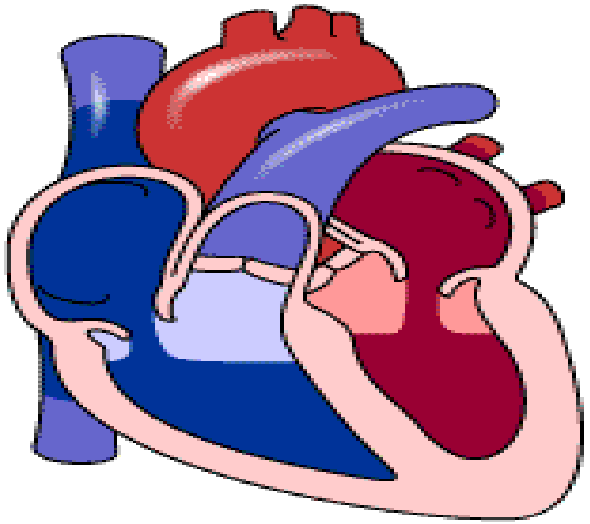
CARDIAC MUSCLE: CONTRACTILE MECHANISM OF CARDIAC MUSCLE



Prof. Sultan Ayoub Meo
MBBS, M.Phil, Ph.D (Pak), M Med Ed (Dundee), FRCP (London), FRCP (Dublin), FRCP (Glasgow), FRCP (Edinburgh)
Professor and Consultant, Department of Physiology,
College of Medicine, King Saud University, Riyadh, KSA

CARDIAC MUSCLE

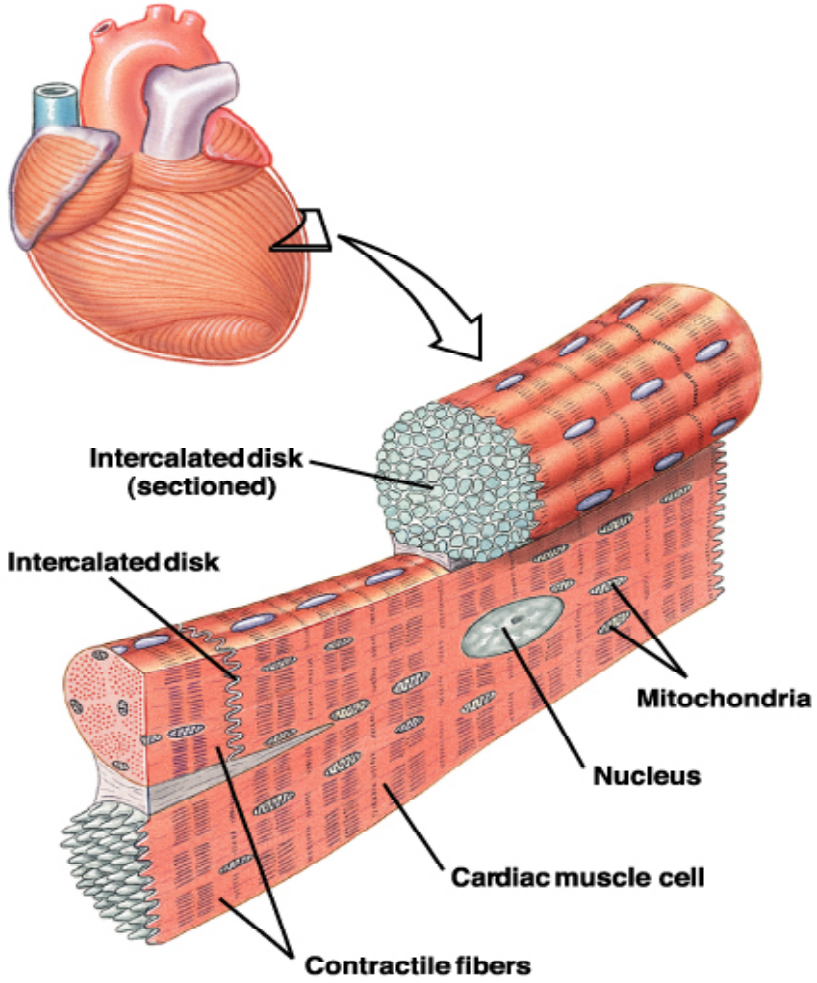
Heart is composed of three major types of cardiac muscle

- Atrial Muscle
- Ventricular Muscle
- Specialize Excitatory & Conductive Muscle

- The atrial and ventricular muscle contract in much the same way as skeletal muscle, except duration of contraction is much longer.
- The specialized excitatory and conductive fibers contract weakly because they contain few contractile fibrils

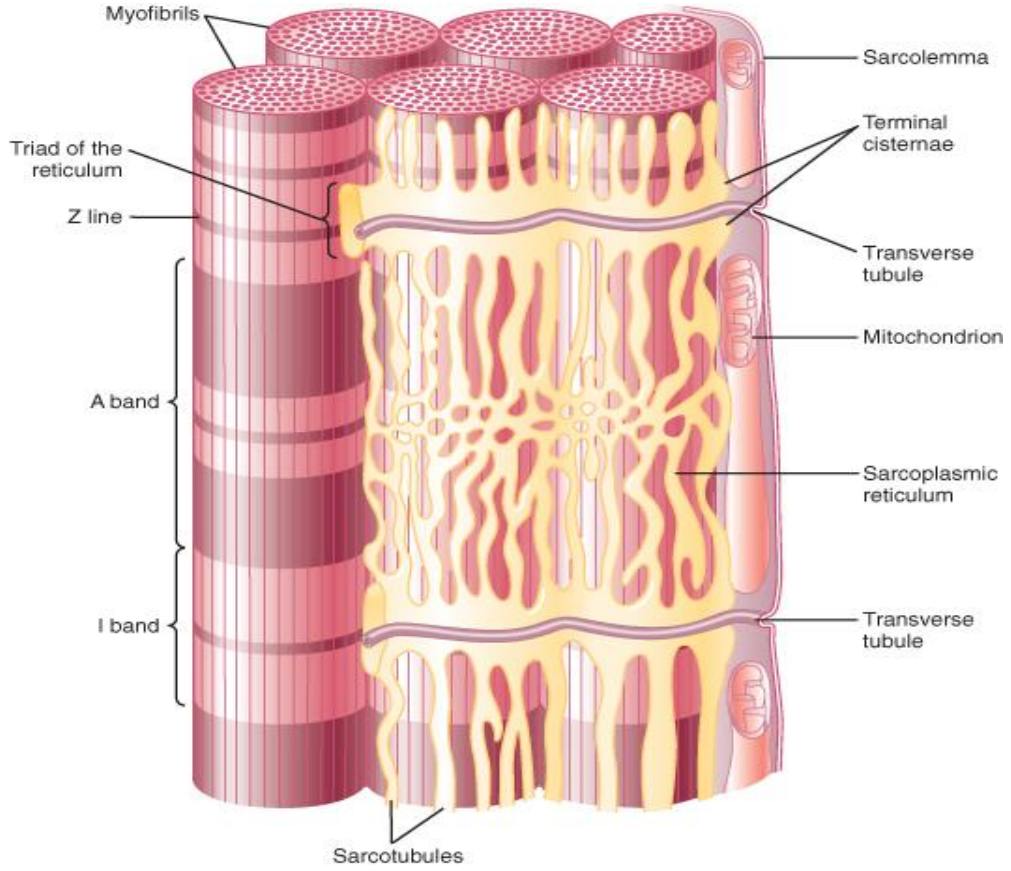
Guyton pp 109

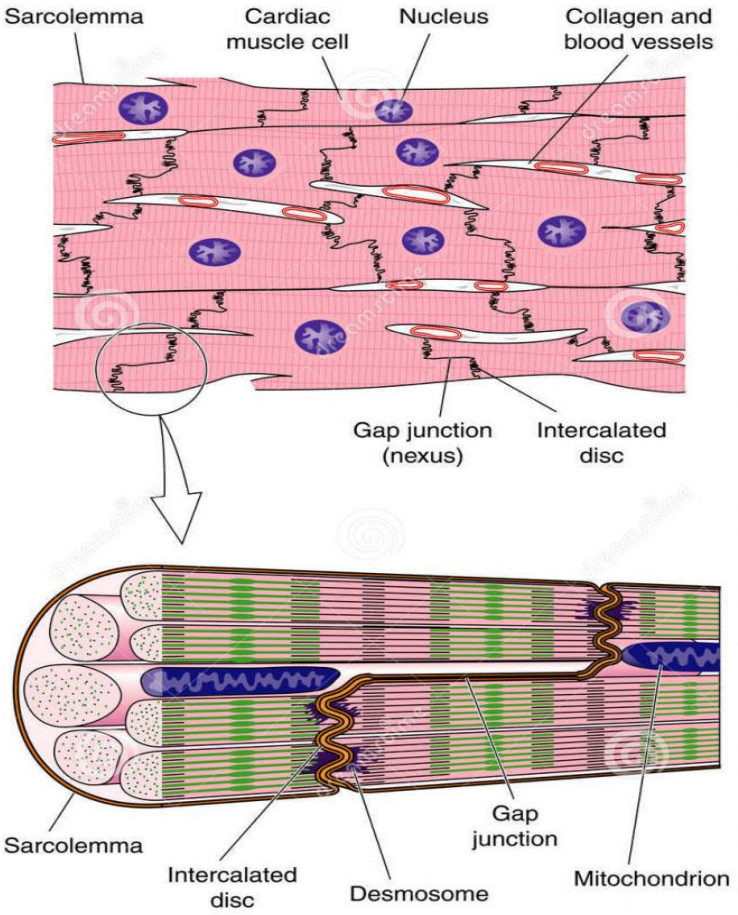
CARDIAC MUSCLE



- Cardiac muscle fibers are striated in appearance
- Functional unit is called Sarcomere
- Fibers are branched; connect to one another at *intercalated discs*.
- The discs contain several **Gap Junctions**
- Nuclei are centrally located
- Abundant Mitochondria
- Sarcoplasmic Reticulum is less abundant than in skeletal muscle, but greater in density than smooth muscle
- Sarcolemma: Has specialized ion channels that skeletal muscle does not – voltage-gated Ca2+ channels
- Fibers are not anchored at ends; allows for greater sarcomere shortening and lengthening

CARDIAC MUSCLE





CARDIAC MUSCLE

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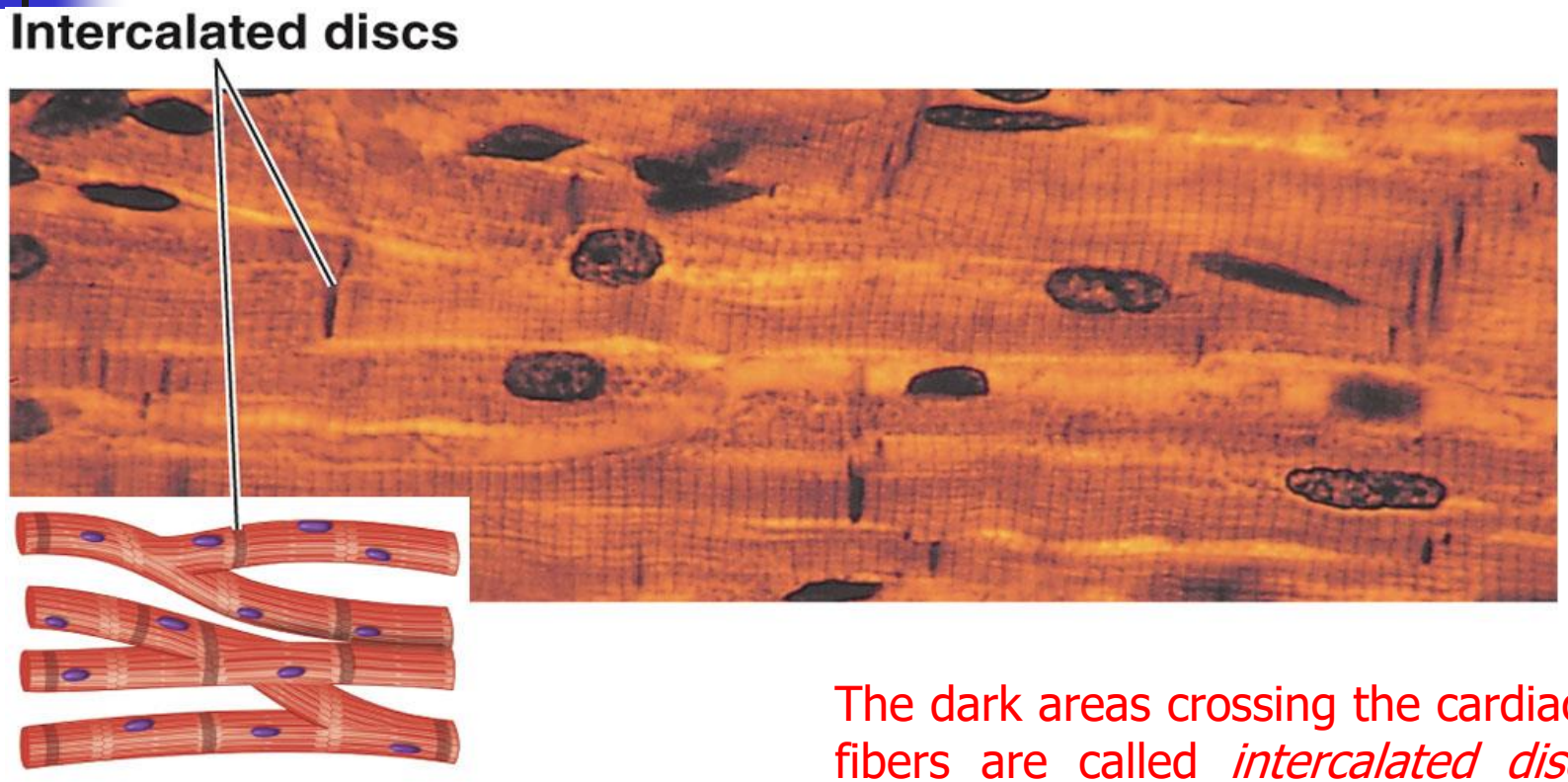


(b) Cardiac muscle fibers branch and are interconnected by intercalated discs.

The dark areas crossing the cardiac muscle fibers are called *intercalated discs;* they are **actually cell membranes that separate individual cardiac** muscle cells from one another. Guyton pp 109

CARDIAC MUSCLE

At intercalated disc cell membranes fuse with one another, form permeable **"communicating" junctions (gap junctions)** allow free diffusion of ions.

Ions move with ease in the intracellular fluid along the longitudinal axes of the cardiac muscle fibers, so that action potentials travel easily from one cardiac muscle cell to the next

Thus, cardiac muscle is a *syncytium* of many heart muscle cells, action potential spreads to all of them.

Guyton pp 104

CARDIAC MUSCLE

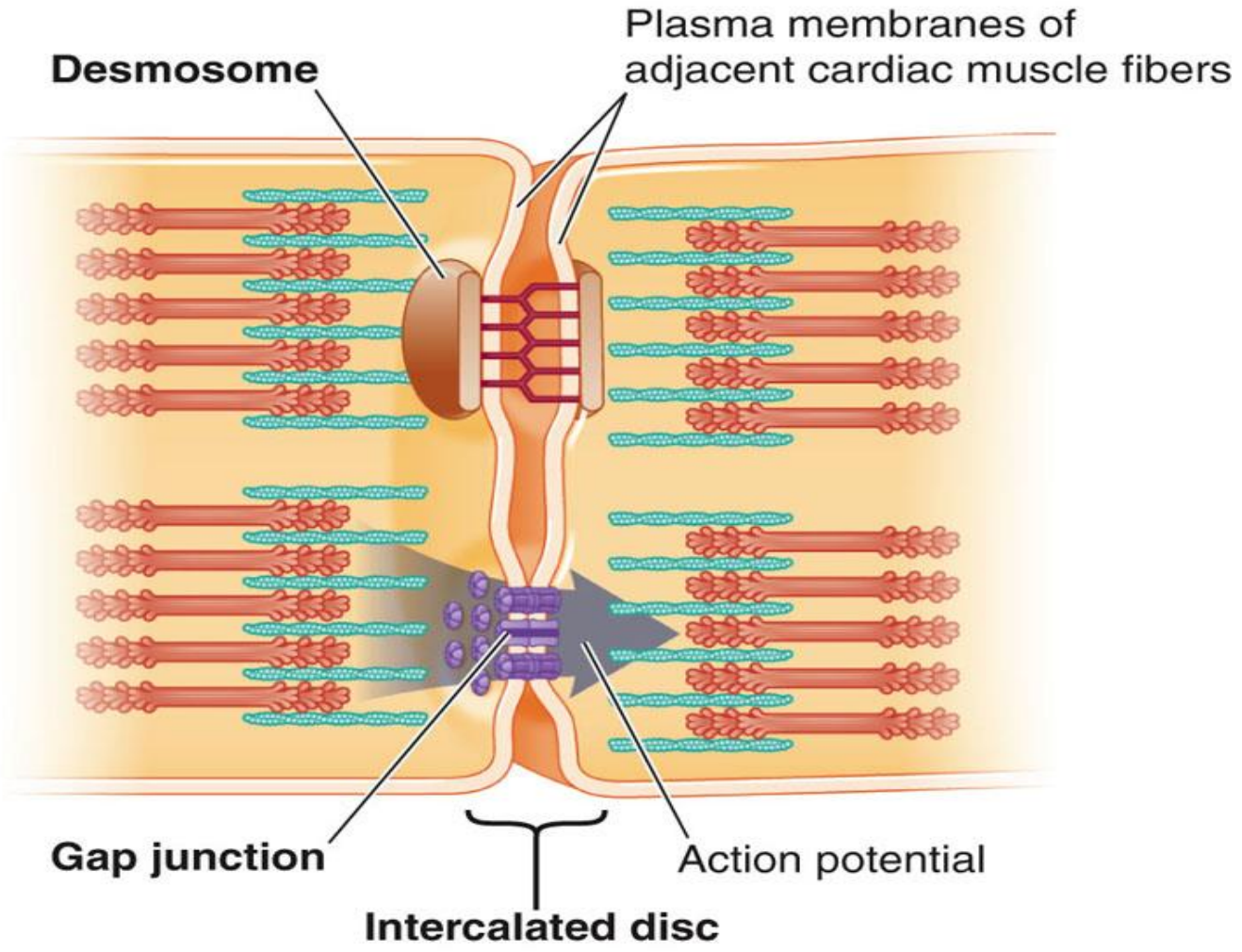
Isometric Contraction: Muscle contraction without significant shortening or change in distance

Isotonic Contraction: Muscle contraction without significant change in force of contraction

CARDIAC MUSCLE

- Interconnected by intercalated discs and form functional syncytia
- Within intercalated discs – two kinds of membrane junctions
  - Desmosomes
  - Gap junctions

CARDIAC MUSCLE



CARDIAC MUSCLE

- Heart beats rhythmically as result of action potential, it generates by itself (Auto-rhythmicity)

- Two specialized types of cardiac muscle cells
  - Contractile cells
    - 99% of cardiac muscle cells
    - Do mechanical work of pumping
  - Autorhythmic cells
    - Do not contract
    - Specialized for initiating and conducting action potentials responsible for contraction of working cells

CARDIAC MUSCLE PROPERTIES

The cardiac muscle cells are responsible for the electrical stimulation leads to mechanical function. The electro-physiologic properties of cardiac muscles are:

Automaticity: Ability to spontaneously generate an electrical impulse.

Excitability: Ability to respond to an electrical impulse.

Conductivity: Allows transmission of electrical impulse to another cardiac cell.

Contractility: Ability to contract after electrical impulse response

Rhythmicity: Ability to send electrical impulses in a regularly manner.

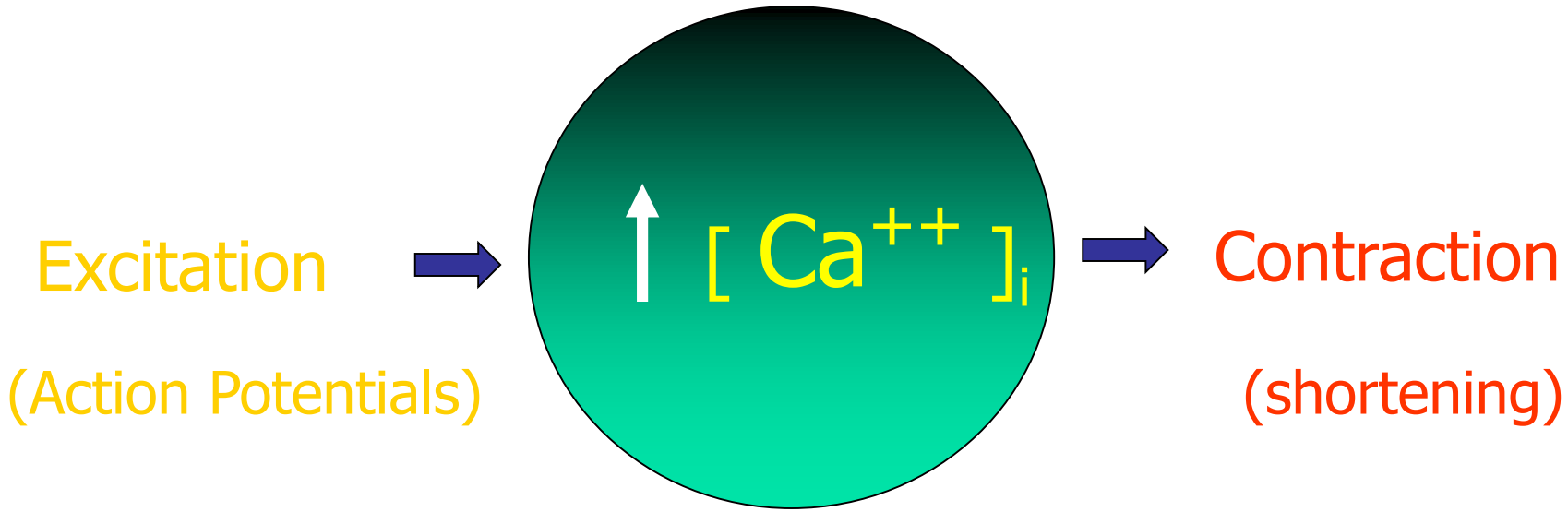
FEATURES OF DIFFERENT TYPES OF MUSCLE

Table III-2-1. Histologic Features of Skeletal, Cardiac, and Smooth Muscle

Skeletal	Cardiac	Smooth
Striated	Striated	Nonstriated
Actin and myosin form sarcomeres	Actin and myosin form sarcomeres	Actin and myosin not organized into sarcomeres
Sarcolemma lacks junctional complexes between fibers	Junctional complexes between fibers including gap junctions	Gap junctions
Each fiber innervated	Electrical syncytium	Electrical syncytium
Troponin to bind calcium	Troponin to bind calcium	Calmodulin to bind calcium
High ATPase activity (fast muscle)	Intermediate ATPase activity	Low ATPase activity (slow muscle)
Extensive sarcoplasmic reticulum	Intermediate sarcoplasmic reticulum	Limited sarcoplasmic reticulum
T tubules form triadic contacts with reticulum at A-I junctions	T tubules form dyadic contact with reticulum near Z lines	Lack T tubules, SR controlled by second messengers
Surface membrane lacks calcium channels	Voltage-gated calcium channels	Voltage-gated calcium channels

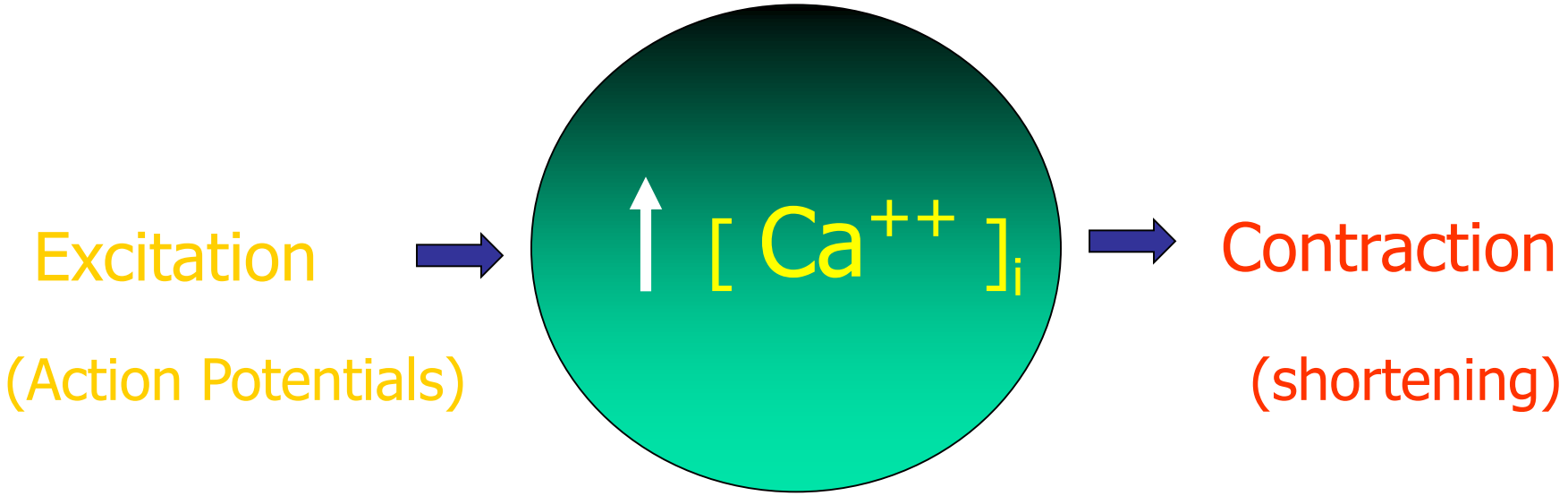
Excitation-Contraction coupling

Excitation-Contraction coupling

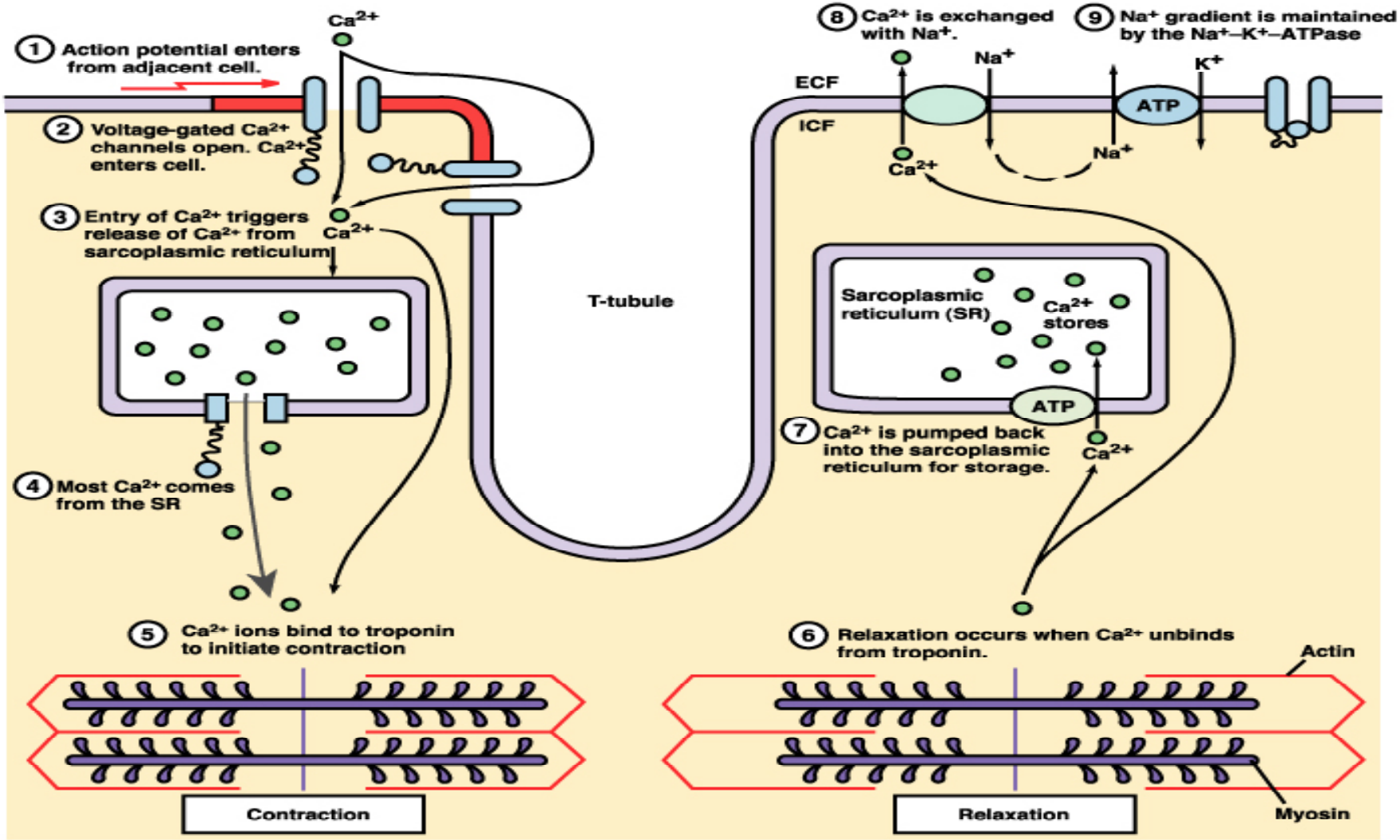


Excitation-Contraction coupling

Excitation of the heart is triggered by electrical impulse rather than neural transmitters.
Contraction of the heart is triggered by elevation of intracellular calcium influx.



Excitation-Contraction coupling



Calcium ions regulate the contraction of cardiac muscle:
Entry of extracellular calcium ions causes the release of calcium from the sarcoplasmic reticulum (calcium-induced calcium release), source of about 95% of calcium in cytosol.

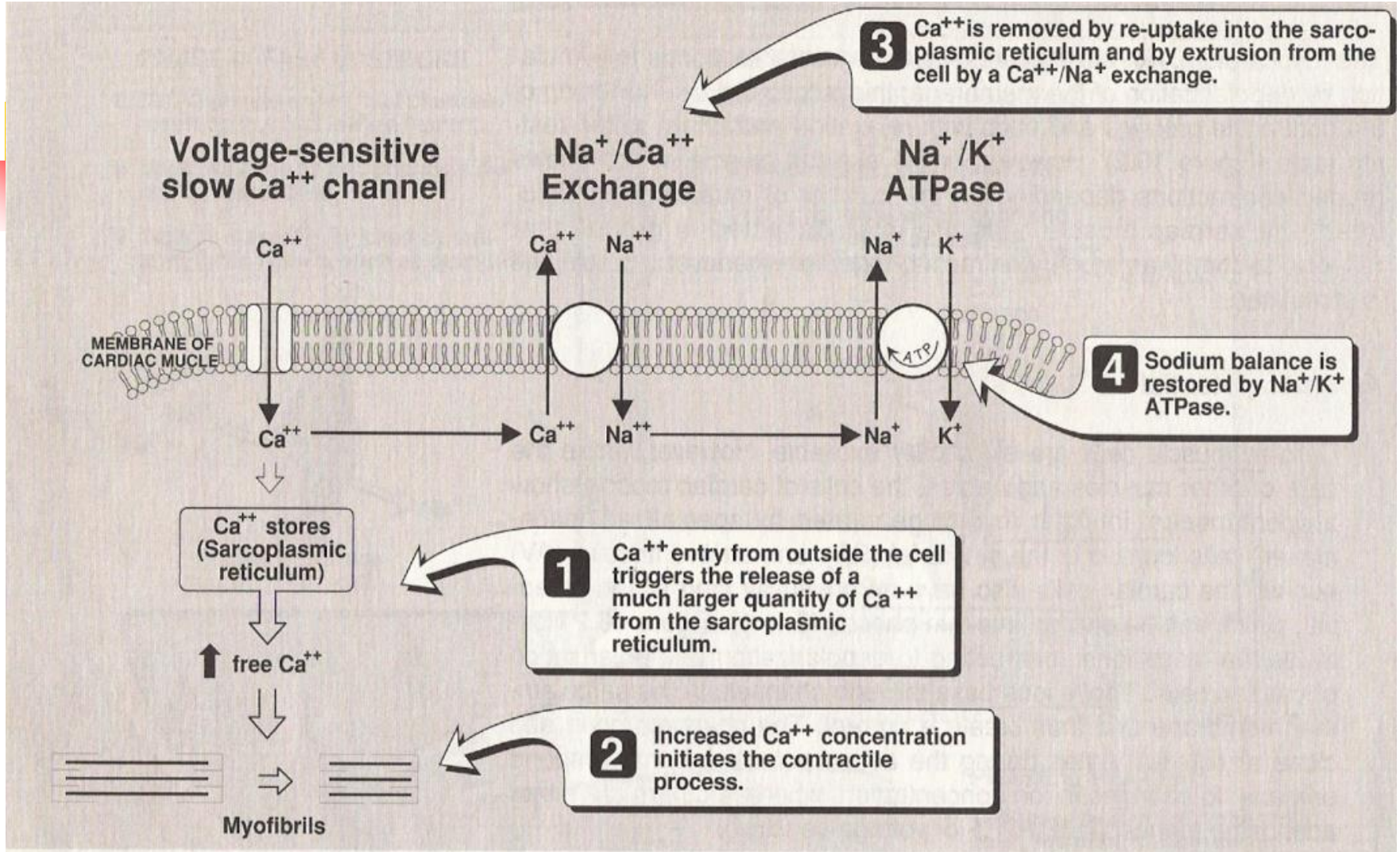


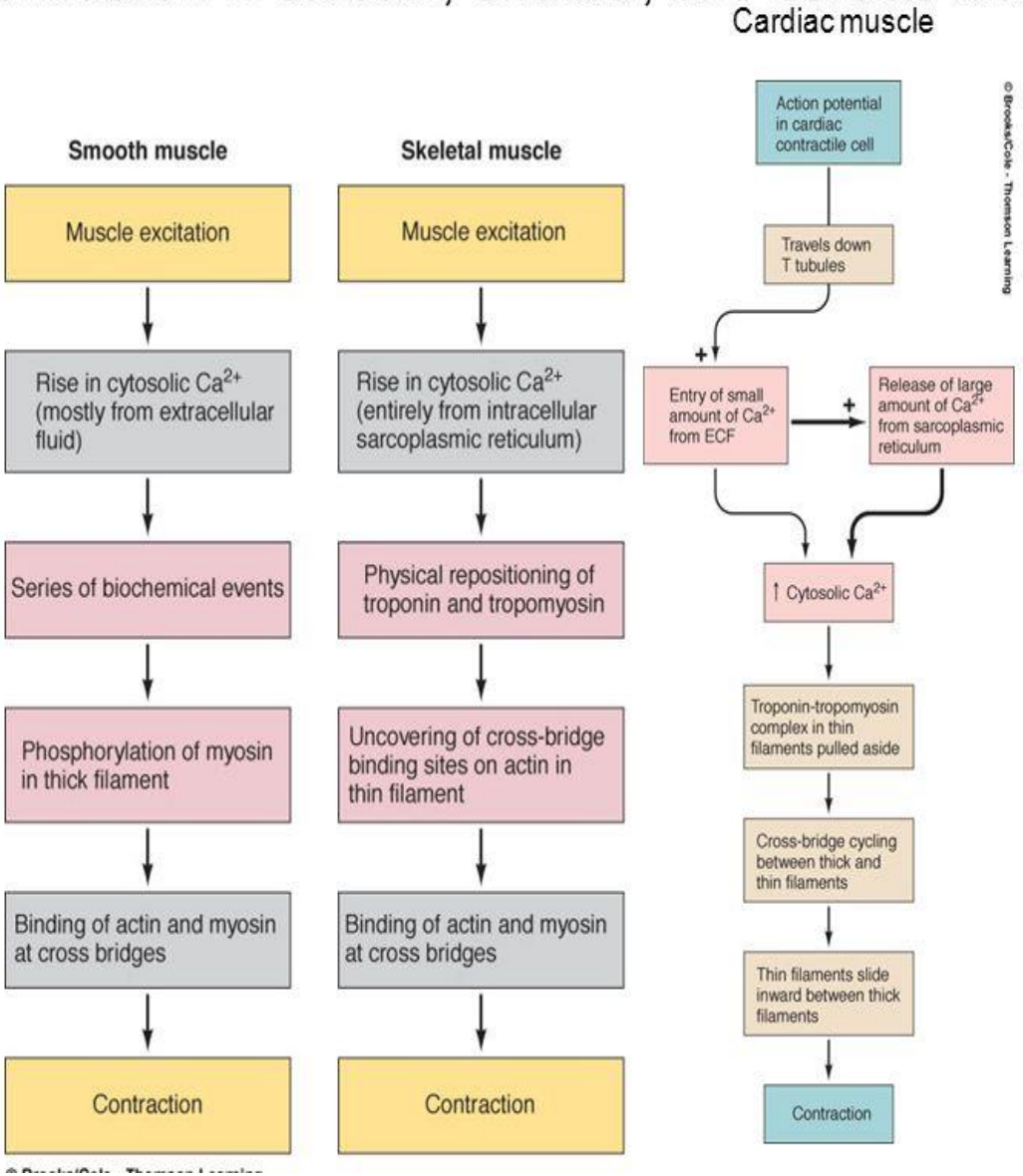
Figure 16.3
Ion movements during the contraction of cardiac muscle.

TABLE 3-1 SUMMARY OF EXCITATION–CONTRACTION COUPLING.

1. Ca^{++} enters cell during depolarization and triggers release of Ca^{++} by terminal cisternae.
2. Ca^{++} binds to TN-C, inducing a conformational change in the troponin complex.
3. Myosin heads bind to actin, leading to cross-bridge movement (requires ATP hydrolysis) and reduction in sarcomere length.
4. Ca^{++} is resequestered by sarcoplasmic reticulum by the SERCA pump.
5. Ca^{++} is removed from TN-C, and myosin unbinds from actin (requires ATP); this allows the sarcomere to resume its original, relaxed length.

ATP, adenosine triphosphate; SERCA, sarco-endoplasmic reticulum calcium ATPase; TN-C, troponin-C.

Comparison of Role of Calcium In Bringing About Contraction in Smooth, Skeletal, and Cardiac Muscle

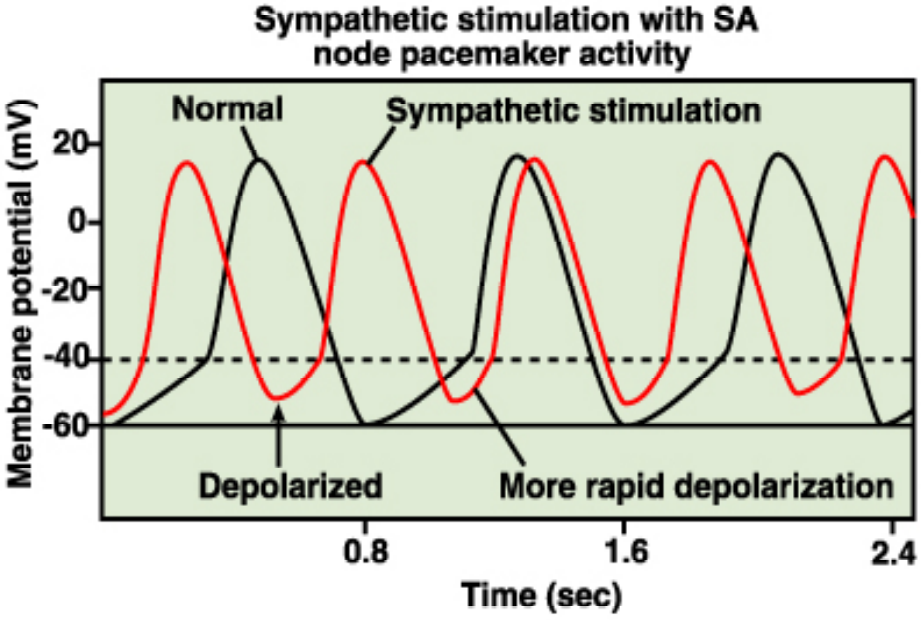


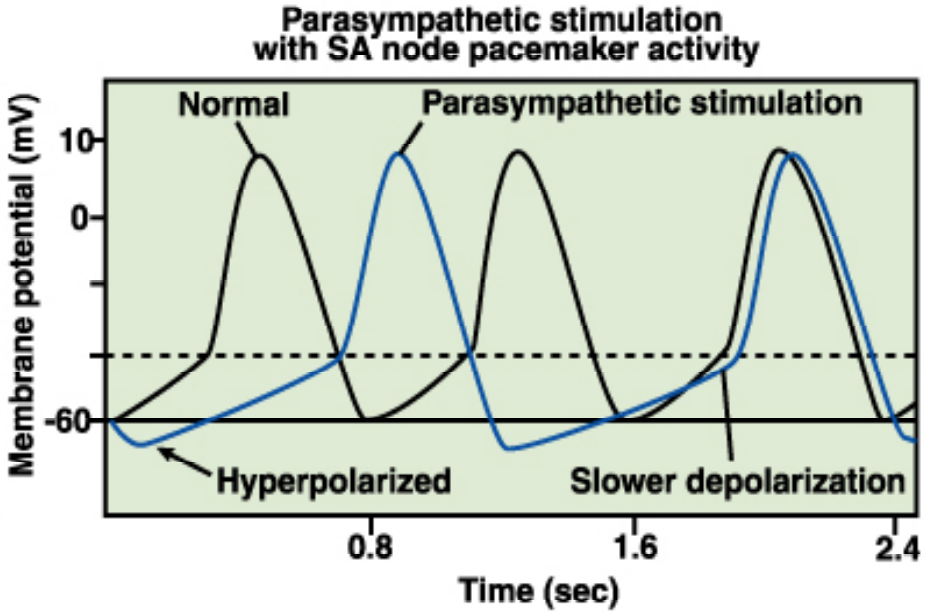
Factors regulating contractility

Table 14.1 Effects of Autonomic Nerve Activity on the Heart

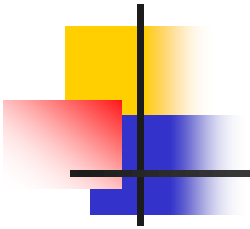
Region Affected	Sympathetic Nerve Effects	Parasympathetic Nerve Effects
SA node	Increased rate of diastolic depolarization; increased cardiac rate	Decreased rate of diastolic depolarization; decreased cardiac rate
AV node	Increased conduction rate	Decreased conduction rate
Atrial muscle	Increased strength of contraction	Decreased strength of contraction
Ventricular muscle	Increased strength of contraction	No significant effect

Factors regulating contractility





- Autonomic nervous system modulates the frequency of depolarization of pacemaker
- Sympathetic stimulation (neurotransmitter); binds to b1 receptors on the SA nodal membranes
- Parasympathetic stimulation (neurotransmitter); binds to muscarinic receptors on nodal membranes; increases conductivity of K+ and decreases conductivity of Ca2+



THANK YOU