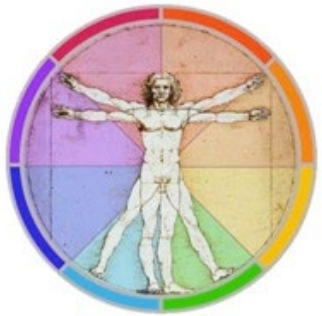
# HUBS 191 Lecture Material

This pre-lecture material is to help you prepare for the lecture and to assist your note-taking within the lecture,
it is NOT a substitute for the lecture !



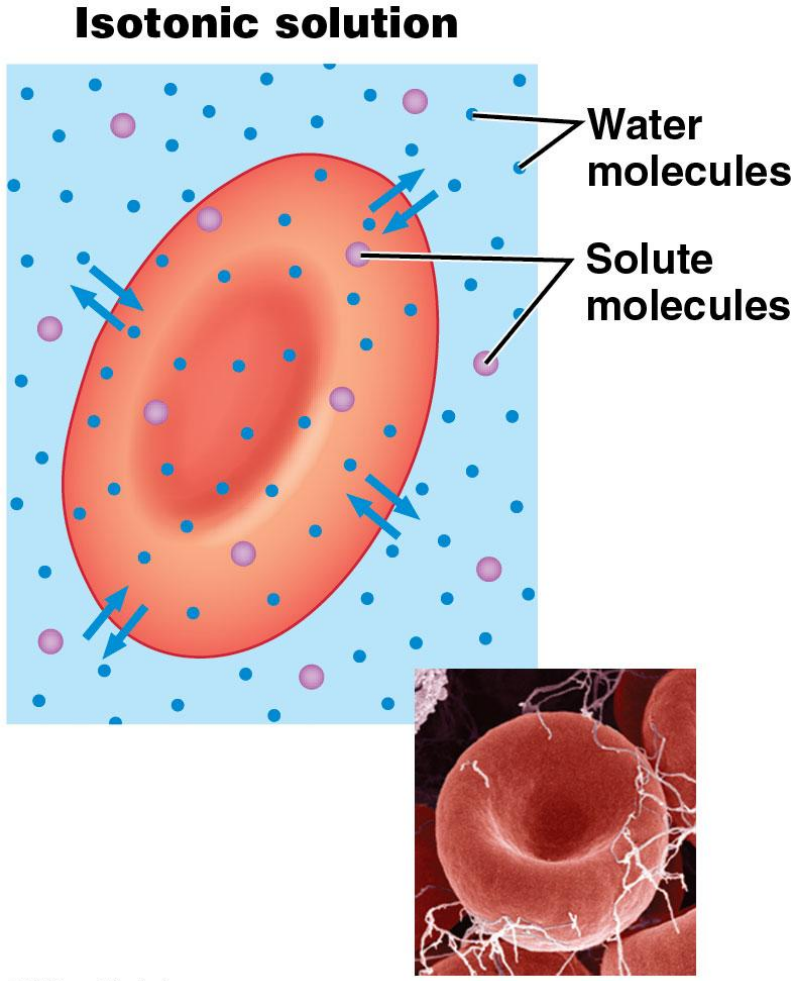
Please note that although every effort is made to ensure this pre-lecture material corresponds to the live-lecture there may be differences / additions.

# HUBS 191

Jeff Erickson – Department of Physiology

## Lecture 8
## Skeletal Muscle Structure and Function

# *Example exam question*






If the cell on the left was moved to a hypotonic solution of pure water, which of the following would be most likely to occur?

A. Solute molecules would move into the cell, making it heavier.
B. Water would move into the cell, making it swell.
C. Solute molecules would move out of the cell, disrupting its function.
D. Water would move out of the cell, making it shrivel.

# Objectives and Study Guide

*After this lecture you should be able to:*

- Briefly describe the three main types of muscle in the body
- Describe key elements of skeletal muscle structure at the tissue and cellular levels
- Describe the sequence of events that occur during skeletal muscle excitation

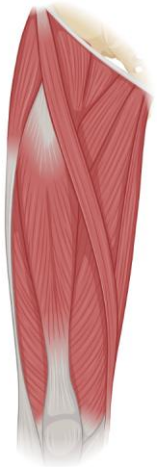
Related reading: Martini et al. Modules **9.2** (p. 358), **9.3** (p. 360), and **9.8** (p. 371)

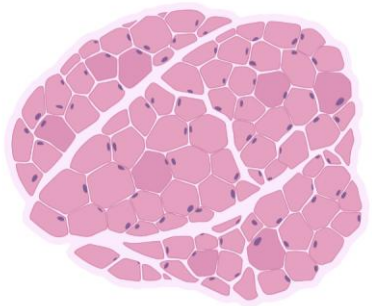
# There are three main “types” of muscle in the human body

- **Smooth** muscles mainly line hollow organs (eg gut, blood vessels) and are not under voluntary control.
- **Cardiac** muscle is located only in the heart, it generates force to pump blood around the body and is not under voluntary control.
- **Skeletal** muscle applies force to the bones to control posture and body movements. It is mostly under voluntary control.
- All three types are made up of cells called **fibres**, and function primarily to generate force via contraction.
- The next two lectures are about ***skeletal muscle***.

# Skeletal Muscle: Introduction

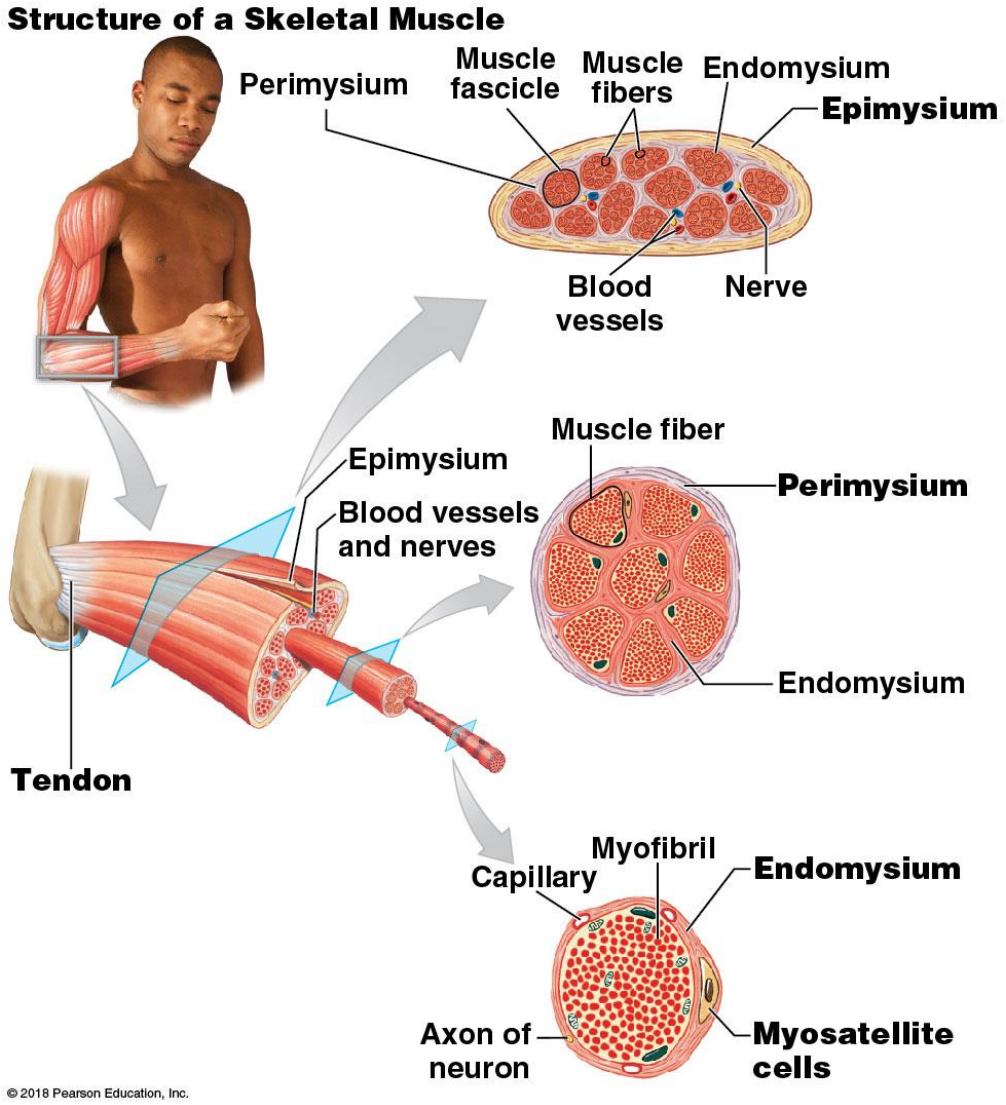
- Skeletal Muscles are mostly under voluntary control…we can choose when to activate them!
- The primary job of skeletal muscle is to develop force
- Muscles develop force by contracting (shortening)
- Important for movement and posture





- Other (secondary) jobs:
  - Support and protection for soft internal organs (e.g. muscles of abdominal wall)
  - Provides voluntary control over major openings
    -allow passage of substances into or out of the body
  - Converts energy (in part) to heat which is used to maintain core temperature (eg. shivering)

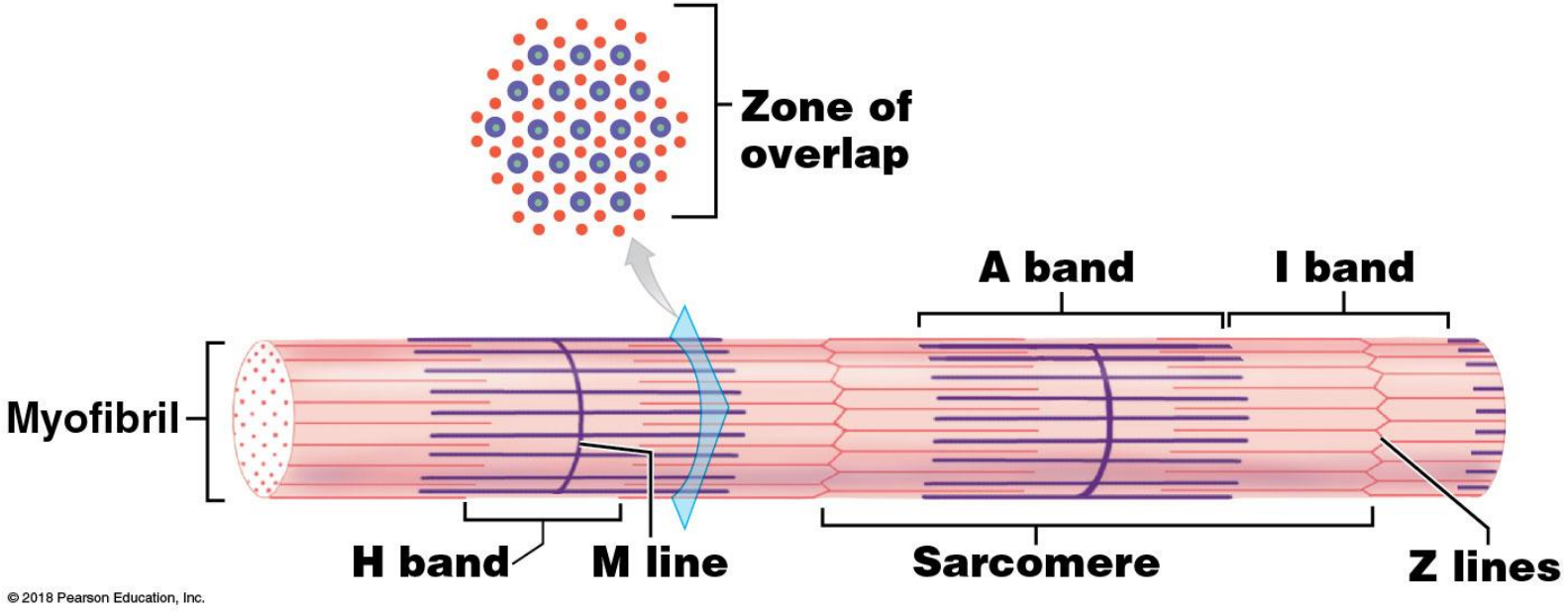
# Whole muscle structure




- Individual muscle cells are called muscle *fibres* (fibers). They gather into bundles called *fascicles.*
- Fascicles are further bundled into *muscles.*
- Fibres, fascicles, and muscles contain many blood vessels and nerves, and they are sheathed in connective tissue.
- Connective tissue is gathered together to form *tendons*, which connect muscles to bones.
- Not shown: muscle fibres also contain hundreds or even thousands of nuclei!

*Martini - Visual Anatomy and Physiology (2018) Module 10.1 p. 393.*

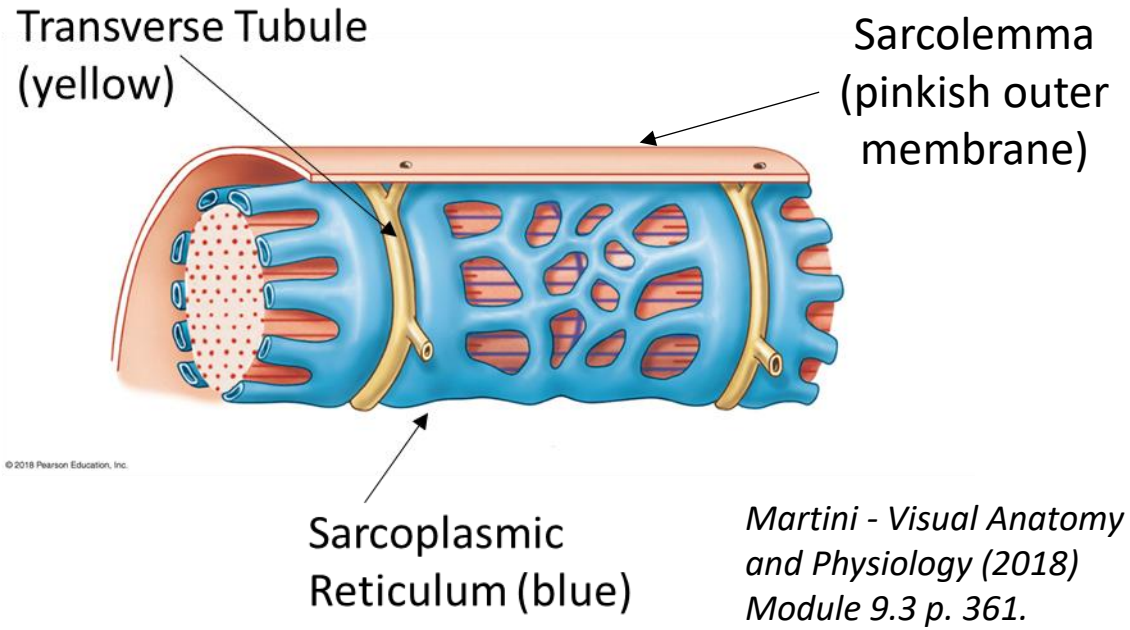
# Individual fibres – Cellular structure



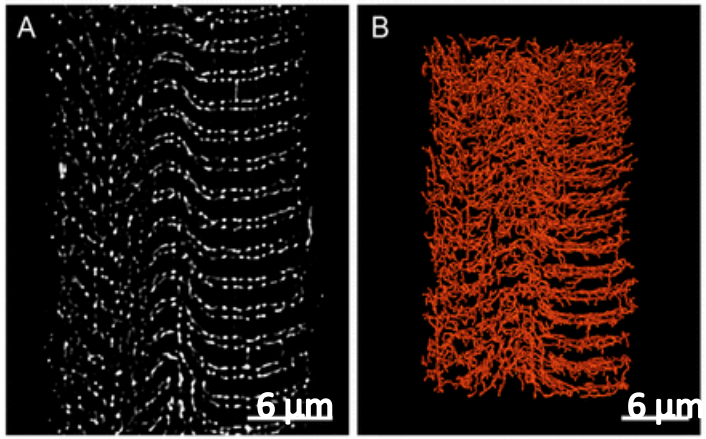

*Martini - Visual Anatomy and Physiology (2018) Module 9.3 p. 360.*

- A muscle fibre is comprised of bundles of myofibrils, which are made of repeating units known as *sarcomeres.*
- Sarcomeres are made of contractile proteins or *myofilaments:*
  - *actin* (thin filaments)
  - *myosin* (thick filaments)
- The organization of these myofilaments give muscle it's *striated* (striped) appearance.

# Individual fibres – Cellular structure



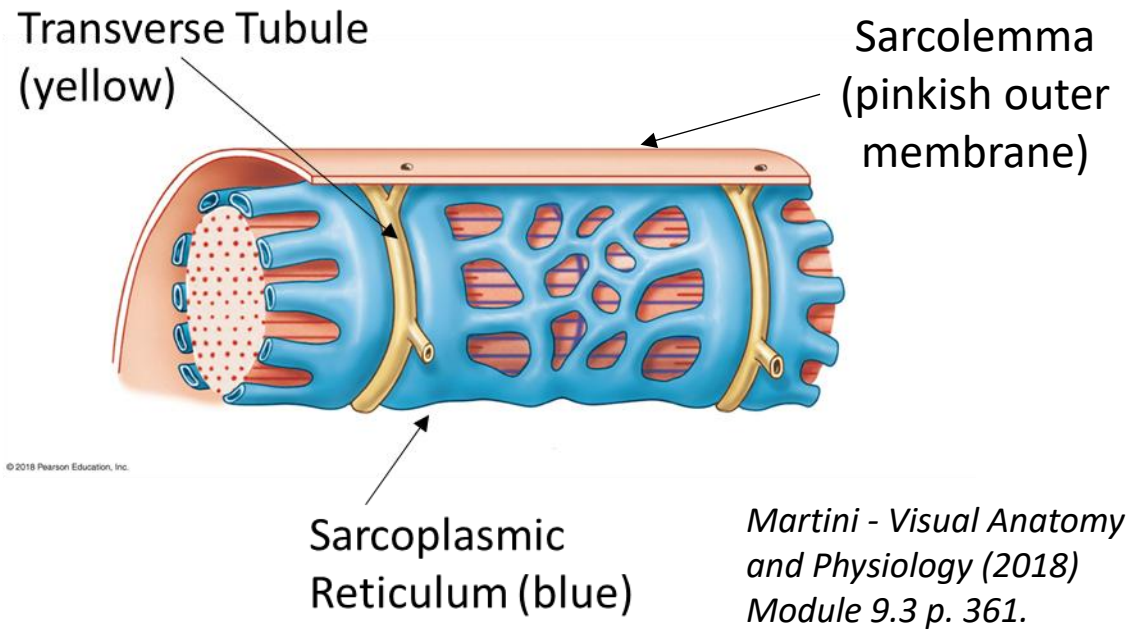

*Martini - Visual Anatomy and Physiology (2018) Module 9.3 p. 361.*




Jayasinghe and Launikonis, Journal of Cell Science, 2013

- Muscle fibres possess a system of structures organized to regulate the activity of the force-producing elements.
- The muscle fibre is lined by a cell membrane with a special name: the *sarcolemma.*
- *Transverse tubules* (T-tubules) are tube-like extensions (invaginations) of the sarcolemma.
- Their job is to conduct electrical signals (*action potentials*) deep into the core of the fibre.

# Individual fibres – Cellular structure




*Martini - Visual Anatomy and Physiology (2018) Module 9.3 p. 361.*

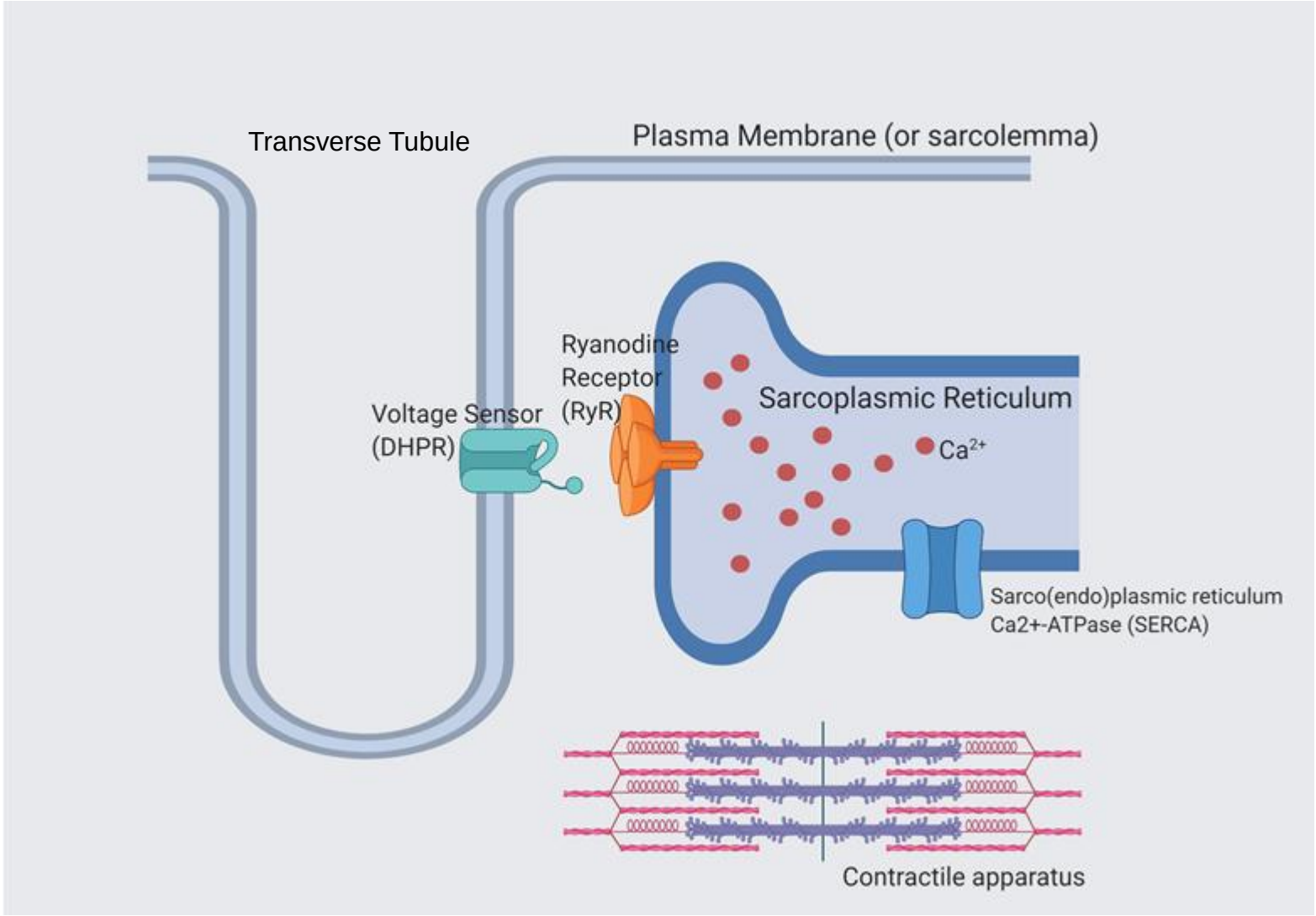
- *Sarcoplasmic reticulum (SR)* is an extensive membrane network associated with the T tubules at regular intervals.
- The job of the SR is to take up and store calcium ($Ca^{2+}$) while the muscle is relaxed, and then to release calcium into the cytoplasm when the muscle contracts.

# *Example exam question*

Which of the following statements about muscle fibre structure is NOT correct?

A. Sarcomeres are primarily composed of actin (thin filaments) and myosin (thick filaments).
B. Transverse tubules (t-tubules) are extensions of the sarcolemma deep into the fibre.
C. Skeletal muscle appears striated (striped) due to the organization of the myofilaments.
D. The sarcoplasmic reticulum (SR) houses muscle cell DNA because nuclei are absent.

# Excitation-Contraction Coupling (EC-coupling) is the pairing of a signaling event (excitation of the muscle cell) with a mechanical event (contraction of the muscle cell)



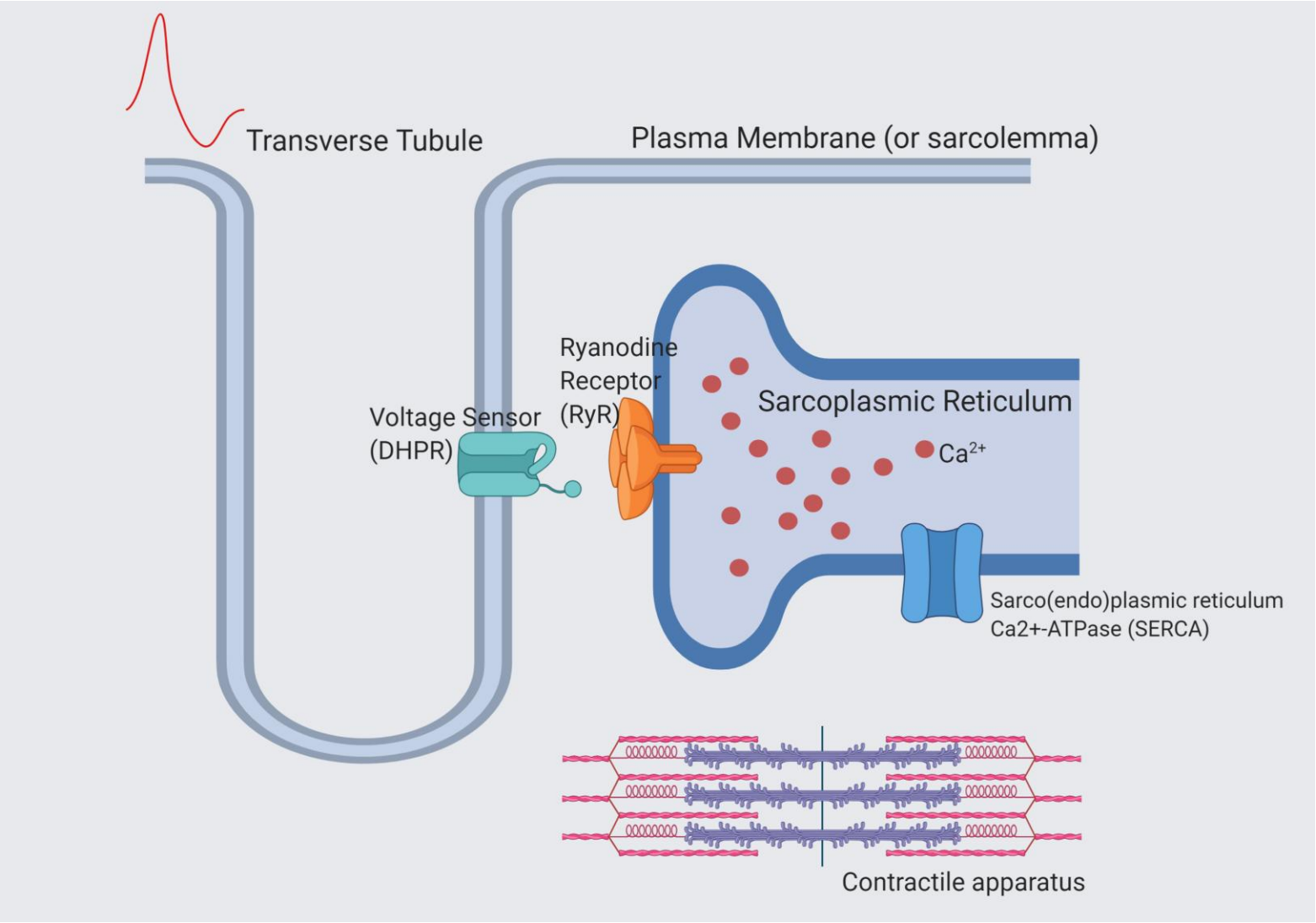

Three key proteins participate in excitation (the signalling event)

**The voltage-gated sensor (DHPR)**
Receives signals from the t-tubules and interacts with the ryanodine receptors

**The ryanodine receptor (RyR)**
A passive calcium channel on the SR that can open to allow $Ca^{2+}$ out into the cell

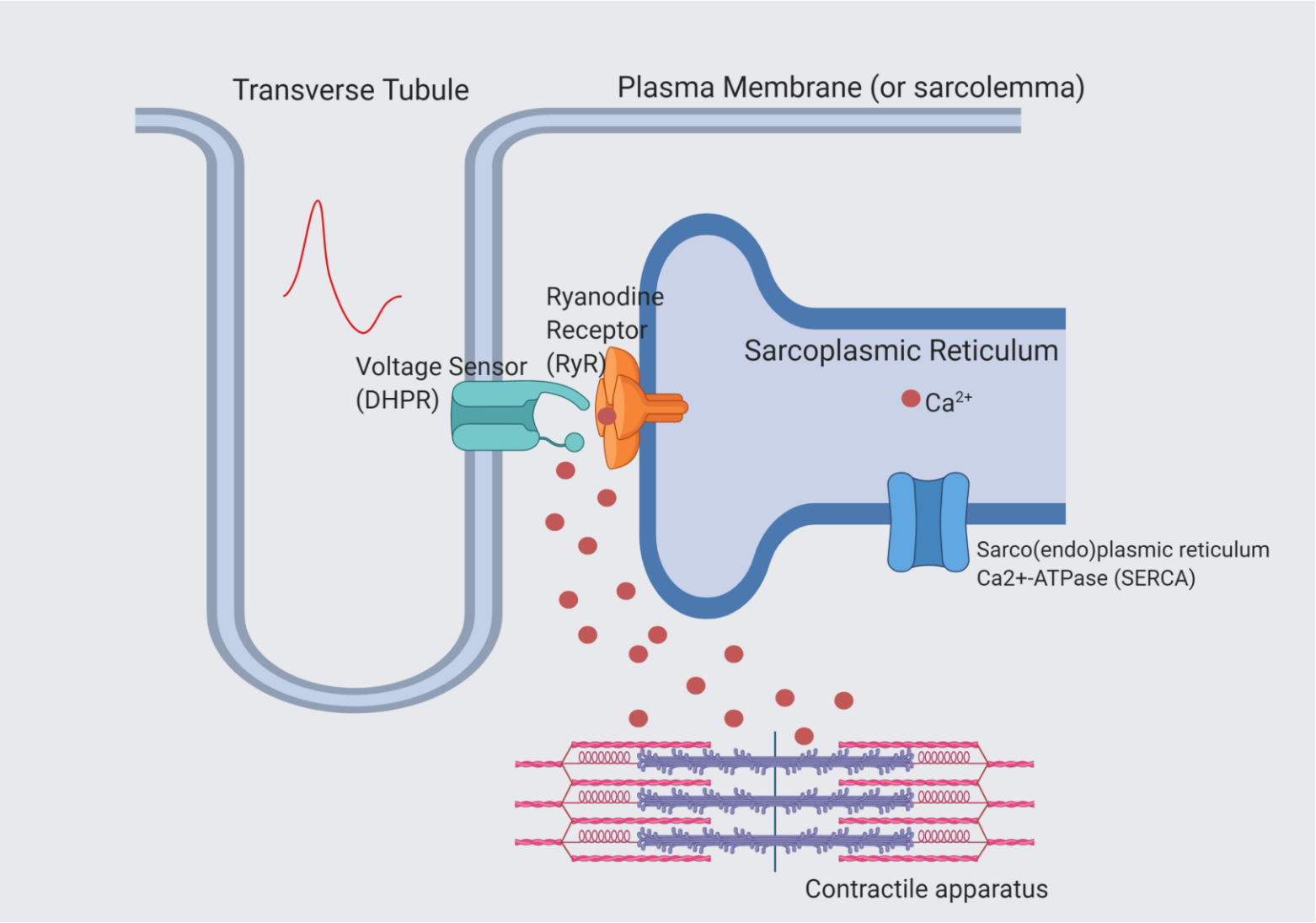
**The SR Calcium-ATPase (SERCA)**
An active calcium pump that uses ATP to move $Ca^{2+}$ back into the SR against its concentration gradient, ending the excitation.

# EC-Coupling is initiated when a signal is transmitted down the T-tubules



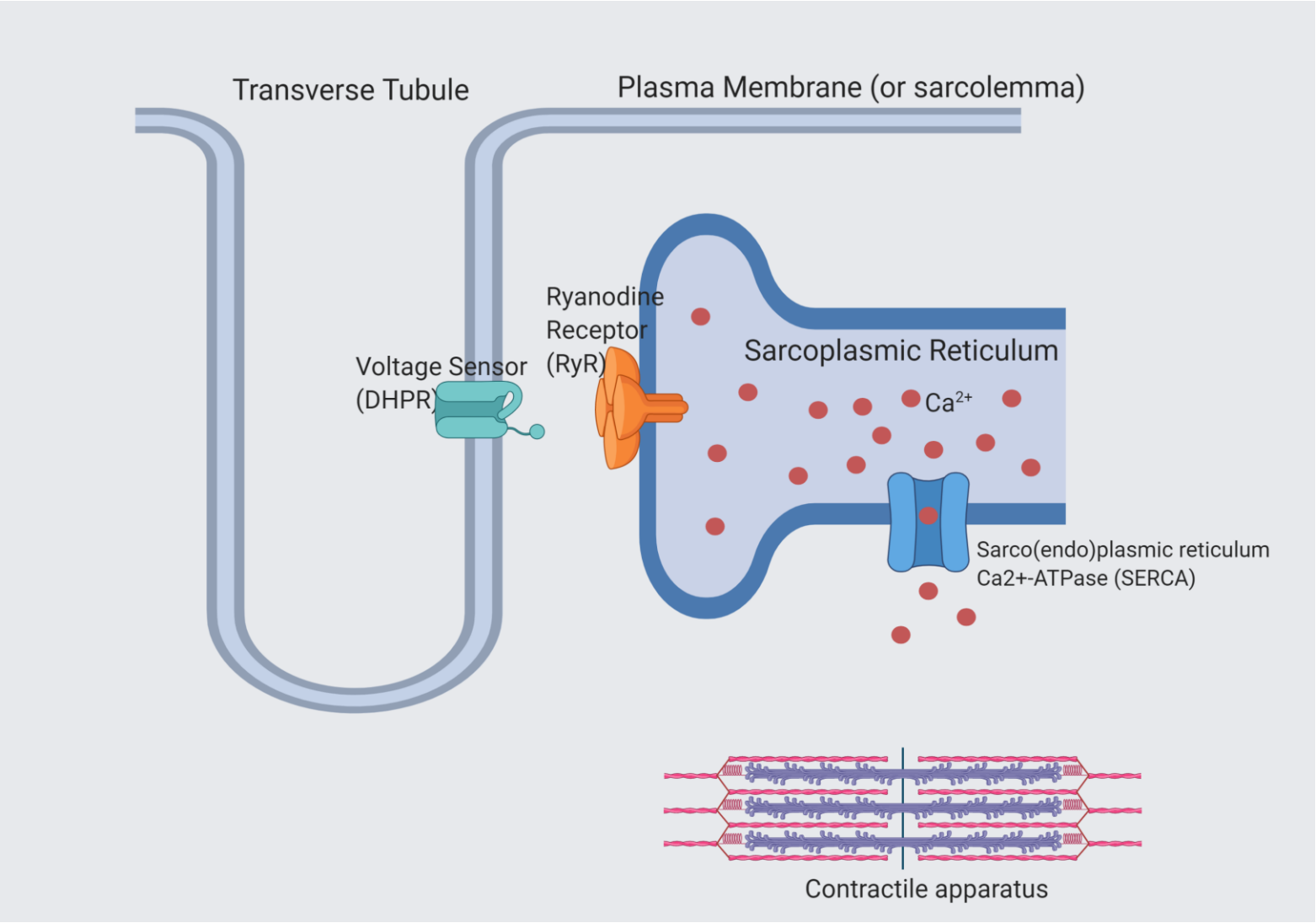

- The signal is coming from the nerves running throughout the muscle
- Remember – skeletal muscle is under voluntary control!
- You'll learn more about this in your upcoming section on nervous function.

# The excitation signal moves into the cell and causes a release of calcium stores, triggering a contraction




- The voltage sensor (DHPR) is activated by the signal moving through the T-tubule.
- The active DHPR interacts with nearby ryanodine receptors (RyR), causing them to open.
- RyR is a passive calcium channel…once it opens, calcium starts pouring out of the SR and into the cell!
- That calcium then diffuses throughout the cell, activating the myofilaments and causing a contraction. (More on this tomorrow!)

# For relaxation to occur, calcium must be removed from the cell by pumping it back into the SR




- The SR Calcium-ATPase pump (SERCA) senses the rise in intracellular calcium.
- SERCA burns some ATP to produce energy and then uses that energy to pump calcium back into the SR, against the concentration gradient.
- This removes the calcium from the cell, stopping the signaling event and allowing the muscle to relax.

# Did you catch it?


Looneytunes.fandom.com

- What is excitation-contraction coupling (EC-coupling)?
- What are the three key proteins involved in excitation? Where are they located?
- When the nerves signal to the muscle that it's time to contract, how does that signal get inside the cell and how does it cause a contraction? How is the signal stopped so the contraction can end?

# *Summary*

- The three muscle types are smooth, cardiac, and skeletal. These types have many similarities but a few key differences.

- At the tissue level, skeletal muscle fibres are organized into fascicles and muscles. They are associated with nerves, vessels, and connective tissue.

- At the cellular level, skeletal muscle fibres are organized into sarcomeres comprised of myofilaments, which give the muscle a striated appearance. They also have critical signalling components, including the T-tubules and the sarcoplasmic reticulum.

- Excitation-contraction coupling pairs a signalling event with a mechanical event. Three key proteins contribute to excitation signalling (DHPR, RyR, and SERCA).

# *Example exam question*

Which of the following events during EC-coupling would contribute to relaxation of a muscle cell?

A. A signal arrives at the cell through the t-tubules.
B. The SERCA pump moves calcium into the SR.
C. The voltage-gated channel (DHPR) is activated.
D. The ryanodine receptor (RyR) releases calcium from the SR.

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# HUBS191