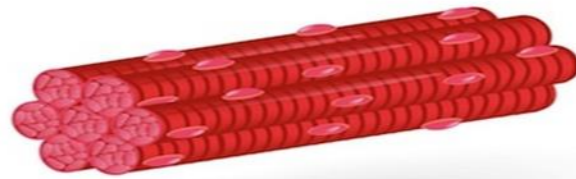


**MSS MODULE
PHYSIOLOGY (LECTURE 2)
PHYSIOLOGY OF MUSCLE II
BY**

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Associate Professor of Medical Physiology
Faculty of Medicine – Mutah University
2025-2026**

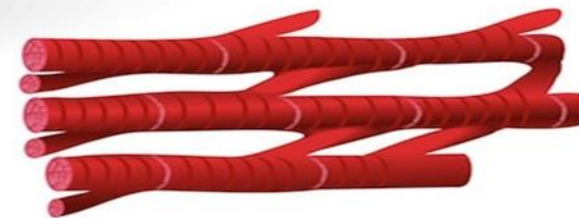
Skeletal muscle



Smooth muscle



Cardiac muscle



TYPES OF SKELETAL MUSCLE CONTRACTION

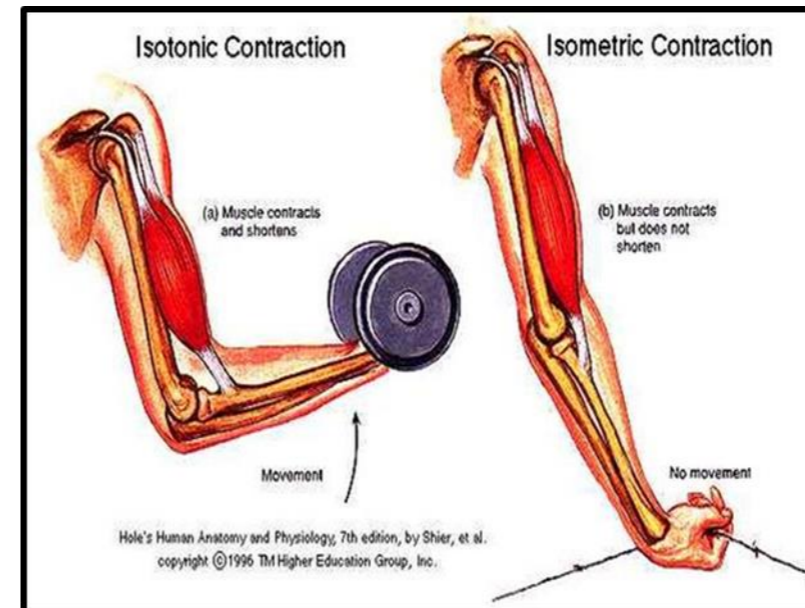
- There are **TWO TYPES** of muscle contraction:
 - ❑ **Isometric** contraction.
 - ❑ **Isotonic** contraction.
- Normal muscle activity is a **combination** of isometric and isotonic contractions.

عند توتين نعمل مع العضلة:

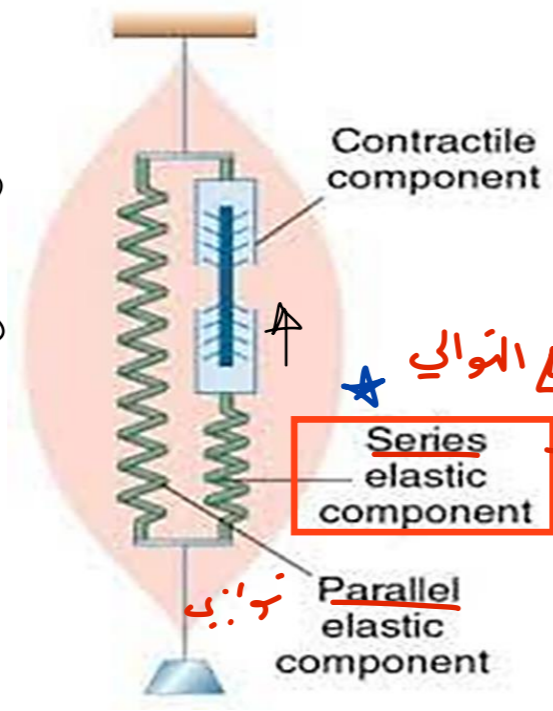
1) load (Action)

2) tension نتجه العضلة
لتناقص الوزن

حسب ما يغلب نوع التمرين



① نحاول Cont
تقرب
② ان فضلت

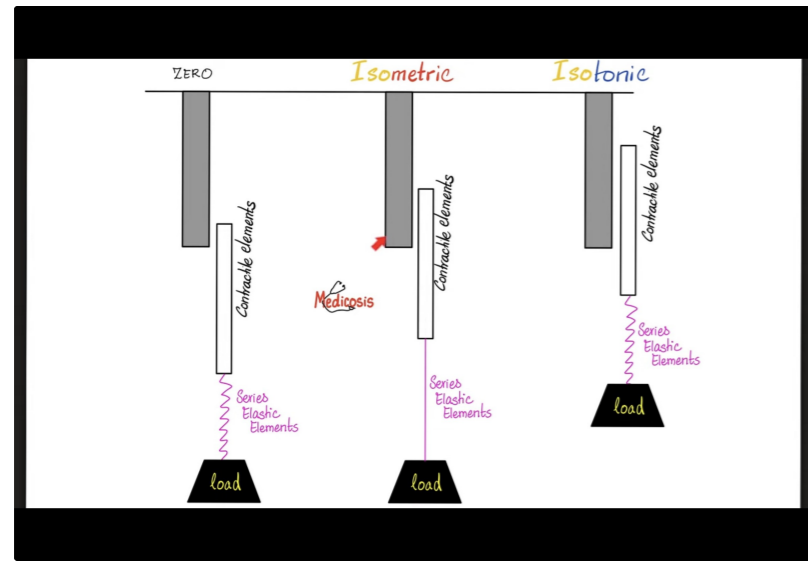
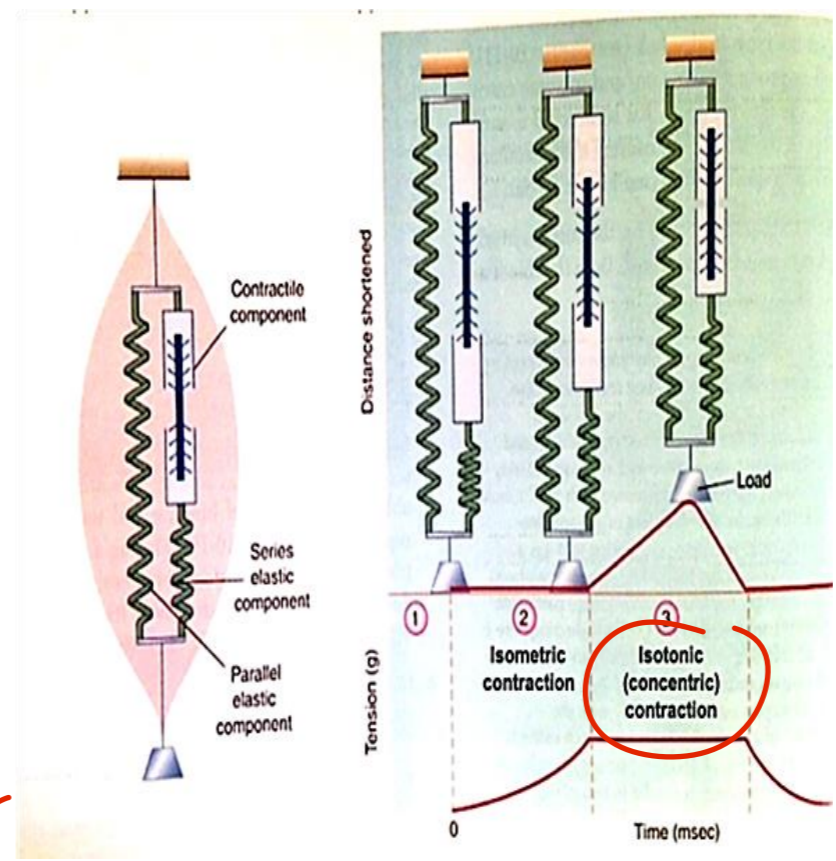


على التوالي
Series elastic component
in tendon tension

توازي
Parallel elastic component

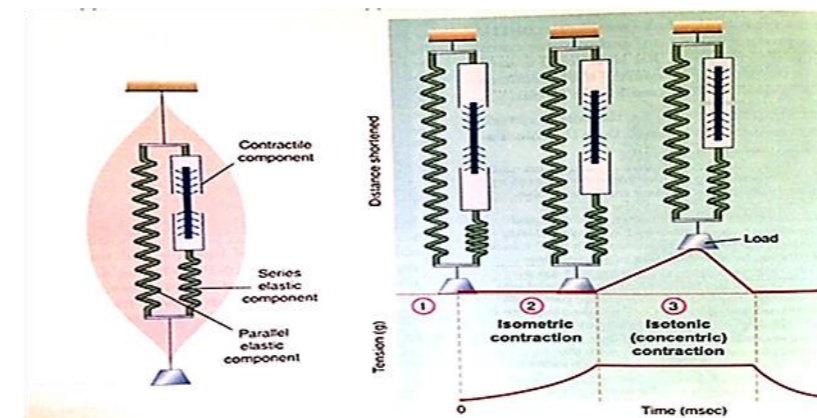
صافنا
يستغل اذا
تension > contraction
يفعل
فينا نمد elastic

contract metrically (iso-) ?



ISOMETRIC CONTRACTION

- Involves the **development of tension without** any change in length (constant length).
↳ Active tension
- The muscle **contract without shortening** but the tension is much **increased**.
- **Mechanism:** The muscle fibers are formed of **contractile** parts (CE) and elastic tissue (SE). When the contractile part (sarcomere) is shortened → **pull** on the **elastic tissue** which is markedly **stretched** (because the **load is not moved**) → so that the **total length** of the muscle fiber **doesn't** change (i.e. **length is constant but tension is increased**).

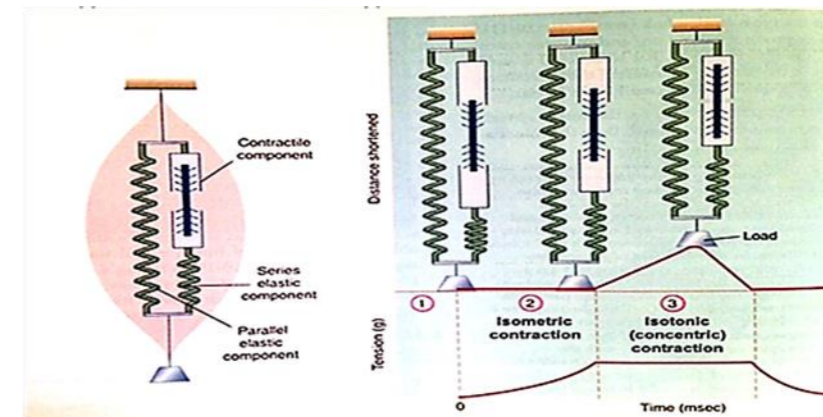


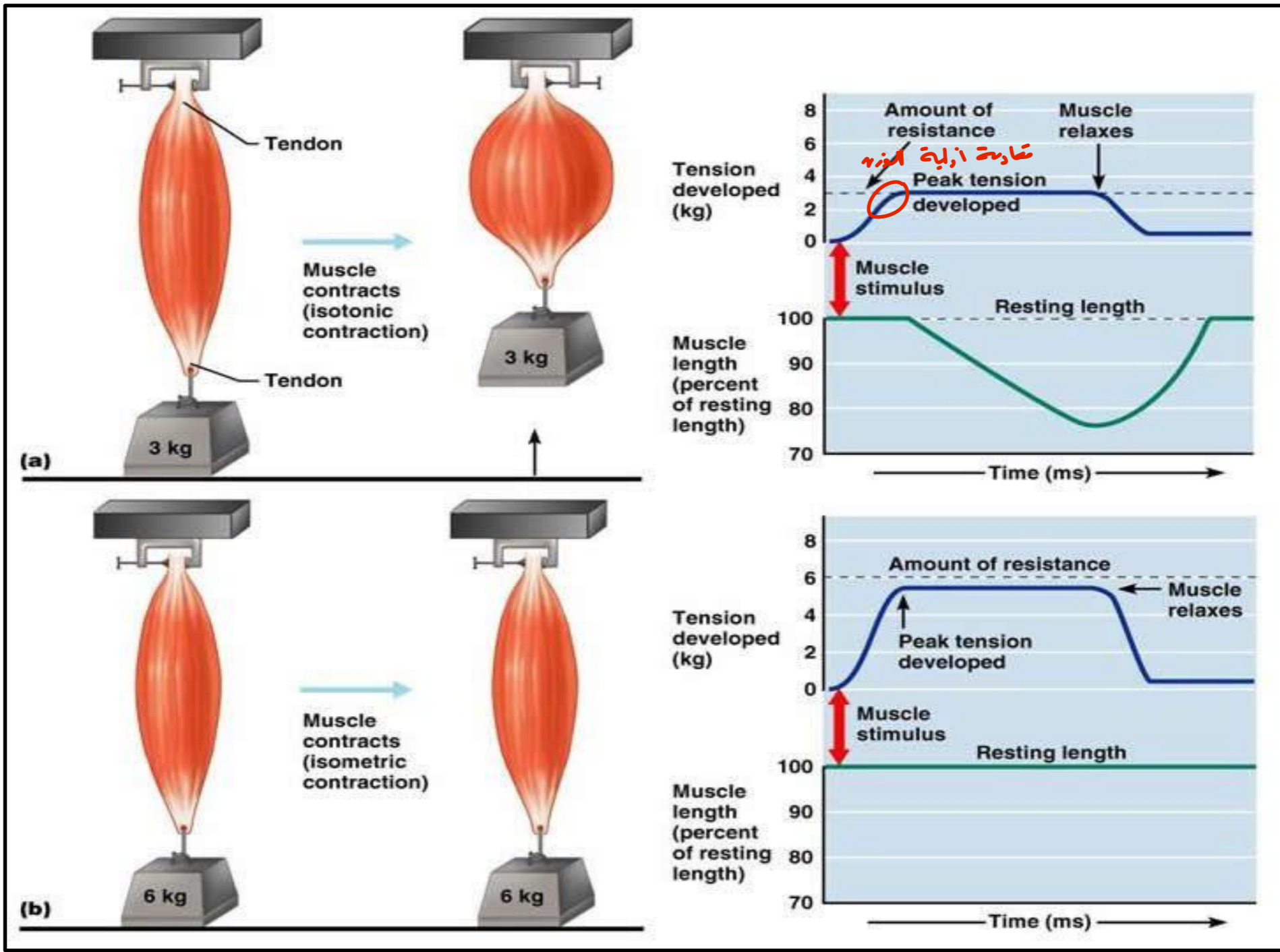
ISOTONIC CONTRACTION

- Involves the change in length **without any** change in tension (constant tension). *Passive, so no active*
- The muscle **shortens** and carries a weight (i.e. **mechanical work is done**) **without** change in tension.
- **Mechanism:** *يبدى قاطبة! (تجاهل الزيادة)*

The CE shortens and **SE is not markedly** stretched (because load is **moved**) → the whole muscle is shortened and tension remains constant.

*tension > load
(muscle)
force*





Types of Skeletal Muscle Contraction

Item	Isotonic	Isometric <i>خبر هنا نلصك Actin و myosin ديكور محاولة لزلل استهلاك ATP</i>
Length of muscle	Decreases; the muscle shortens	Constant length
Tension	Constant	Much increased
Work	The muscle performs external work	No work is done
Mechanical efficiency	20-25% The rest of energy production is released as heat	Zero <i>تحاول فتتفشل ثم يعوف elastic</i> Though energy is consumed ✓
Example	Carrying a <u>weight against gravity</u>	Carrying a weight that is <u>too heavy</u> to be carried

بكل الى الميره CE
يعمل دكر قوته قد لا تكفي لرفع الجسم
نيمير الصفا على الجبل SE

Load–Velocity Relation

- A **load** on a contracting muscle is a **reverse force** that opposes the contractile force caused by muscle contraction.
- **As the load increases → Velocity of shortening is decreased.**
- **At zero load →** the muscle contracts with a **maximal velocity** of shortening.
- A heavy load that cannot be lifted doesn't allow shortening of the muscle → **isometric contraction**. ✓

shortening X

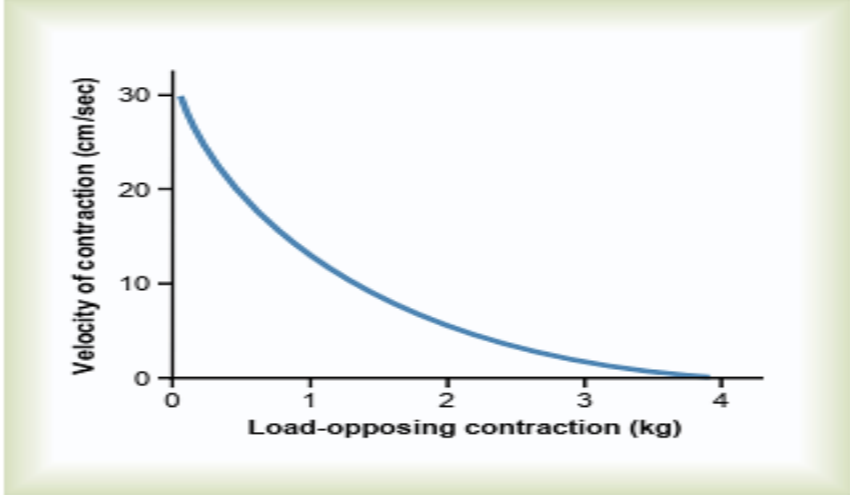
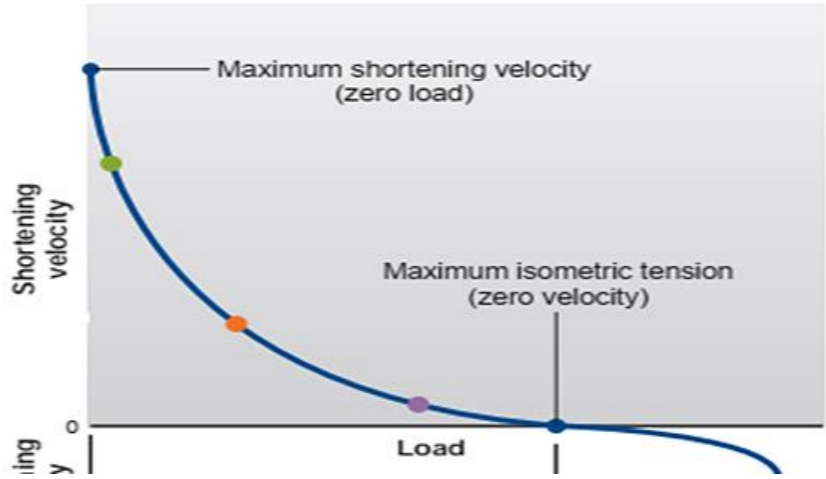


Figure 6-10

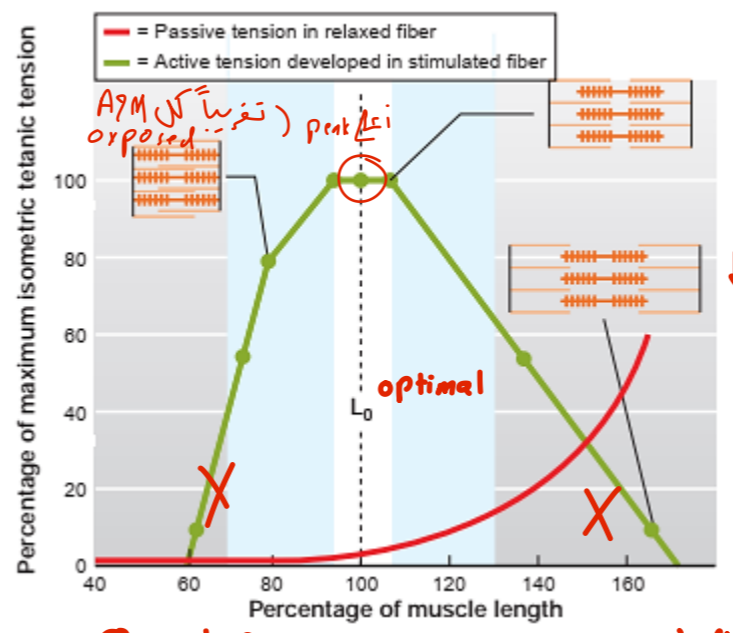


Length–Tension Relation

- It is the relationship between muscle length and **active tension**.
- The **active tension**: The amount of tension is determined for a **muscle** undergoing an **isometric contraction**.
- The **tension developed** by a contracting muscle **depends** on the **number of points of attachment** between **actin** and **myosin** during the myosin power stroke.
- The **maximum amount of tension** developed by the sarcomere is where **every myosin head** is **across from** an **actin molecule** (at the optimal length of the muscle; L_0).

- **At lengths longer than the optimal length (L_0)** → some myosin heads are **NOT** across from actin (filaments apart) → these heads **cannot** participate in the power stroke → the **tension developed** by the contracting sarcomere is **diminished**.
- **At sarcomere lengths shorter than optimal (L_0)** → the myosin filaments are already approaching the point of attachment for the actin filaments, **overlap** occurs between actin molecules → **tension decreases**.
- **Both overstretch and understretch** of resting muscle → ↓ **the developed tension**.
- The **resting length** of the muscle (before contraction is initiated) helps to determine the **maximal amount of tension** that can be developed during contraction.
 $= L_0$
- **For skeletal muscle** → the **optimal length (L_0)** is the normal resting length of the muscle (i.e. inside the body).

رج بجاوں A&M
 یقرب اکر
 فشر elatic
 اقوت ا



↑ Attachment = ↑ tension

↓ A&M

Overlap

away

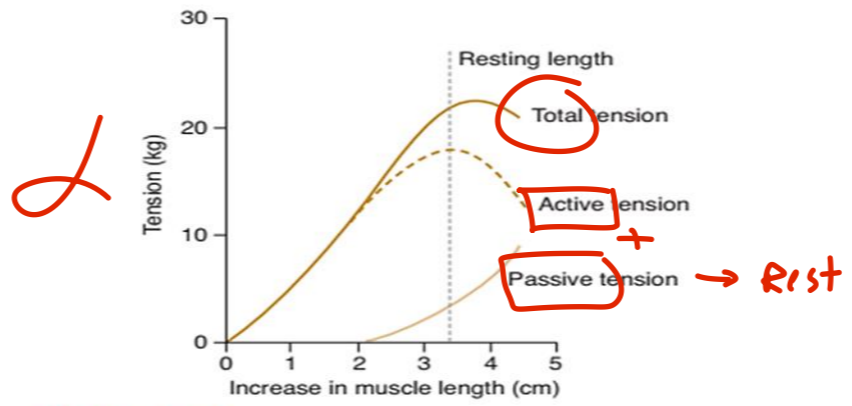


FIGURE 5-11 Length-tension relationship for the human triceps muscle. The passive tension curve measures the tension exerted by this skeletal muscle at each length when it is not stimulated. The total tension curve represents the tension developed when the muscle contracts isometrically in response to a maximal stimulus. The active tension is the difference between the two.

TWITCH CONTRACTIONS

- The RMP of skeletal muscle is -90 mV.
- Initiation of muscle contraction begins with action potential (AP) in the muscle fiber that is conducted from the surface to the interior of the muscle fiber along the T-tubule.
- The mechanical response of a muscle fiber to a single action potential is known as a twitch. *contraction of one A.P.*
- Following the action potential, there is an interval of a few milliseconds known as the latent period before the tension in the muscle fiber begins to increase.
- During this latent period, the processes associated with excitation-contraction coupling (ECC) are occurring.
- The time interval from the beginning of tension development at the end of the latent period to the peak tension is the contraction time. */ length*
- The muscle regains its excitability completely just after beginning of the contraction phase and can respond to a second stimulus.



Depolarization

- Not all skeletal muscle fibers have the same twitch contraction time.
- The total duration of a contraction depends in part on the time that cytosolic Ca^{2+} remains elevated so that cross-bridges can continue to cycle. This is closely related to the Ca^{2+} -ATPase activity in the sarcoplasmic reticulum; activity is greater in fast-twitch fibers and less in slow-twitch fibers.

$\uparrow \text{Ca}^{2+}$, \uparrow time = slower

→ هذه التي يميز
أنواع الألياف

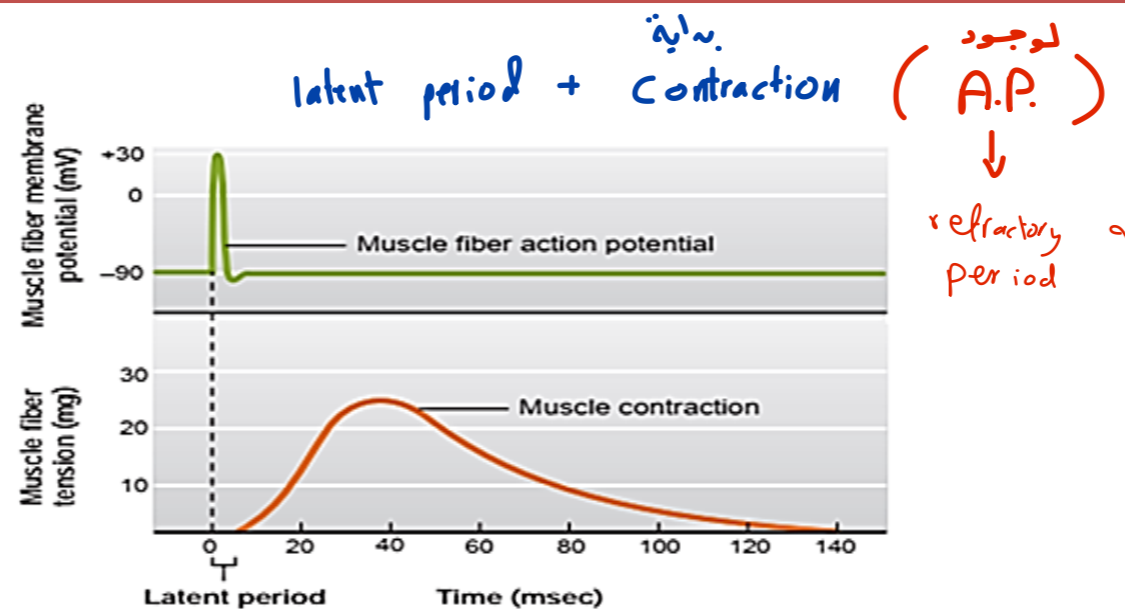


Figure 9.10 Time relationship between a skeletal muscle fiber action potential and the resulting contraction and relaxation of the muscle fiber. The latent period is the delay between the beginning of the action potential and the initial increase in tension.

Frequency–Tension Relation

- A single **action potential** in a skeletal muscle fiber lasts **only 1 to 2 msec** but the twitch may last for **100 msec**.
- It is possible for a second action potential to be initiated during the period of mechanical activity.
- Following the first stimulus, $S_1 \rightarrow$ isometric twitch lasts **150 msec**.
- **When the second stimulus, S_2 , applied to the muscle fiber 200 msec after $S_1 \rightarrow$ the fiber has completely relaxed \rightarrow causes a second identical twitch.**
- **When a stimulus is applied before a fiber has completely relaxed from a twitch \rightarrow it induces a contractile response with a peak tension greater than that produced in a single twitch (S_3 and S_4).**
- **If the interval between stimuli is reduced further \rightarrow during contraction phase \rightarrow the resulting peak tension is even greater; mechanical summation (S_5 and S_6).**

\rightarrow tension \uparrow time

- contraction interrupted
by partial relaxation



تخلية في →

- At **low stimulation** frequencies → each stimulus falls during the **relaxation phase** of the preceding twitch → the muscle fiber **partially relaxes** between stimuli → producing an **unfused (incomplete) tetanus** or **clonus**.
- At **higher stimulation** frequencies → each stimulus falls during the **contraction phase** of the preceding twitch → **fused (complete) tetanus** is produced.
- **Tetanus (tetanic contraction): A maintained contraction in response to repetitive stimulation.**
- Different muscle fibers have **different contraction times**, so the stimulus **frequency** that will produce a **maximal tetanic tension** differs from fiber to fiber.

تفرق بين وقت ووقت stimulus للتاني
منه يوضح

continuous contraction
←
= tetanus

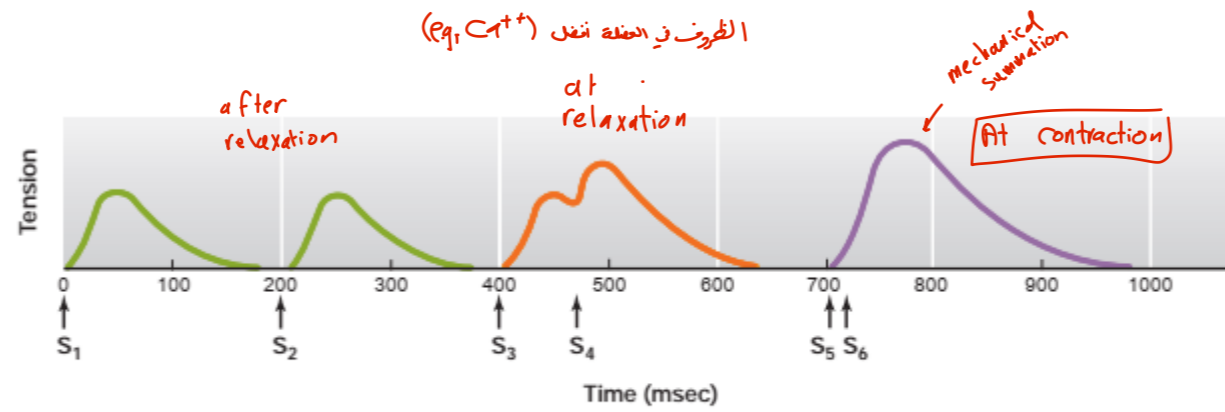


Figure 9.19 Summation of isometric contractions produced by shortening the time between stimuli.

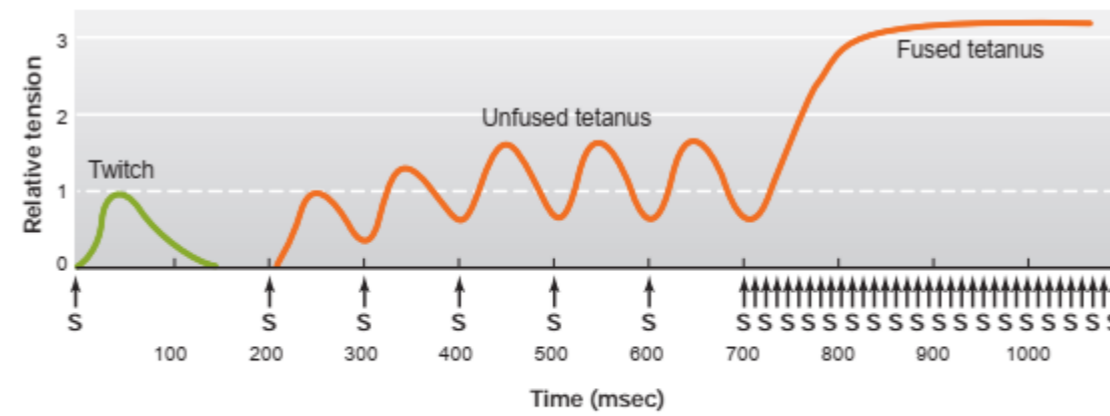


Figure 9.20 Isometric contractions produced by multiple stimuli (S) at 10 stimuli per second (unfused tetanus) and 100 stimuli per second (fused tetanus), as compared with a single twitch.

Types and causes of fatigue

Fatigue: A transient and recoverable reduction in the force of muscle contraction.

Types and causes:

• **Muscle fatigue:**

indirect & direct →

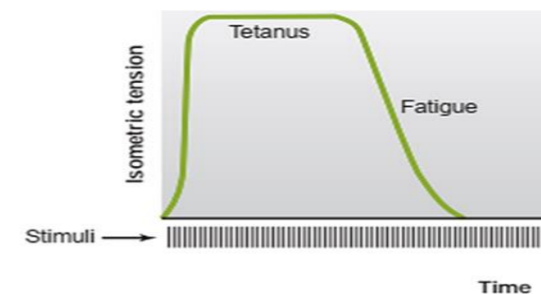
Due to depletion of the energy stores (ATP, CP and glycogen) and accumulation of metabolites (e.g. lactic acid).

تعبه من الجسم مباشرة Direct

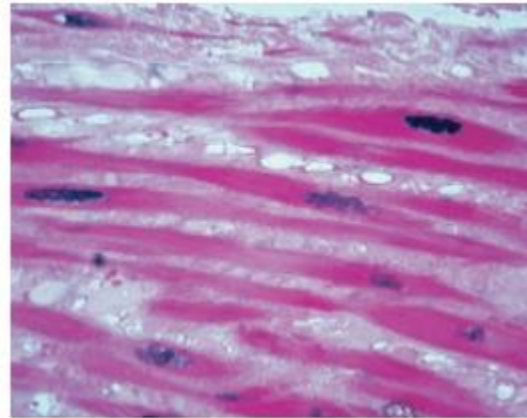
أولاً

• **Motor end plate (MEP) fatigue:** *not nerve*

Due to depletion of chemical transmitter (ACh) at the MEP.



SMOOTH MUSCLE



No troponin

- **Two characteristics are common to all smooth muscles:**
 - They lack the ~~cross-striated~~ banding pattern found in skeletal and cardiac fibers (which makes them “smooth”).
 - The nerves to them are part of the **autonomic division of the nervous system** rather than the somatic division. Thus, **smooth muscle is not under ~~voluntary control~~**.
- Just like skeletal muscle fibers, smooth muscle cells have thick myosin-containing filaments and thin actin-containing filaments.
- Although **tropomyosin** is present in the thin filaments, the regulatory protein **troponin is absent**.

Ca^{++} → thick (myosin) ≠ thin (troponin)

MECHANISM OF SMOOTH MUSCLE CONTRACTION

Cross-bridge activation

The following sequence of events occurs after an **increase in cytosolic Ca^{2+}** in a smooth muscle fiber:

- (1) **Ca^{2+} binds to calmodulin**, a Ca^{2+} -binding protein that is present in the cytosol and whose structure is related to that of troponin.
- (2) **The Ca^{2+} -calmodulin complex** binds to another cytosolic protein, **myosin light-chain kinase**, thereby **activating the enzyme**.
- (3) **Active myosin light-chain kinase** then uses **ATP** to phosphorylate **myosin light chains** in the **globular head** of myosin.
- (4) **Phosphorylation of myosin** drives the cross-bridge away from the thick filament backbone, allowing it to **bind to actin**.
- (5) Cross-bridges go through repeated cycles of force generation as long as myosin light chains are phosphorylated.

✓ A key difference here is that Ca^{2+} -mediated changes in the **thick filaments** turn on cross-bridge activity in **smooth muscle**, whereas in **striated muscle**, Ca^{2+} mediates changes in the **thin filaments**.

- ✓ The smooth muscle form of myosin has a **very low** rate of **ATPase activity** less than that of skeletal muscle myosin.
- ✓ Because the rate of ATP hydrolysis **determines** the rate of **cross-bridge cycling** and shortening velocity, smooth muscle shortening is **much slower** than that of skeletal muscle.
- ✓ Due to this slow rate of energy usage, smooth muscle **does not** undergo **fatigue** during prolonged periods of activity.

MECHANISM OF SMOOTH MUSCLE RELAXATION

- To **relax** a contracted smooth muscle, myosin must be **dephosphorylated** because dephosphorylated myosin is unable to bind to actin.
- This **dephosphorylation** is mediated by the enzyme **myosin light-chain phosphatase**, which is continuously active in smooth muscle during periods of rest and contraction.
- When **cytosolic Ca^{2+} concentration increases**, the rate of myosin phosphorylation by the **activated kinase** exceeds the **rate of dephosphorylation** by the **phosphatase** and the amount of phosphorylated myosin in the cell increases, producing an increase in tension.
- When the **cytosolic Ca^{2+} concentration decreases**, the rate of phosphorylation decreases below that of dephosphorylation and the amount of phosphorylated myosin decreases, producing relaxation.

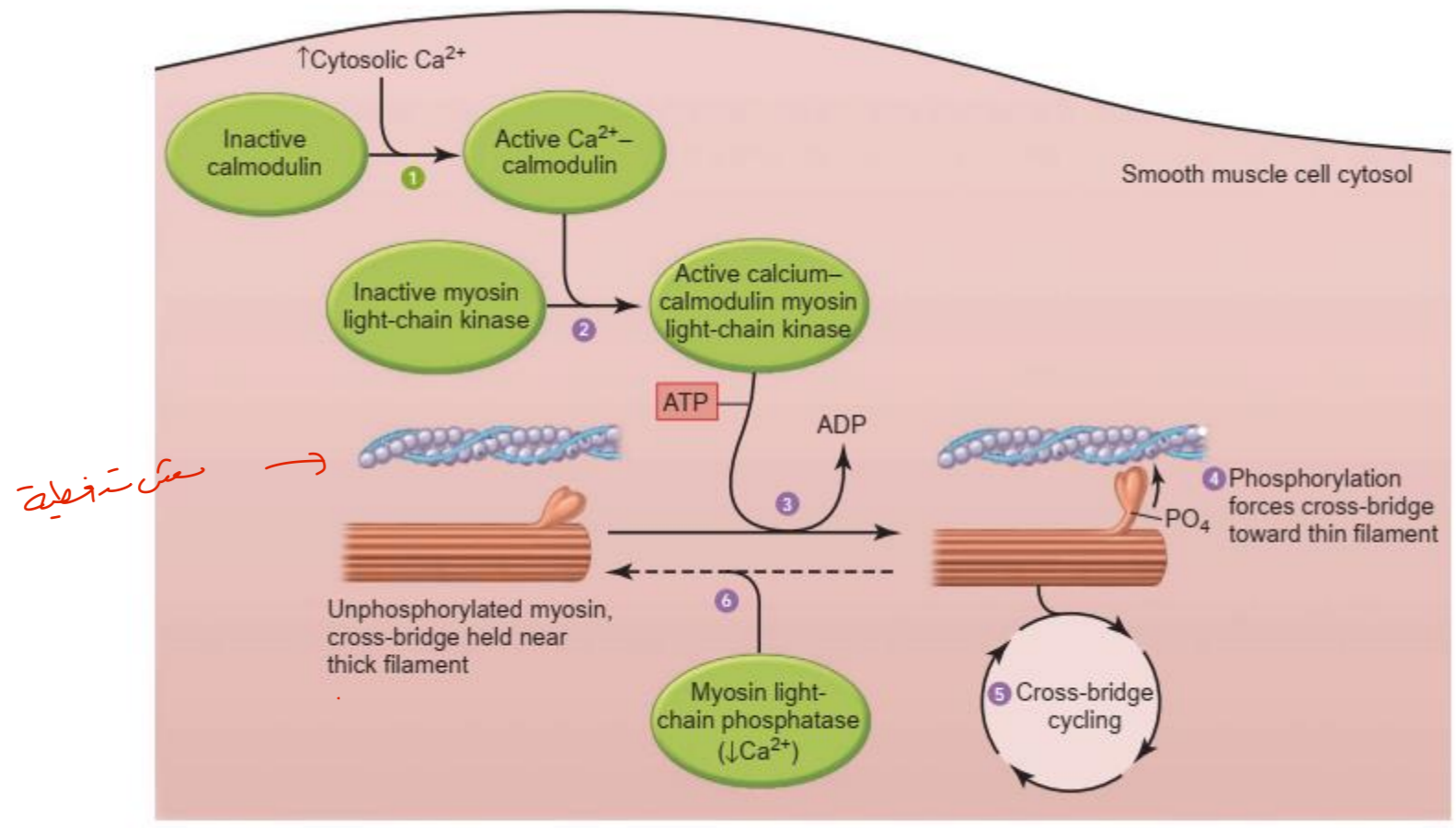


Figure 9.34 Activation of smooth muscle contraction by Ca^{2+} . See text for description of the numbered steps.

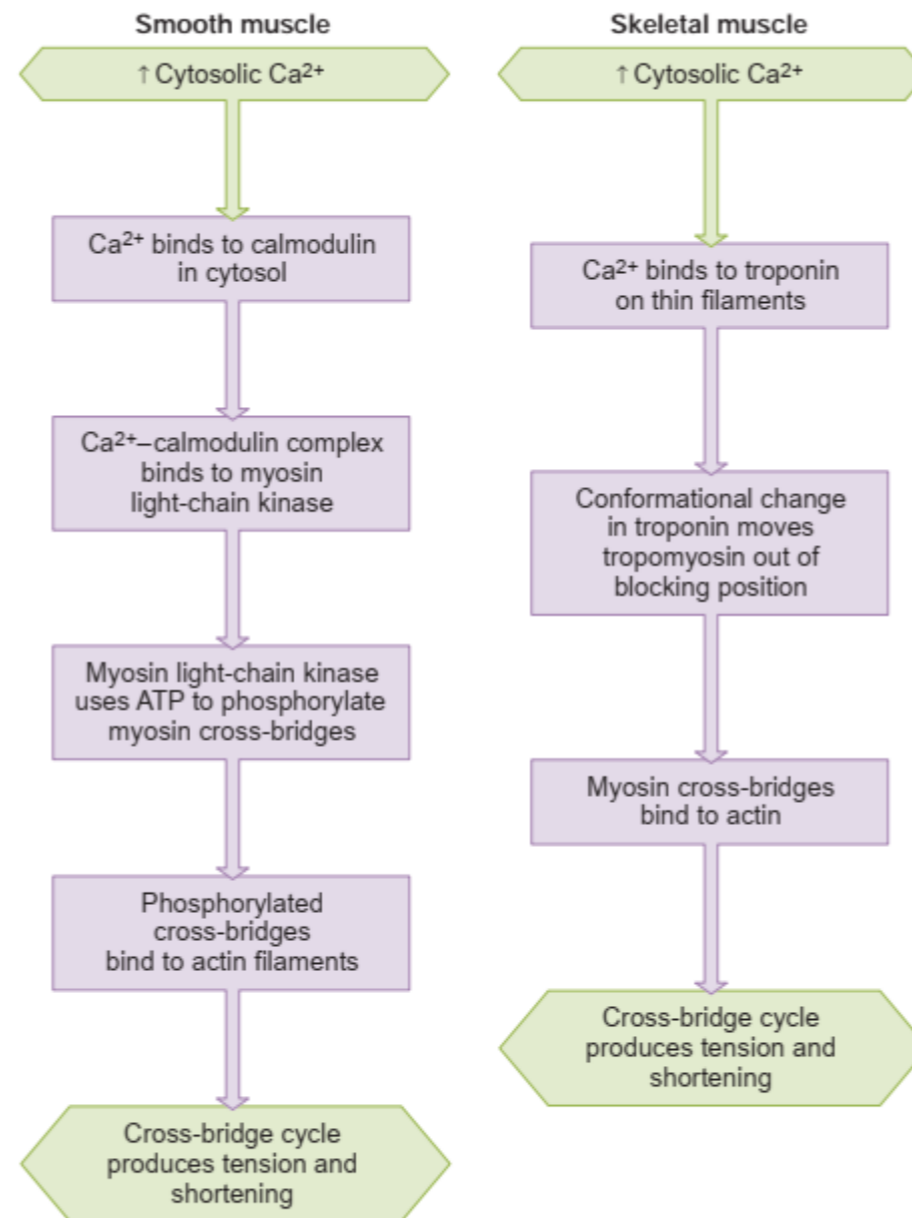


Figure 9.35 Pathways leading from increased cytosolic Ca^{2+} to cross-bridge cycling in smooth and skeletal muscle fibers.

Thank
you

The image features the words "Thank you" written in a highly decorative, cursive calligraphic font. The text is rendered in a dark teal or black color with a subtle white drop shadow, giving it a three-dimensional appearance. The words are arranged in two lines: "Thank" on top and "you" below it. The entire text is framed by a lush, circular arrangement of various floral and leaf motifs. These include small pink and red flowers, orange and yellow leaves, and teal-colored sprigs with small buds. The overall composition is vibrant and celebratory, set against a plain white background.