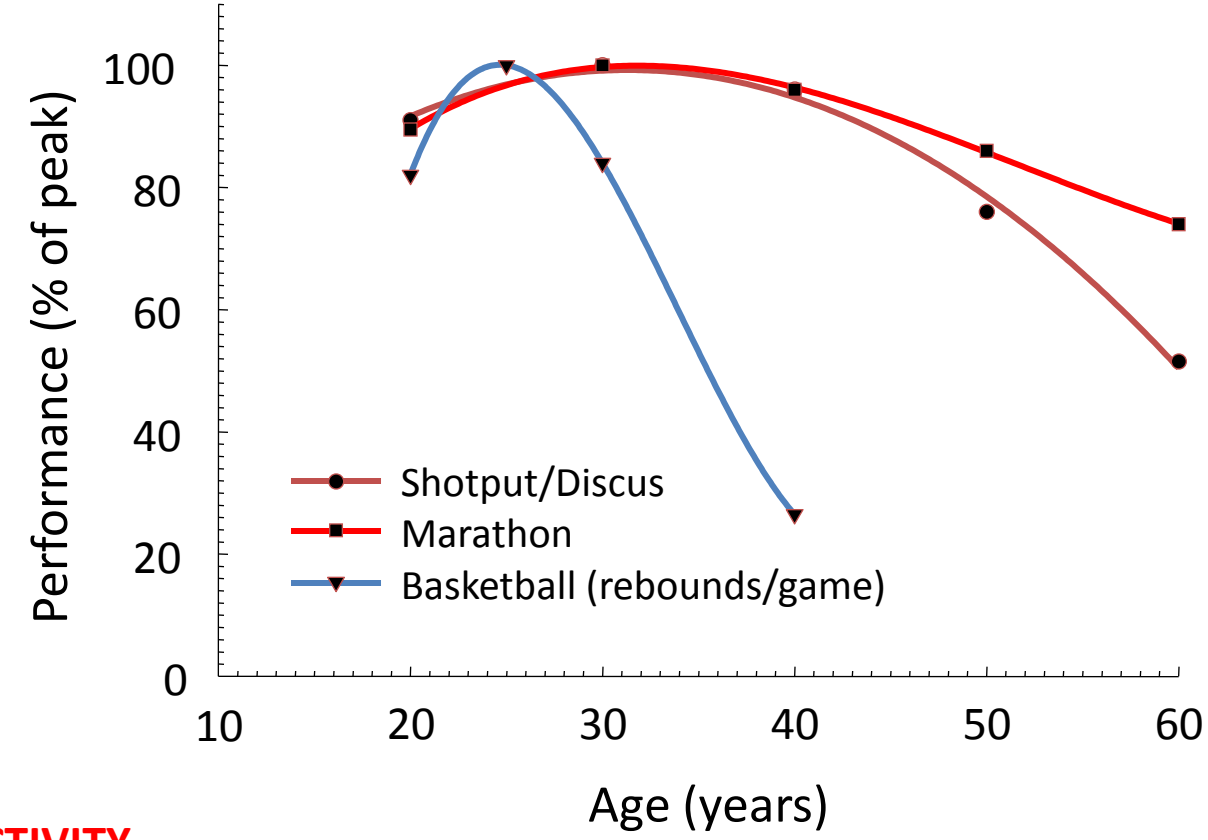
Disuse causes atrophy -- USE IT OR LOSE IT!

- Muscular **Atrophy** is a result of decrease in **myofibrils** through disuse
- Individual fiber atrophy (loss of myofibrils) with no loss in fibers.
- Effect more pronounced in Type II fibers.
- “Completely reversible” (in young healthy individuals).

Control Cast for 6 weeks

Images courtesy of John Faulkner

Performance Declines with Aging --despite maintenance of physical activity



GROUP ACTIVITY

- Can you write a CONCLUSION for this graph?
- **Try and explain what you see – not just decribe!**

D.H. Moore (1975) *Nature* 253:264-265.
NBA Register, 1992-1993 Edition

STARTER

Try the skeletal muscle matching activity in your work book!

Match the structure with the correct description.

B	The connective tissue that surrounds a muscle	A. Endomysium
F	Connective tissue that encloses a bundle of muscle fibers	B. Epimysium
C	Bundle of muscle fibers	C. Fascicle
A	Connective tissue wrapped around each muscle fiber	D. Fiber
G	Strong cord of fibrous connective tissue; extends from the muscle to the bone	E. Myofibril
D	Muscle cell	F. Perimysium
E	Smaller fibers that are found in a muscle fiber; consist of thick and thin myofilaments	G. Tendon

Learning Objectives

Everyone should

Draw and label a neuron

Define a reflex arc

Most will

Describe the structure of a motor unit

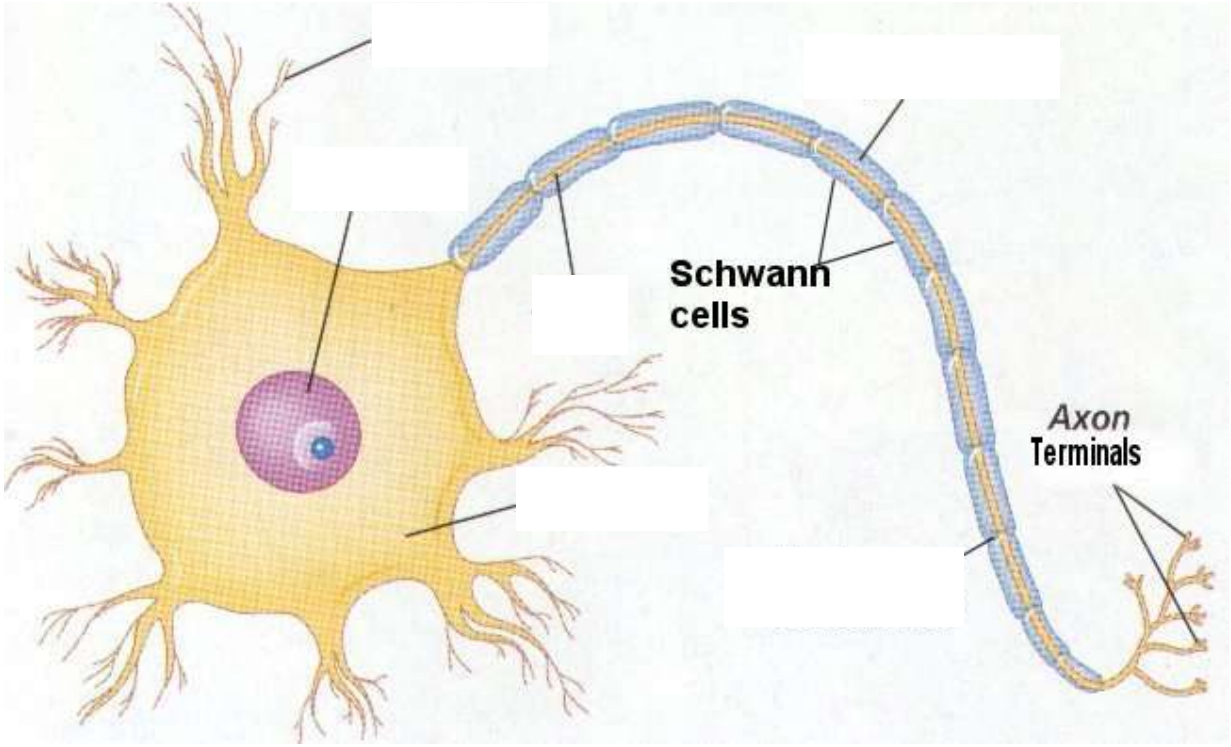
Distinguish between the 3 different types of motor unit

Some might

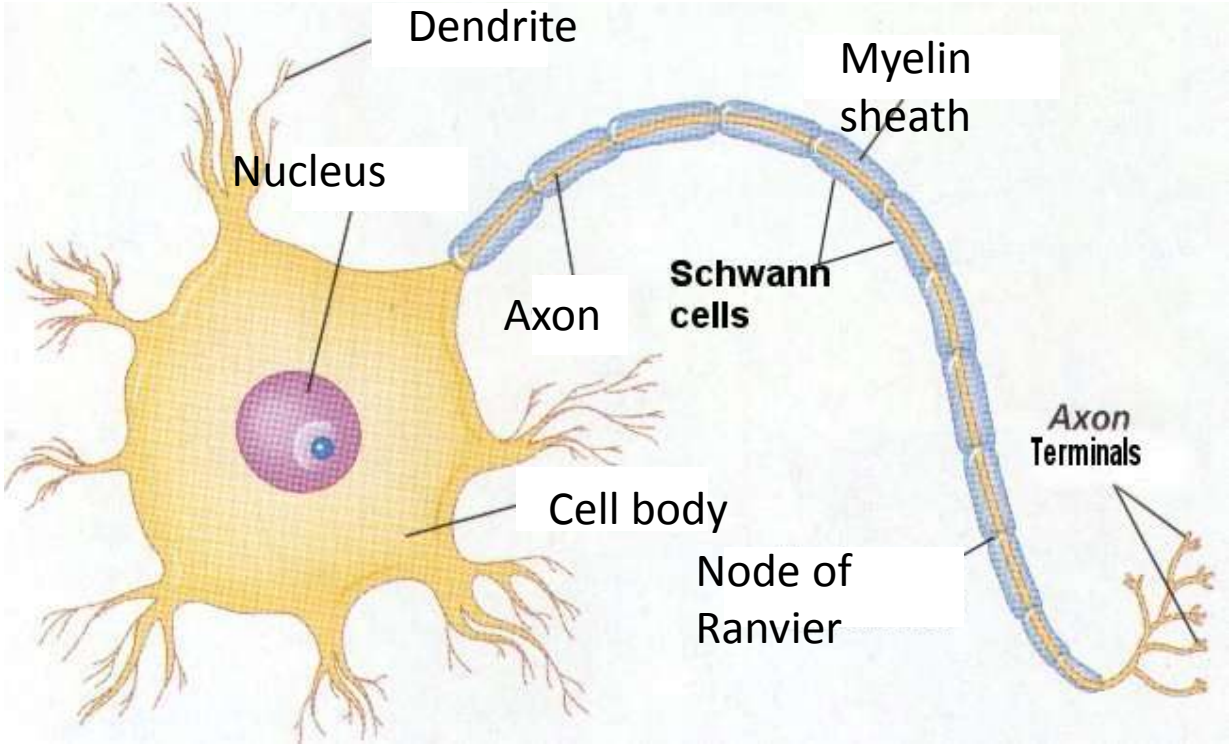
Predict the ratio of motor units in an athlete depending on their sport

GROUP ACTIVITY

Can you label me?

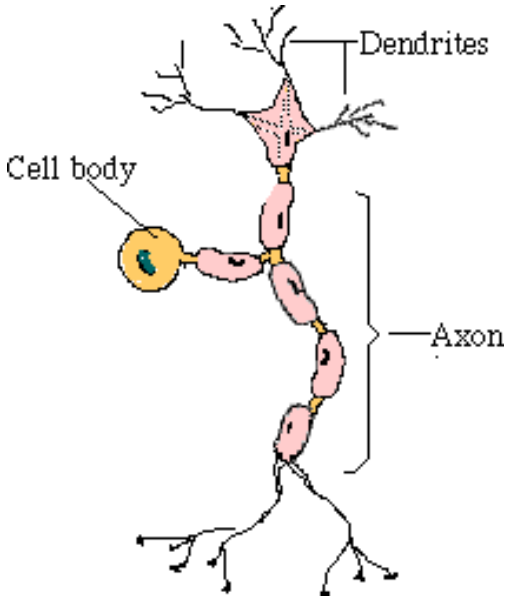


- Words that might help:
- Dendrite
- Nucleus
- Axon
- Node of Ranvier
- Myelin sheath
- Cell body

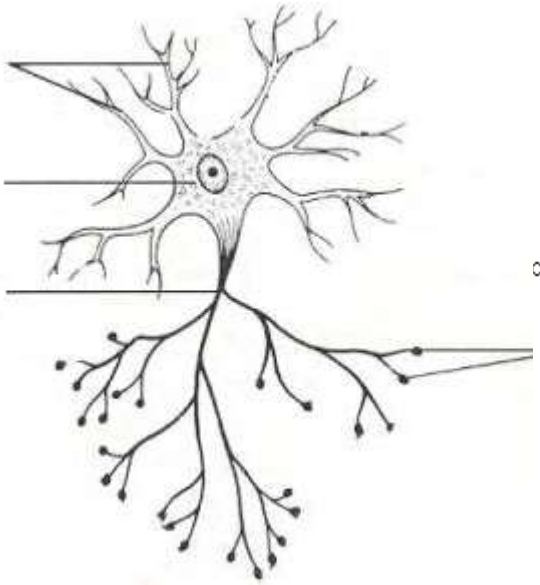


Now complete the structure of a neuron section in your workbook

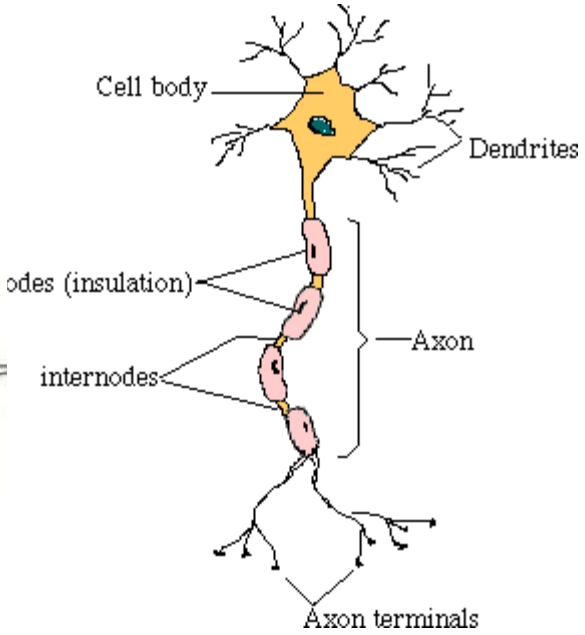
3 main types of nerve cells



sensory neurone

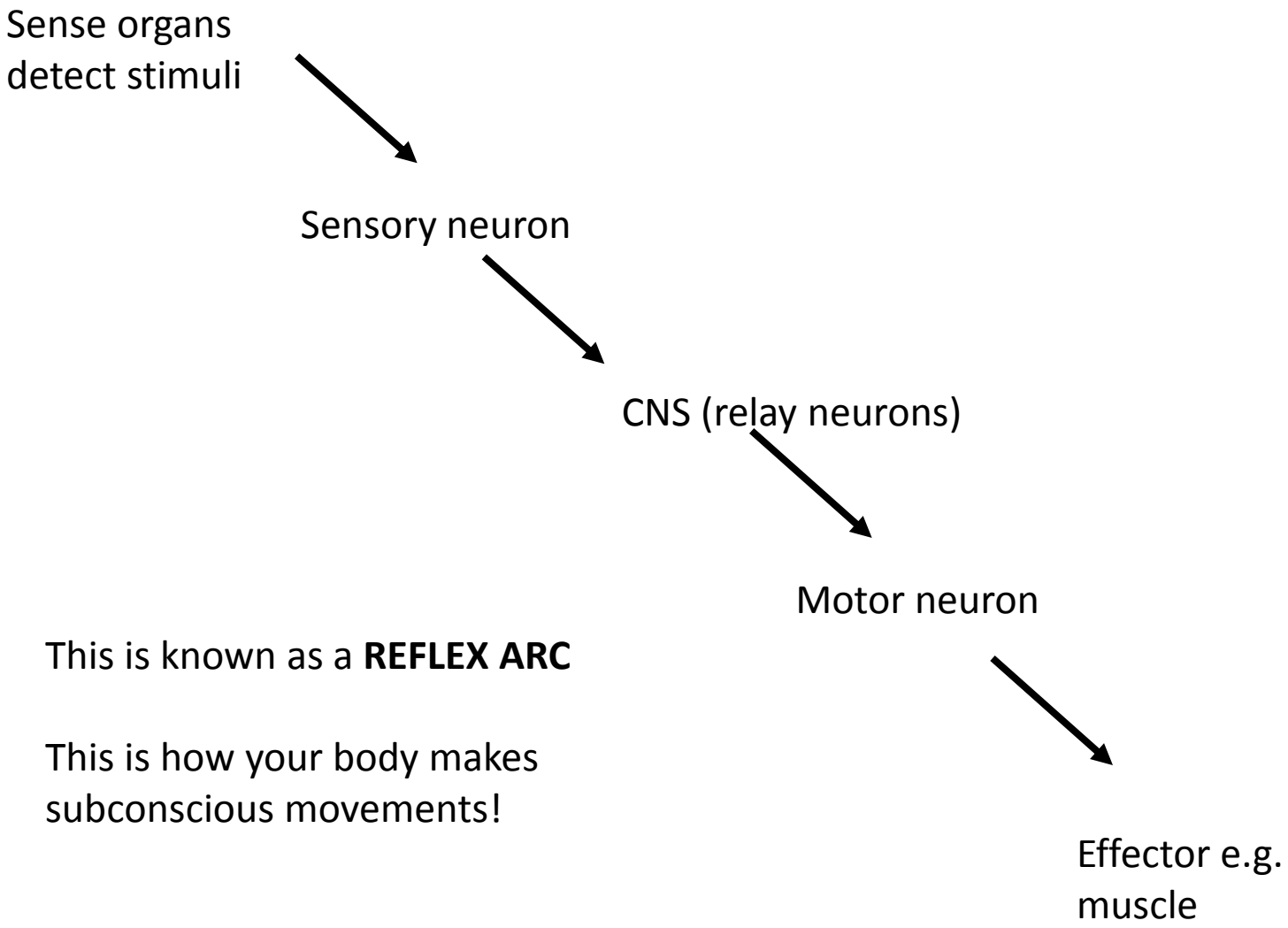


relay neurone



motor neurone

Receptors and Sense Organs



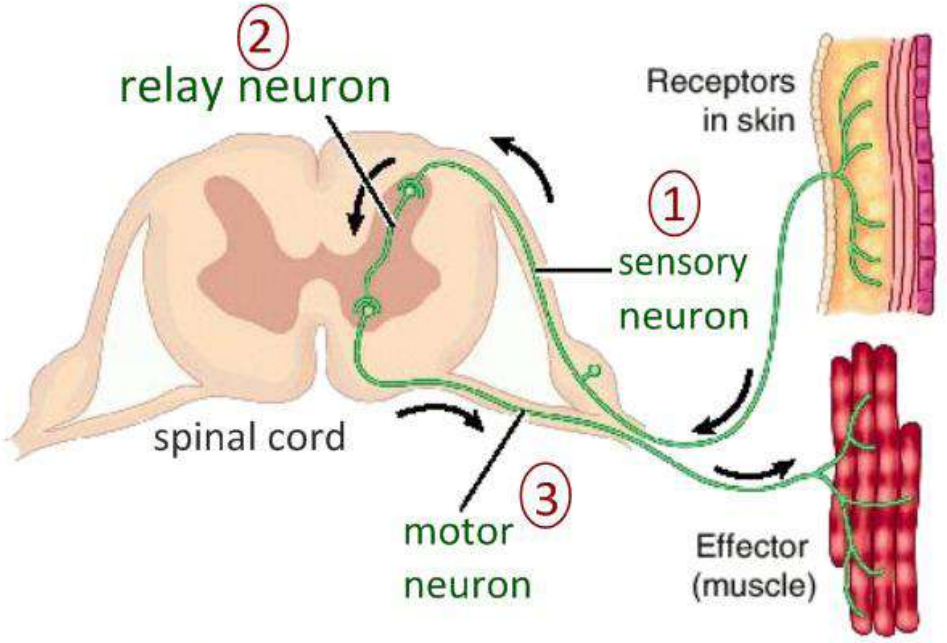
This is known as a **REFLEX ARC**

This is how your body makes subconscious movements!

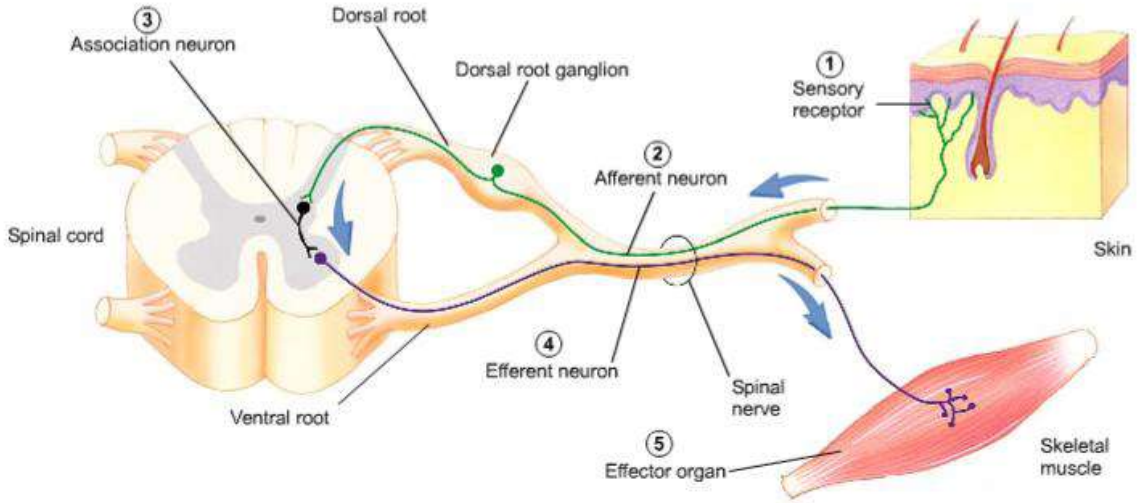
The reflex arc

Nerve impulse conduction:

1. receptor to CNS: sensory neurons
2. within CNS: relay neurons
3. CNS to effectors: motor neurons



Animation:

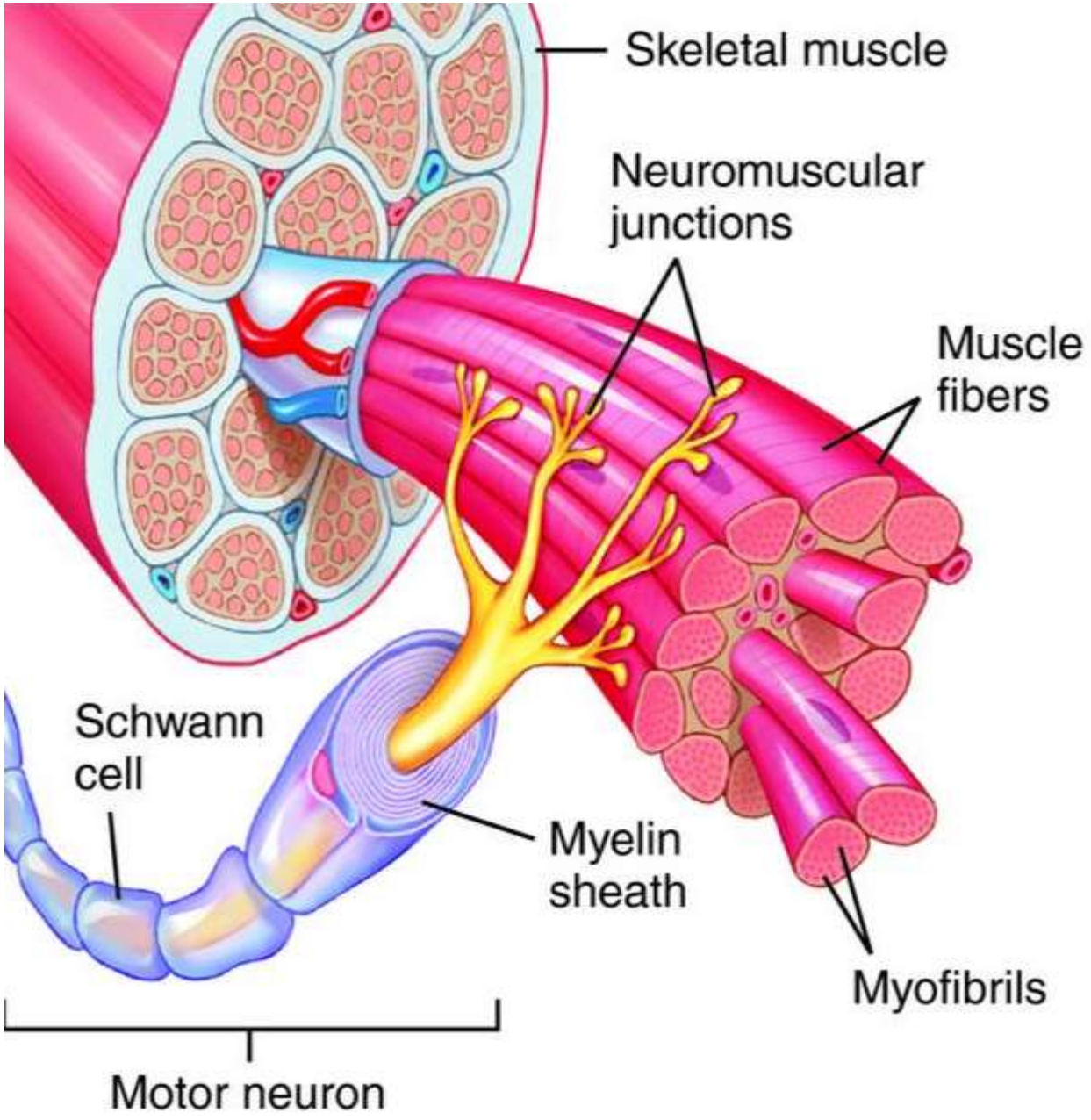


http://medical-dictionary.thefreedictionary.com/ARC

Now complete the Reflex Arc section of your workbook

FIGURE 12.19 **Reflex Arc**

http://msjensen.cchd.umn.edu/1135/Links/Animations/Flash/0016-swf_reflex_arc.swf



A MOTOR UNIT

Single motoneuron and the muscle fibers it **innervates**

Large no. of fibers per motoneuron = large forces

When a motor unit is innervated all the muscle fibres contract at once.

This is called the **all-or-nothing response**

To innervate – supply an organ orbody part with nerves

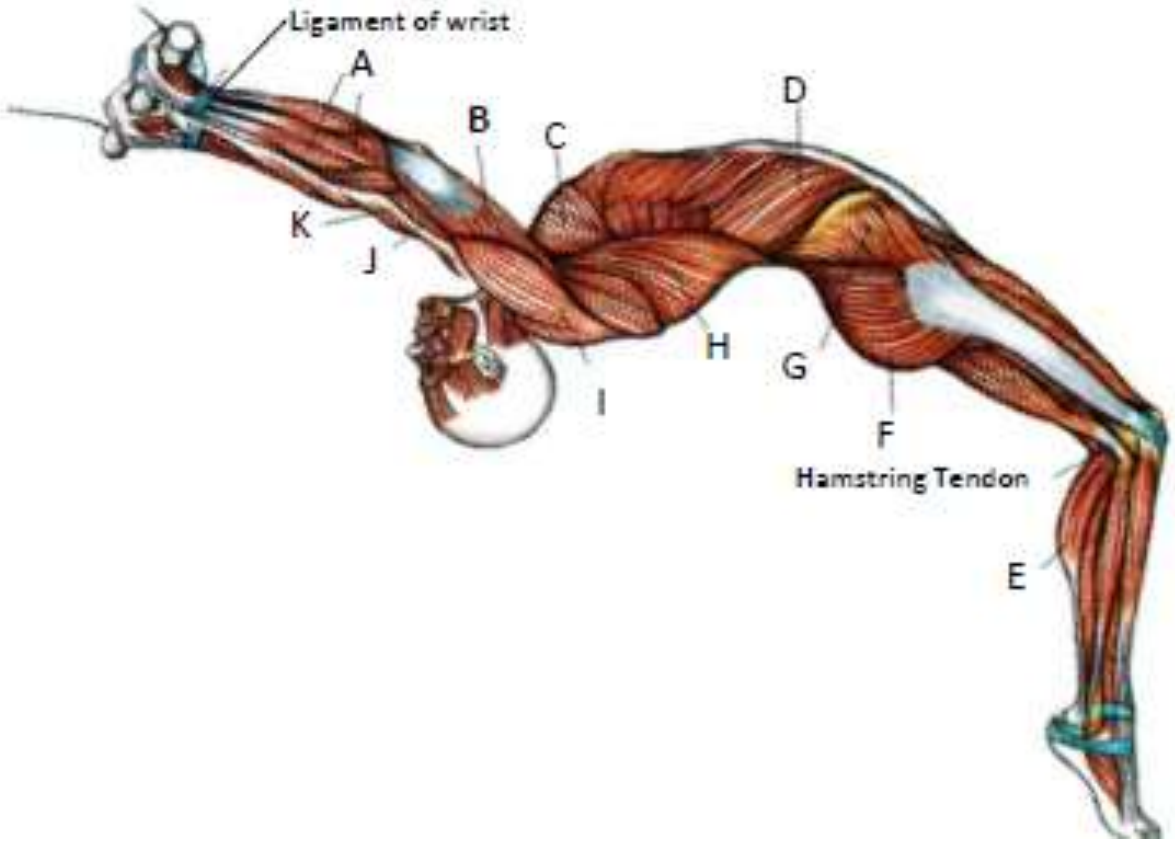
Motor units

- 3 different types of motor unit that contain 3 different types of fibres

Complete the table in your workbook and try the activity below it

	SLOW OXIDATIVE FIBERS	FAST OXIDATIVE FIBERS	FAST GLYCOLYTIC FIBERS
METABOLIC CHARACTERISTICS	1	2a	2b
Speed of contraction	Slow	Fast	Fast
Myosin ATPase activity	Slow	Fast	Fast
Primary pathway for ATP synthesis	Aerobic	Aerobic (some anaerobic glycolysis)	Anaerobic glycolysis
Myoglobin content	High	High	Low
Glycogen stores	Low	Intermediate	High
Recruitment order	First	Second	Third
Rate of fatigue	Slow (fatigue-resistant)	Intermediate (moderately fatigue-resistant)	Fast (fatigable)
ACTIVITIES BEST SUITED FOR			
	Endurance-type activities—e.g., running a marathon; maintaining posture (antigravity muscles)	Sprinting, walking	Short-term intense or powerful movements, e.g., hitting a baseball
STRUCTURAL CHARACTERISTICS			
Color	Red	Red to pink	White (pale)
Fiber diameter	Small	Intermediate	Large
Mitochondria	Many	Many	Few
Capillaries	Many	Many	Few

STARTER – Group Activity



Label: place the letter next to the name.

Gluteus maximus **F**

Latissimus dorsi **H**

Pectoralis major **C**

Gastrocnemius **E**

Muscles to fingers **F**

Triceps **F**

Brachioradialis **A**

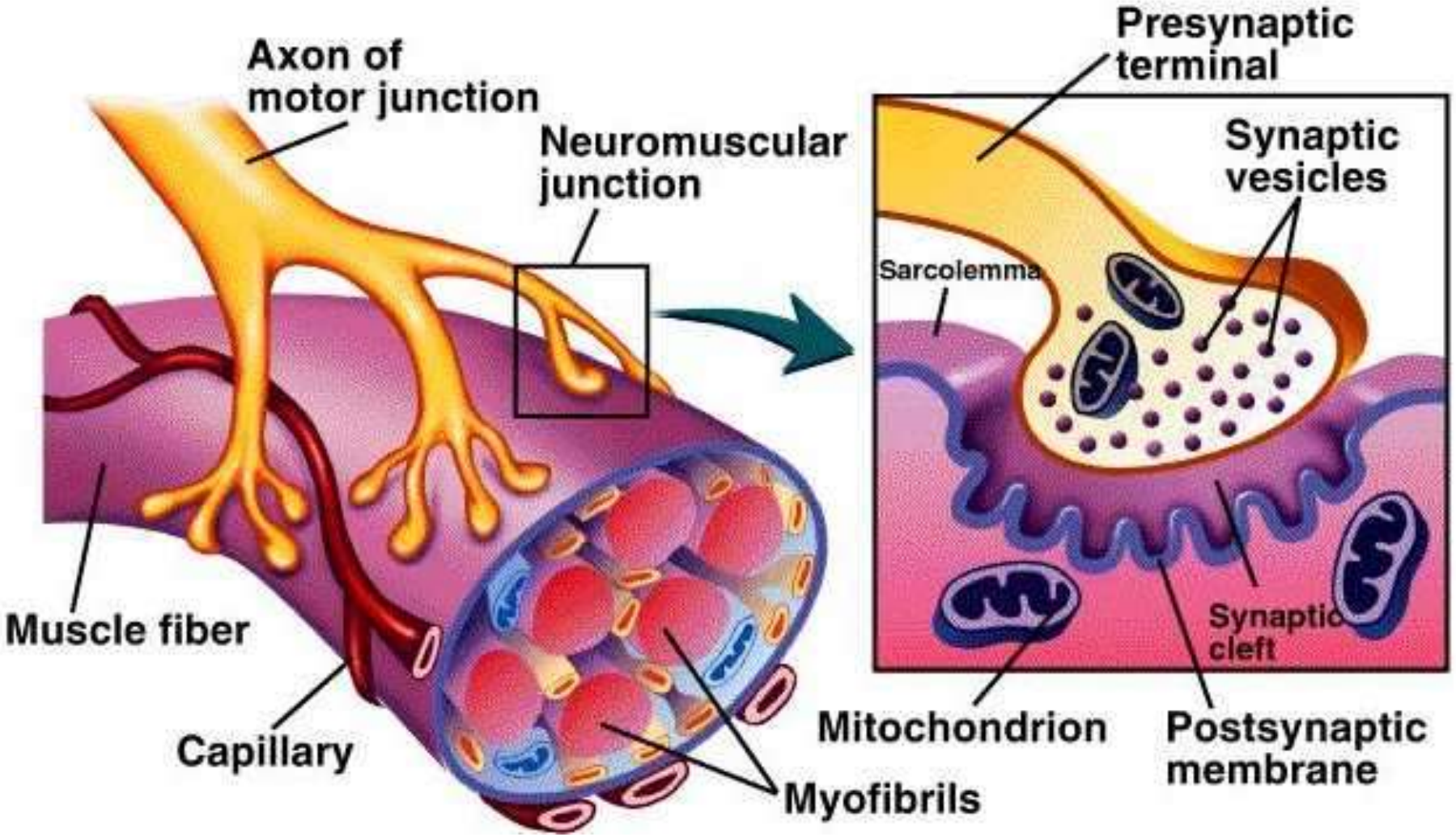
Deltoid **I**

Biceps **F**

Exterior oblique **F**

Gluteus medius **G**

Neuromuscular Junction



Individual activity – colouring exercise

COLORING INSTRUCTIONS

Color each structure and its name at the same time, using the same color. On the top figure:

1. Color the nuclei black in each figure.
2. Color the muscle cells for each muscle type (Ⓐ to Ⓒ).

COLORING INSTRUCTIONS

On the middle figure:

1. Color the bones (Ⓖ, Ⓘ), tendons Ⓓ, and the muscle body Ⓔ. Use light colors for the bones (Ⓖ, Ⓘ) and the muscle body.
2. Using two dark colors, draw circles at the origins Ⓕ and insertion Ⓗ of the muscle.

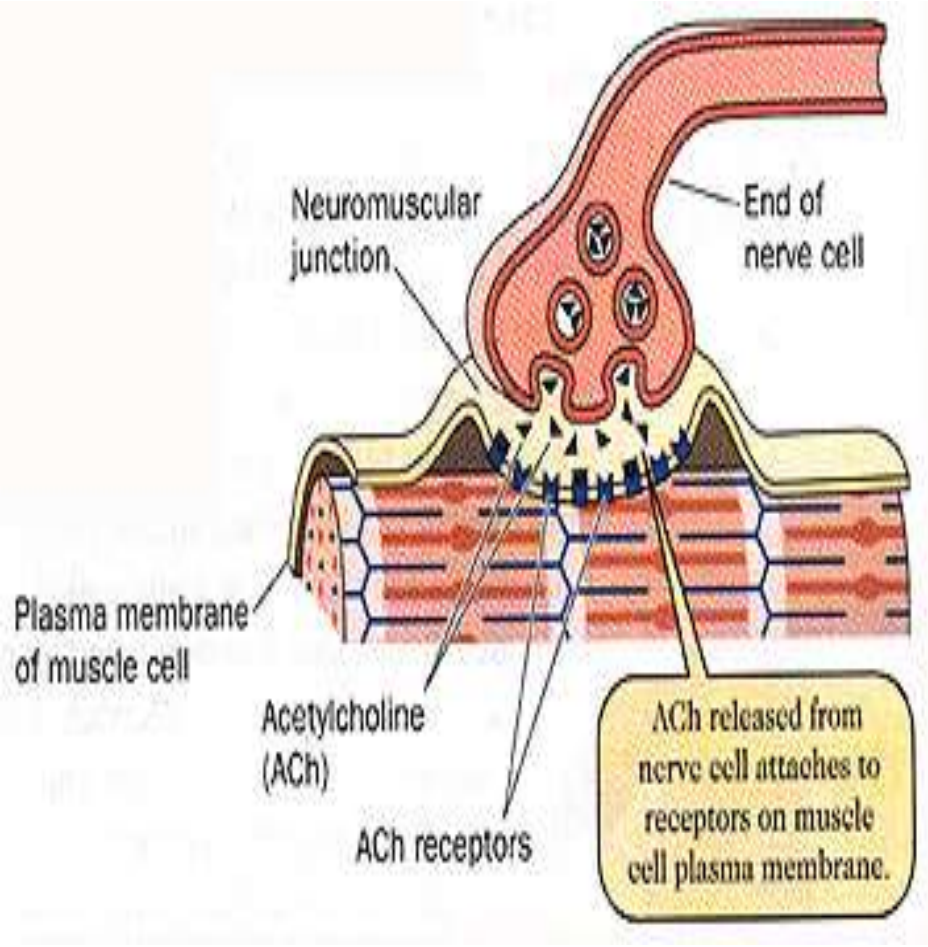
COLORING INSTRUCTIONS

On the bottom figure:

1. Color the bone Ⓘ, tendon Ⓓ, and epimysium Ⓙ.
2. Color the perimysium Ⓛ around the extruded fascicle and in the cross section.
3. Color the fascicle Ⓚ that is labeled in the cross section, and one additional fascicle.
4. Color the endomysium Ⓝ around the extruded muscle fiber. Outline some muscle fibers in the cross-section with the same color, because the endomysium surrounds all fibers.
5. Color the ends of some muscle fibers Ⓒ and the blood vessels Ⓜ.

The Role of Neurotransmitters in stimulating skeletal muscle contraction:

A. <u>Acetylcholine (Ach)</u>: increases the post-synaptic membrane's permeability to sodium and potassium ions spreading the impulse over the entire muscle fiber.



B. Cholinesterase: enzyme that breaks down Ach repolarizing the muscle fiber to await another nerve impulse.

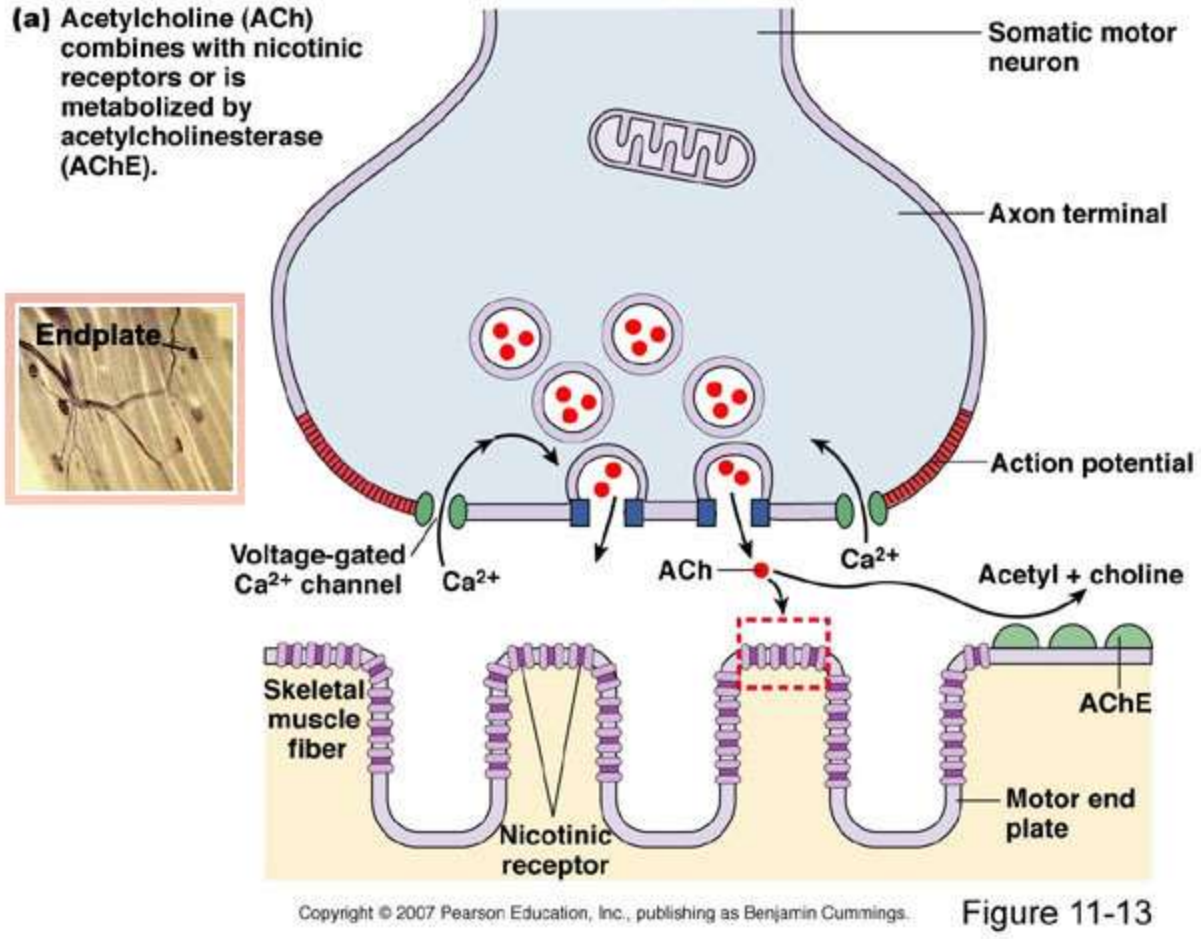
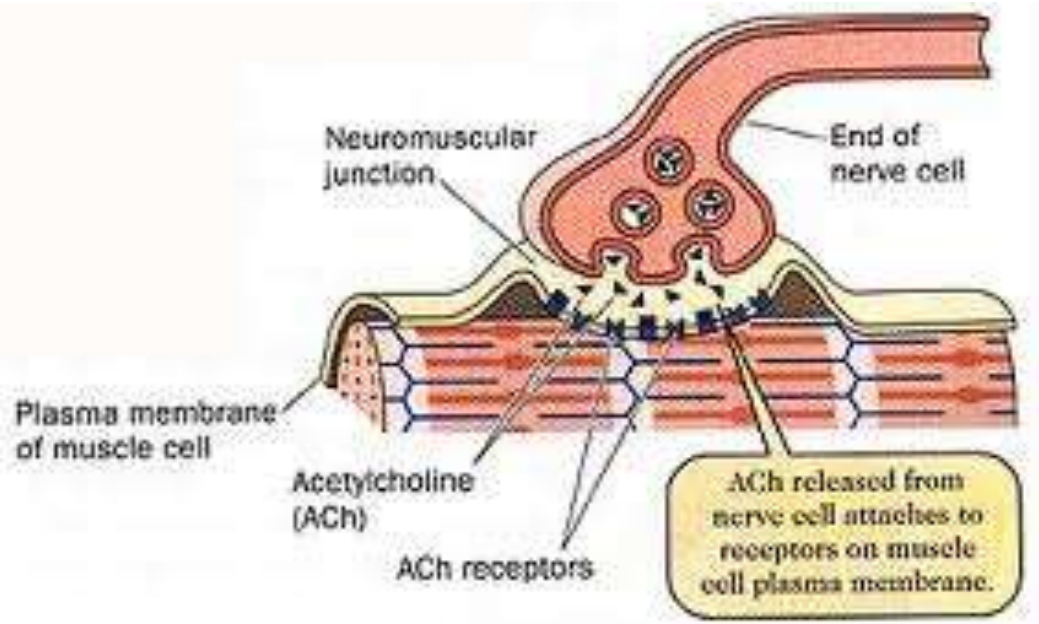


Figure 11-13

Look at the diagram in your workbook as we go through the different structures



The Neuromuscular Junction

- Consists of a **muscle cell** (A) and **motor neuron** (B)
- Each muscle cell contains multiple **nuclei** (C)

Components of a Muscle Cell

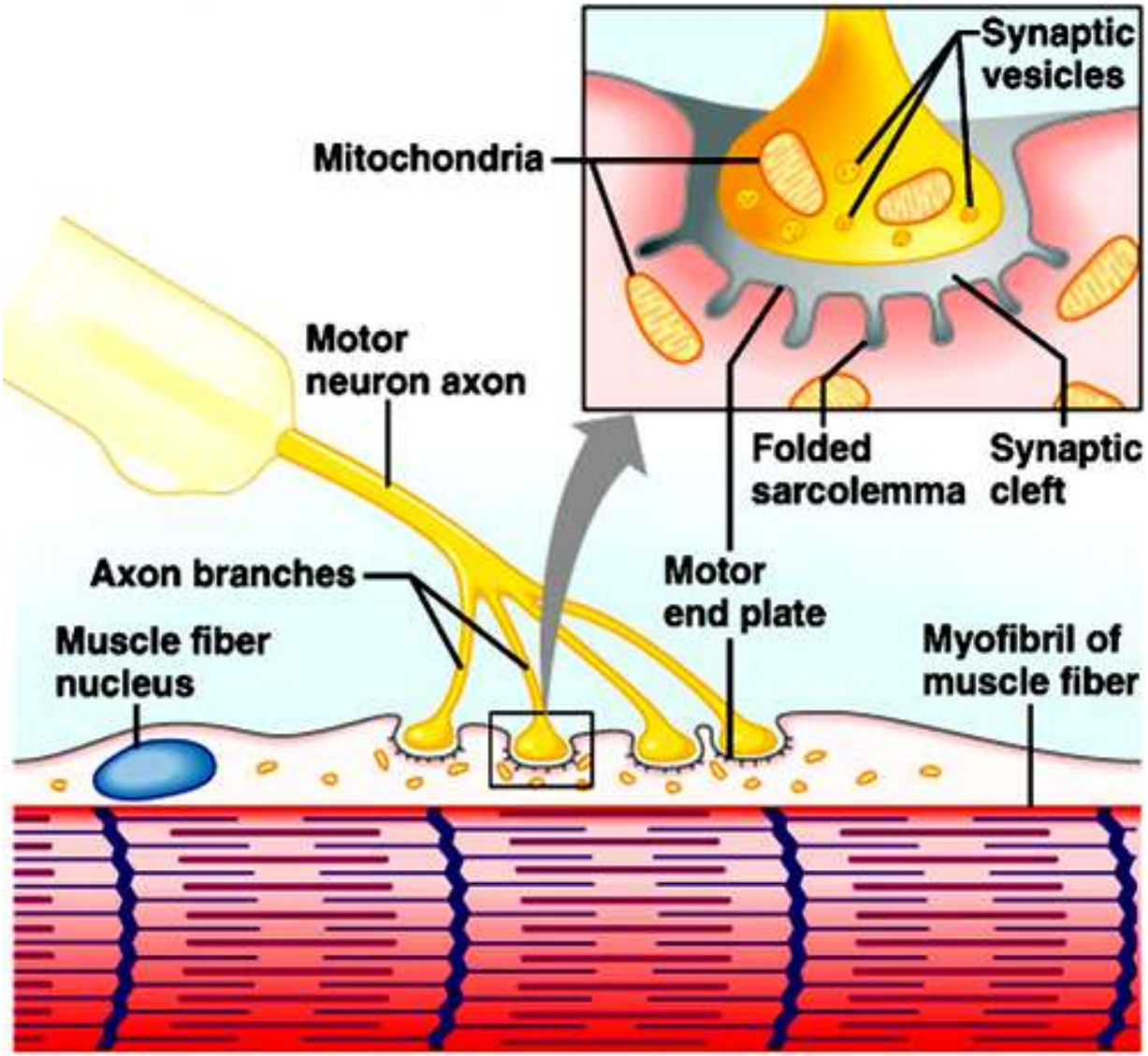
- Muscle cell organized into **sarcomeres** (D)
- Each sarcomere contains **actin** (thin) (E) and **myosin** (thick) (F) filaments

Events at the Neuromuscular Junction

- **Action potential** (G) arrives at **axon branches** (B1) of a **motor neuron** (B)
- **Synaptic vesicles** (H) containing stored neurotransmitters (**acetylcholine**, (I)) fuse with the neuron membrane
- Acetylcholine released into the **synaptic cleft** (J)
- Acetylcholine binds **receptor** (K) in the **motor end plate** (L) (muscle cell membrane)
- Bound receptor creates action potential in muscle cell
- **Mitochondria** (M) make some neurotransmitters and provide ATP

Starter – Group activity

Can you annotate this diagram to exaplin what is happenning WITHOUT your notes?



Learning Objectives

Everyone should

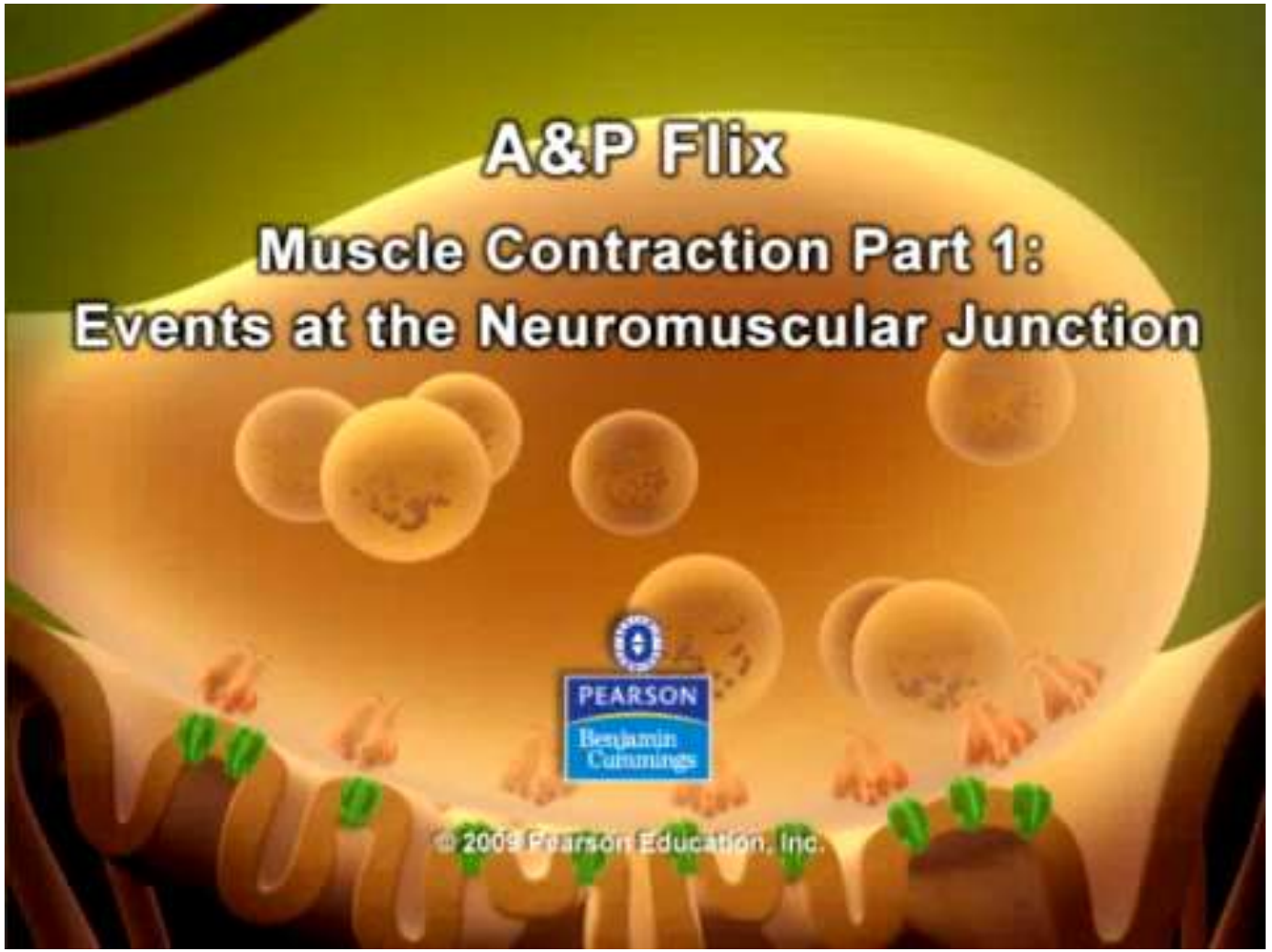
Describe the events that take place at a neuromuscular junction

Most will

State the 3 diferent types of motor unit

INDIVIDUAL ACTIVITY - Can you make a note of the 7 steps involved at a neuromuscular junction?

PAIRS ACTIVITY - Can you explain the process IN YOUR OWN WORDS to your partner – try and replace any words you didn't understand in the video with words you do



Now lets act it out!

- Can you summarise the process by annotating the diagram in your workbooks?

STARTER: Synaptic transmission pop quiz!

Events of a Synaptic Transmission

Number these events in the correct order.

1 ___7___ (a) An action potential is stimulated at the postsynaptic membrane and impulse travels down dendrite.

2 ___6___ (b) An enzyme cleaves the neurotransmitter substance and clears out the synaptic cleft.

3 ___1___ (c) Impulse reaches synapse from the axon.

4 ___2___ (d) Impulse stimulates synaptic vesicles to move to presynaptic membrane.

5 ___4___ (e) Neurotransmitter substance diffuses across the cleft.

6 ___5___ (f) Neurotransmitter substance fits into receptor sites on postsynaptic membrane.

7 ___3___ (g) Synaptic vesicles dump neurotransmitter substance into synaptic cleft.

Learning Objectives

Everyone should

Describe the microanatomy of a muscle fiber

Label the H bands, I bands and Z dics on a sarcomere

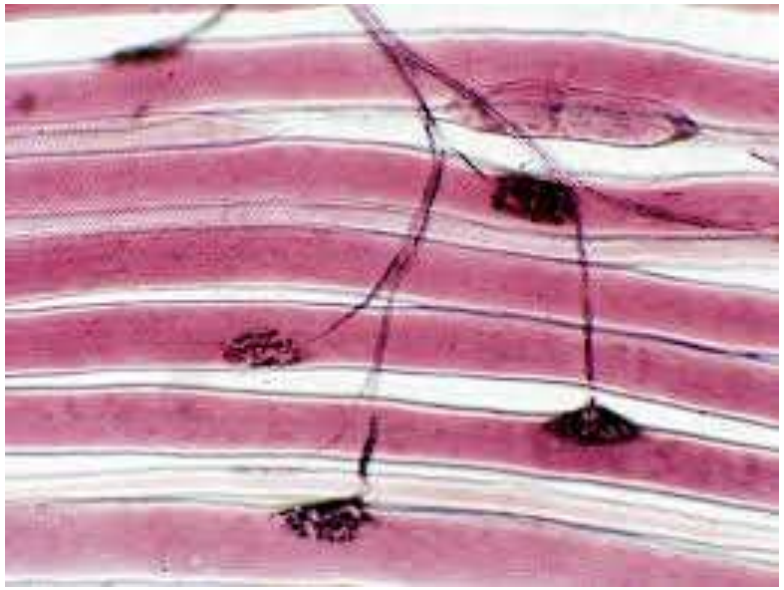
Most will

Explain how skeletal muscle contracts by the sliding filament theory.

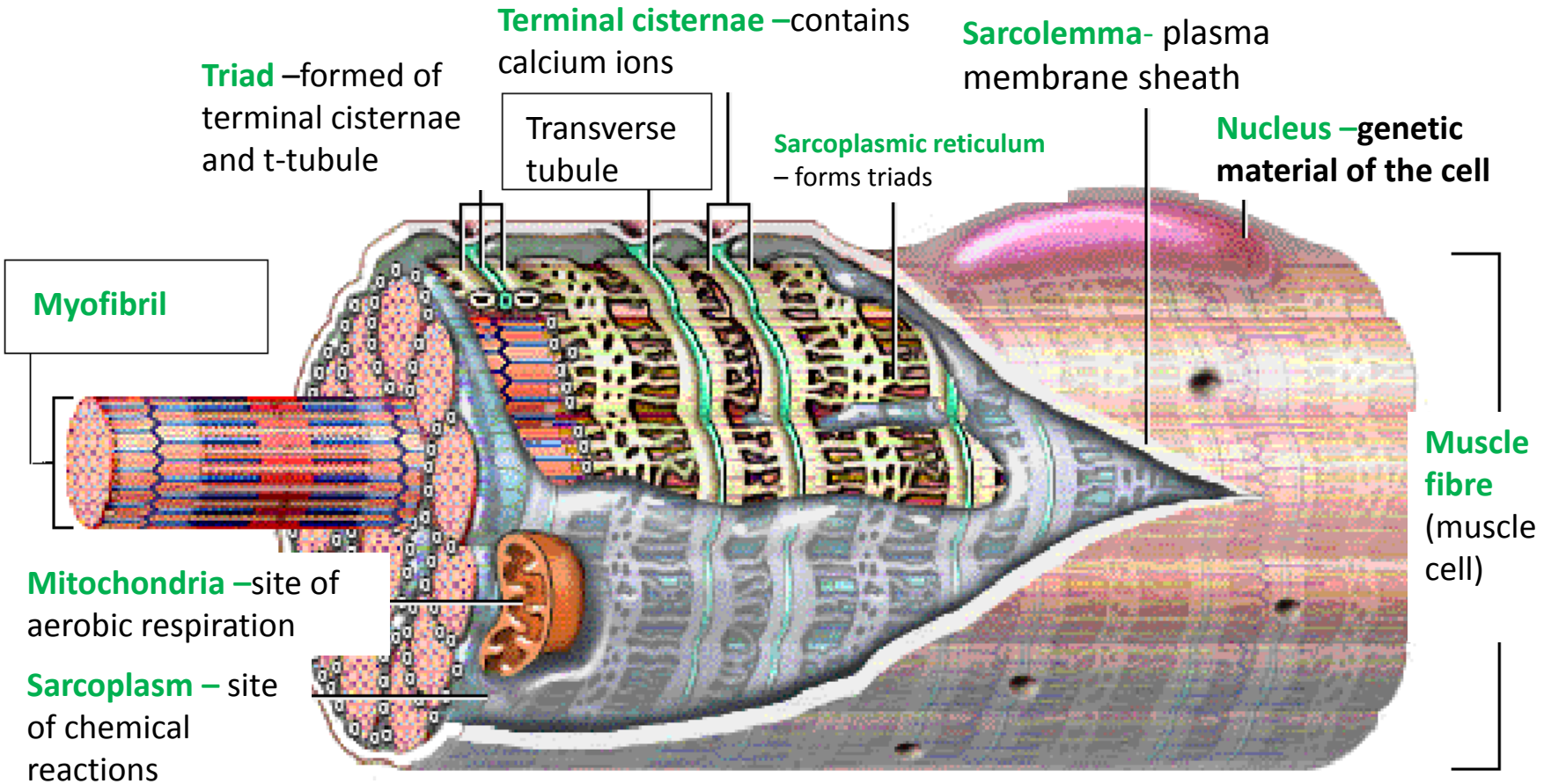
PAIRS ACTIVITY

- Use the microscopes to look at some prepared slides of muscle and connective tissue

- Draw what you see in your workbook!

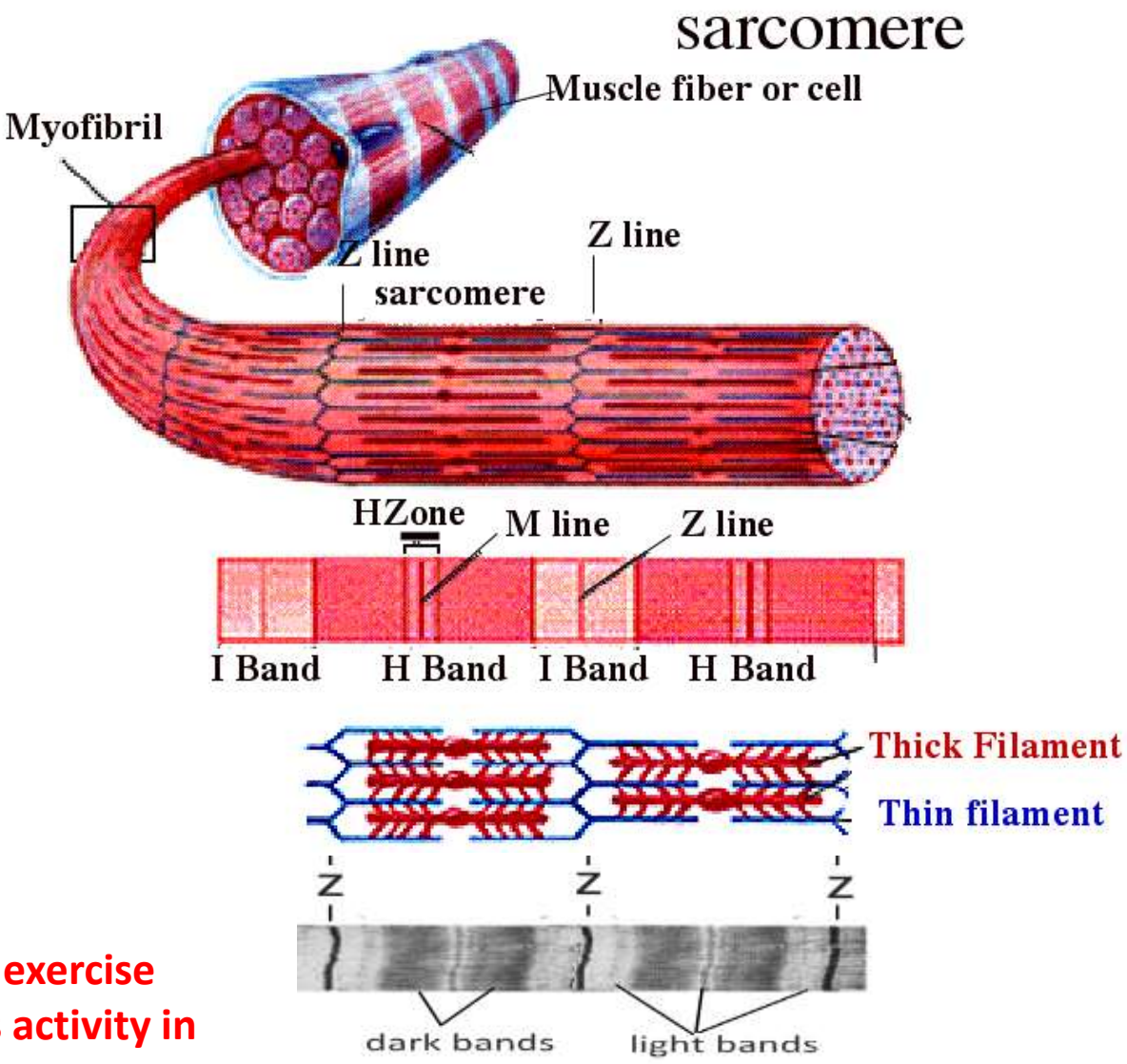


Microanatomy of a skeletal muscle cell



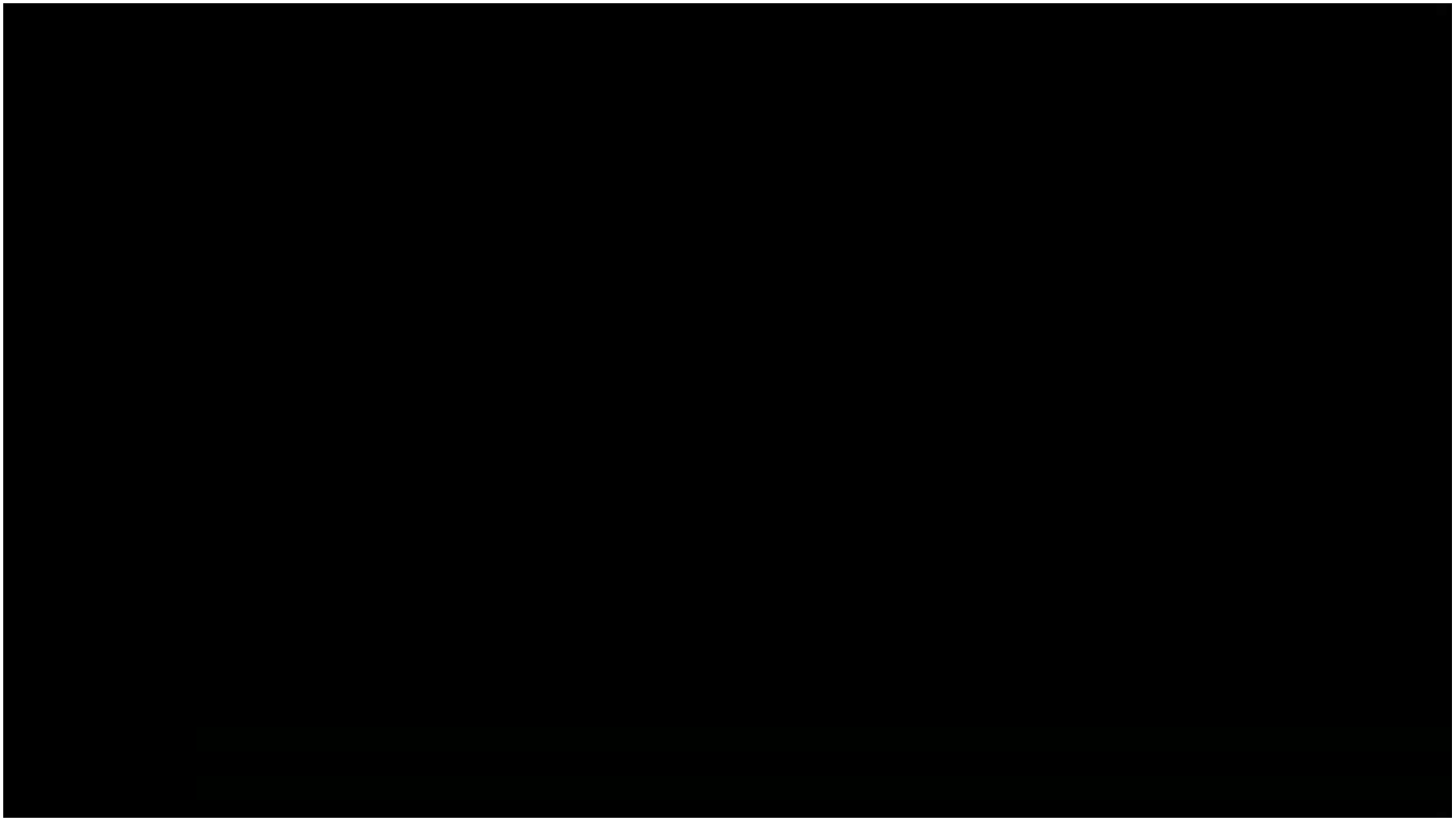
Label your diagram!

Structure of a sarcomere



Try the matching exercise and data analysis activity in your workbook!

Sliding filament theory



As you watch the video – can you put the statements on your handout into order?

(place the correct number in the space provided)

Answers

Step **3**: The *myosin head* binds to the actin, using energy from ATP and forming an *actomyosin bridge*

Step **2**: When the membrane of the muscle is depolarised, *calcium ions* are released from a system of tubes in the muscle fibres.

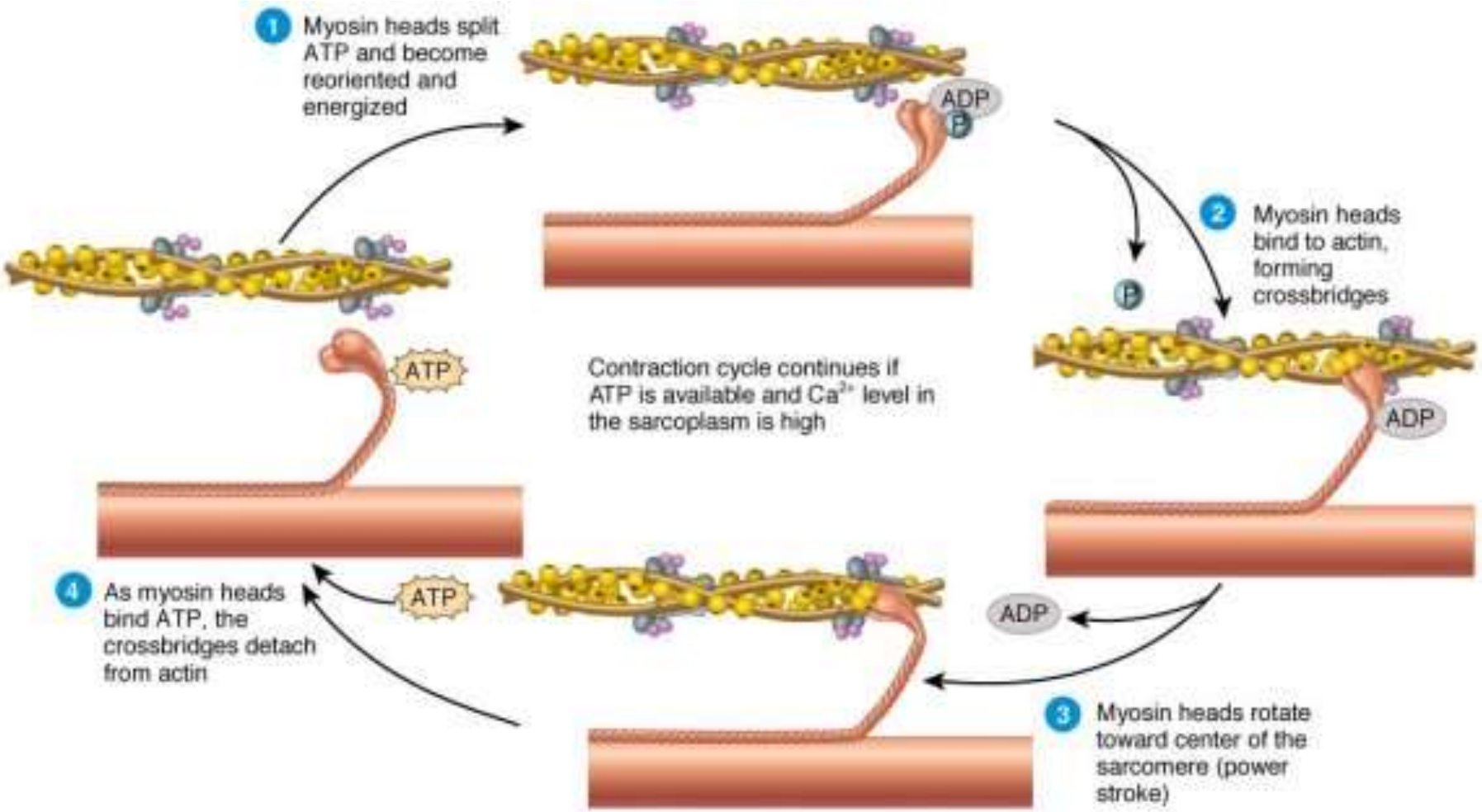
The calcium ions bind with the *troponin* – this displaces *tropomyosin* from the actin *binding*

Step **1**: When the muscle is *relaxed*, the binding sites on the actin are covered by *tropomyosin*

Step **5**: As the actin filaments move past, the myosin heads become detached, and attach to the *next binding site*.

As calcium ions are absorbed back into the tubes, troponin reverts to its original shape.

Step **4**: As the myosin heads attach to the actin filaments they *tilt* causing the actin filaments to slide past them



Now complete your Sliding Filament Theory cut and paste exercise

Cut out all the boxes and then paste them down on the empty page in your workbook.

Once you have finished, try completing the flow chart in your workbook