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The Cardiac Muscles Properties

The 3rd edition

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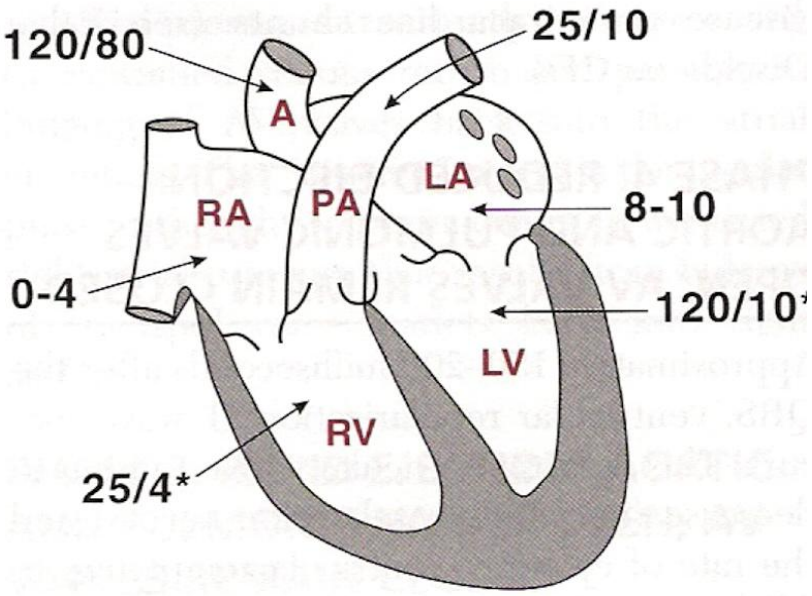
First Version

1431-1432

First of all :

- Heart is located behind the sternum (retrosternal)
- The right ventricle forms anterior surface of the heart .
- The right side of the heart is known as (volume pump) .
- The left side of the heart is known as (pressure pump) : cause it's pump against pressure .

- There are 3 types of vessels : Artery
  Vein
  Lymph



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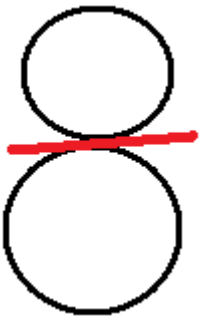
- The left ventricle is 3- 5 times thicker than the right ventricle cause it's work against pressure.
- The left ventricle pressure: -at contraction: 120 - relaxation : 0-10
- Total blood value : 5 liters (60% : present in the vein " venous side of circulation ")

Av ring : a fibrous structure located between the right atrium and the right ventricle



Cardiac Valves :

In the right side of the heart , between ventricle and atrium it called "tricuspid" (which means three cusps) valves .

In the left side of the heart ventricle and atrium , it called "bicuspid" or "mitral" (which means two cusps)

For each cusp there is a muscle (papillary muscle)

Circulation :

- Pulmonary : right side of the heart
- Systemic : left side of the heart

Pulmonary circulation has 2 features :

❶ deoxygenated blood

❷low pressure system

- the right atrium is stimulated to contract and then pump deoxygenating blood (semi lunar valve) through the pulmonary artery to the lung .

Then, pulmonary vein carries the oxygenated blood from the lung to the left atrium to the left ventricle (through mitral valve) and pumped to the body tissues through the Aorta.

Remember !

The pulmonary Artery is the only artery that carries deoxygenated blood !

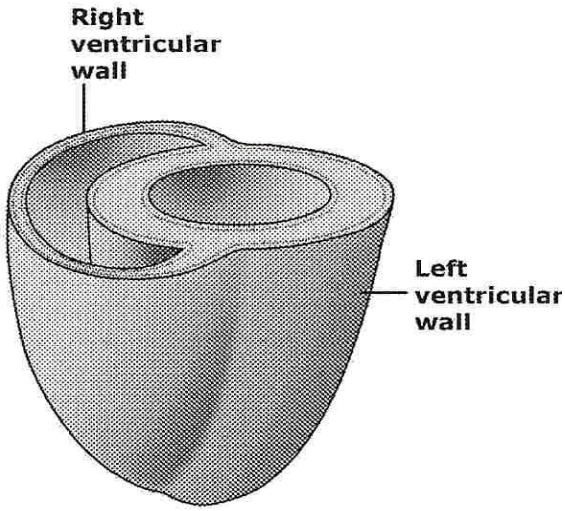
Ventricular wall thickness :

From the figure you can notice that :

→Right ventricular wall is semi lunar shape

→Left ventricular wall is outline In circles

→The left ventricular wall is thicker than the right ventricular wall



figure

Parasympathetic :

The parasympathetic supplies the heart by the vagus nerve , there are 2 :

Right vagus supplies Sino-atrial node (SA node) : found inside the right atrium

- It's powerful : 80 -100 pulse per minute

Left vagus supplies Atrio ventral node (AV) : right atrium , also

- It's less powerful : 40 – 50 per minute

SA node initiate the contraction of the heart

Sympathetic:

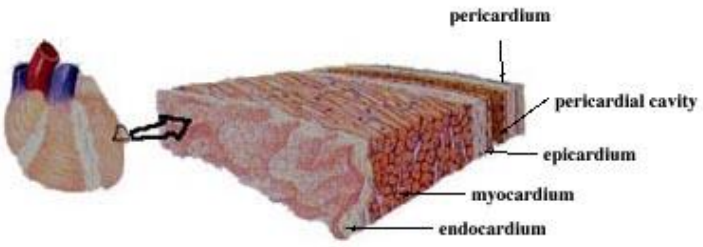
Supplies all parts of the heart

What's the use of the nerve supply ?

To regulate the heart rate

Heart layers :

- **Outer : pericardium**
- **Middle : myocardium**
- **Inner : endocardium**



Cardiac properties

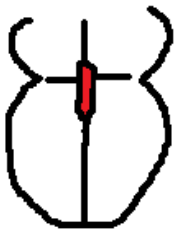
- **Syncytium**
- **Electrical properties**
- **All or none law**
- **Action potential**
- **Rhythmicity**
- **Conductivity**
- **Contractility**

▶ **Syncytium** : if one part of the heart is stimulated, all the heart will contract **(why ?)**

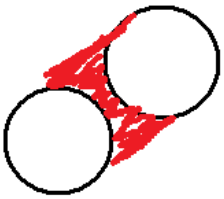
- **Bundle of His**: work like a bridge between Atrium and ventricle to carries electrical impulse
- **intercalated disc** : is the partition between two cardiac cells .
- **gap junction**: is the connection between two cells in the intercalated disc.

signs .

between cardiac cells there is the **intercalated disc**, it has low resistance and it has a **gap junction inside** it , so if you stimulate any part, impulse will move through the gap junction to all the cells..



Bundle of his



Intercalated disc

gap junction

▶ **All ore None law "all will contract or none contract at all "** : 3 types of stimulation

- **Sub threshold** : no contraction
- **Threshold** : all muscle will contracted.
- **Supra threshold** : strong stimulation .

The normal cell is negatively charged inside , why?

Because of the :

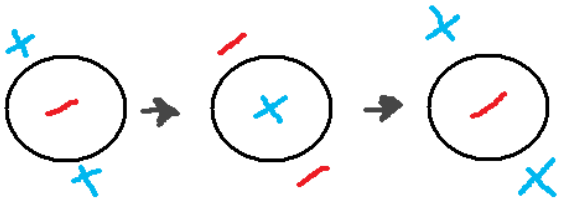
- Na^+ , K^+ AtPease pump (3 Na^+ out , 2 K^+ in)..

- Proteins inside the cell are negatively charged ..

- permeability of K^+ is more than Na^+ ..

All the tissues in the body are negative inside and positive outside and that called = Rest membrane potential (**RMP**) ..

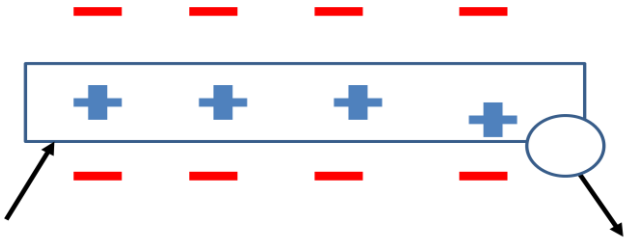
- If we stimulate the cell , then it well change hands (positive in , negative out) and we call that : **De-polarization** .
- After that , the cell will be normal again , we call this : **Re-polarization**



RMP → De-polarization → Re-polarization

- In the left ventricle of the heart , the Rest Membrane Potential inside the cell is : **-80**
- Sometimes, when it's more negative inside it known as : **Hyperpolarize** state

▶**Action potential (also known as : Excitability)** : record of De-polarization wave



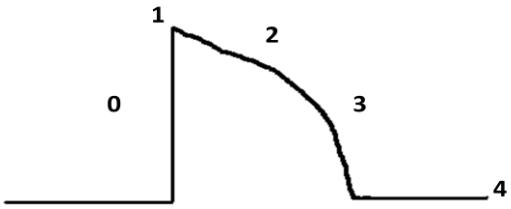
If you stimulate here **the current will appear here (like the Domino fall)**

Types of Action potential **: Type 1 : fast** : ❶ ventricle 1

❷ atrium

❸ purkinje fibers

❶The ventricle action potential : the **RMP** inside the cell is : -80



0 : De-polarization : sodium Na^+ get into the cell .

1: Early Re-polarization : Na^+ channels inactivate , K^+ is going out

2: Plateau Phase: it called flat phase cause Calcium Ca gets into the cell trough L channel and K^+ gets out of the cell to make the cell balance (slow depolarization)

3: Re-polarization :Ka gets out

4: Rest Membrane Cell : RMP

Duration : 250 mil seconds

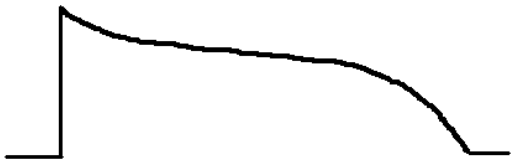
❷The Atrium action potential :

The only difference in the Atrium Action Potential is in the :

Plateau phase (short)

Duration : 100 mill seconds

❸ The Purkinje fibers :



Duration : 350 mil seconds (the widest duration)

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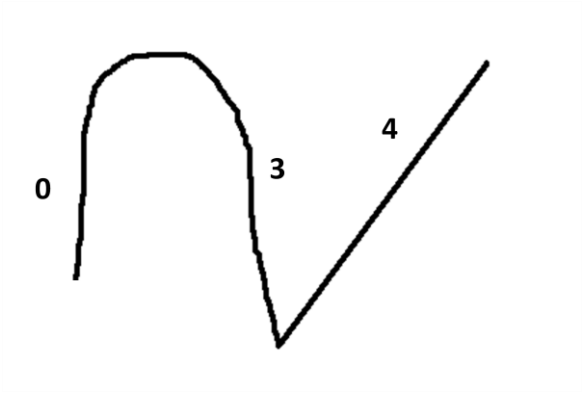
Type 2 slow: ⭘ SA

⭘ AV

⭘ SA :-



The graph shows the **SA** action potential (you can notes that phases 1,2 aren't there)

0 : calcium Ca get into the cell through *L* channel (the only exception in cell **Depolarization**)

3 : Potassium K get out of the cell

4: pre-potential (also named : Pace maker and slow De-polarization potential)

⬢ SA and AV nodes have got similar Action potential shape ..

⬢AV node action potential is slower than SA action node potential

Action Potential

Fast			Slow	
Atrium	**Ventricle**	**Purkinje fibers**	**SA**	**AV**

▶ **Rhythmicity** : when you cut the nerve supply to the heart, it won't stop beating

Why ?

Because of the **: Pre-potential**

3 Ions control **pre-potential (phase 4)** :

1- No potassium (K) getting out of the cell

2- Sodium (Na) get into the cell (increase the positivity +):

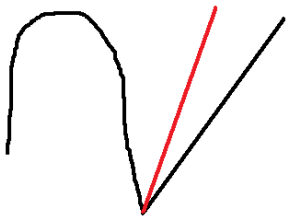
- Na will enter through the funny channel (also F channel or H channel) , that will increase the positivity +, and will slow the De-polarization

It called funny channels because of Na+ entry and out works during hyperpolarization

3- Calcium (Ca) entry the cell through T channels

How to make the heart rate faster ?

the pre- potential (phase 4) Should be more vertical and less horizontal..



= faster

If you increase the heart rate when you stimulate sympathetic it will called : **chronotropic**

The force of contraction called : **Inotropic**

Refractory periods : there are 3 refractory periods :

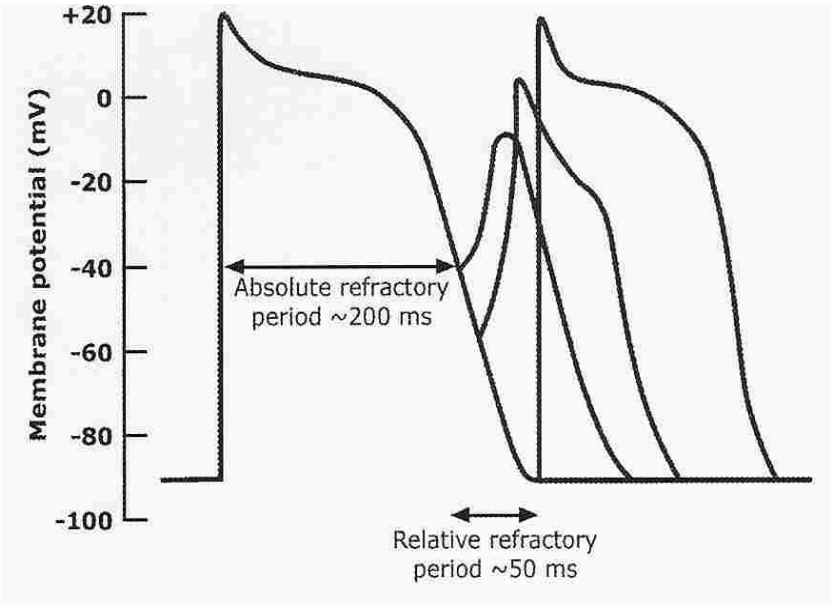
❶ Absolutely Refractory Period (ARP) : no response with the maximum stimulation

Why it couldn't stimulate in ARP?

When Na^+ goes in , all gates are open , you can't open more gates or stimulate more Na^+ , till it's close you can't do anything yet ..

❷Relative Refractory period : begins after the $\frac{1}{3}$ upper of phase 3.

❸ Super normal period : slight stimulation will cause effect.



- There are 2 types of cell in the heart :
    - Conductive cells : carries the impulse
    - Contractile cells : response for the contraction

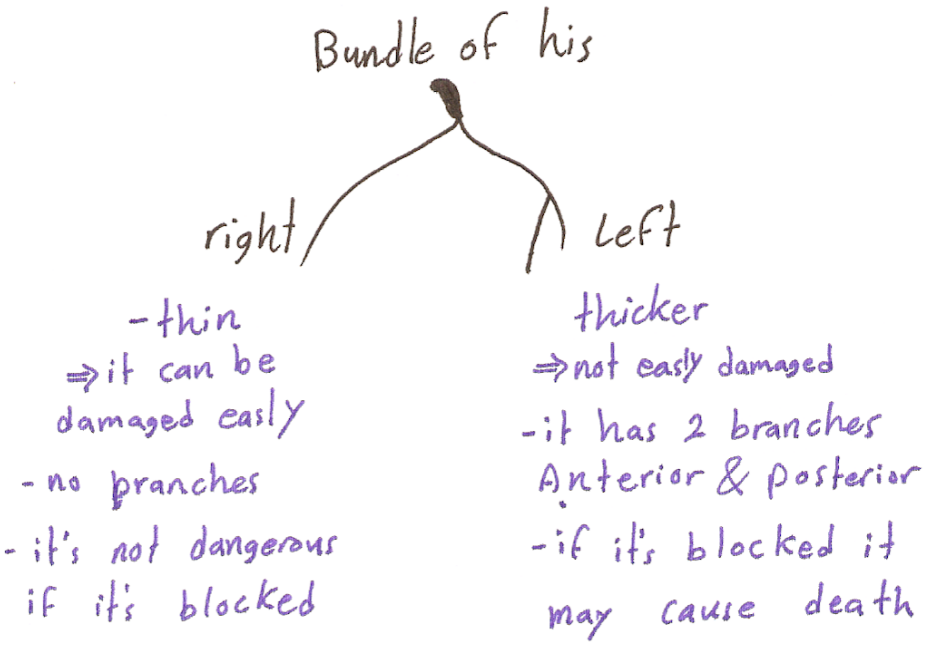
Sympathetic : Supplies all the Muscles in the heart .

Parasympathetic :

- left Vagus supplies AV and SA node
- right Vagus supplies SA node

Interventicular sputum : made of :

- Fibrous
- Muscle



When the Bundle of His divides to many branches it will called Purkinje Fibers

Purkinje Fibers are the last branch of the conductive tissue

It enters into cardiac muscle and naked eye can't differentiate it.

SA node : founded at the root of superior vena cava

Size : 3 mm wide 15 mm long 1 mm thickness it takes : 80-100/ minute

AV node : near the mouth of the coronary sinus, at the back of tricuspids valves

REMEMBER !

Increase in sympathetic = increase in heart rate

Increase in parasympathetic = Decrease in heart rate

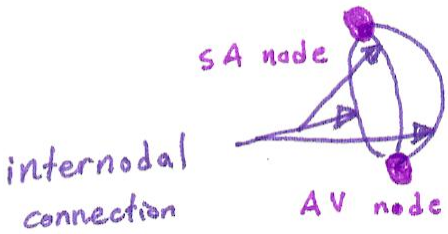
→How do SA node and AV node interact ?

They interact Through 2 ways :

❶ inter nodal connection :

There are 3 inter nodal connection between SA and AV :

- Anterior
- Medium
- posterior



❷ through the wall of the atrium :

- SA node De-polarization in the wall of the atrium then the signal goes to the AV node.

AV node delays 0.1 of SA node .. Why?

if AV and SA work at the same time (no delay) , the atrium and the ventricle will contract at the same time , then the blood well not move .

Conductive velocity

SA

Stimulates

⬢Right atrium

⬢ left atrium

- Connected to Bachmann's bundle

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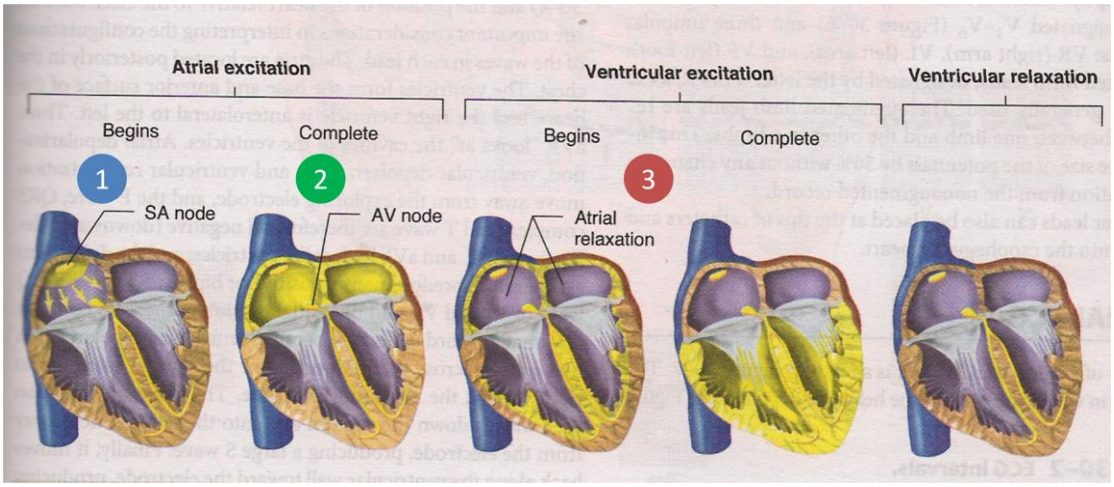


1 SA make depolarization cardiac cell in the right atrium..

2 Bachmann's bundle will depolarize the left atrium

3 impulse will moves to Av node to Bundle of His , that will cause depolarization to interventecular septum

Then impulse will move from left side of septum to the right ventricle..

Impulse will move to the left ventricle first , then the right ventricle , But both ventricles will contract nearly at the same with slight difference at time

⬢ Purkinje fibers is the fastest conduction velocity (why ?) because the :

- Diameter of Purkinje fibers is thick (thicker = faster) .
- They have more gap junction (they give it less resistance and increase the velocity)

⬢ Av and SA are the slowest conduction velocity (why?) because the :

- Network and interconnectivity are so many (chubby or complicated pathway)
- P. cells are more in the SA than the AV

Tissue	Fiber Diameter (μm)	Resting Membrane Potential (mV)	Conduction Velocity (m/sec)
Sinoatrial node	. . .	40–50	0.05
Atrial muscle	8–10	70–80	0.3–0.5
Internodal tracts	15–20	80–90	1.0
Atrioventricular node	Variable	50	0.02–0.05
Purkinje fibers	70–80	70	2.0–4.0
Ventricular muscle	10–16	80	<1.0

The table shows the conduction velocity in heart and it's **IMPORTANT**

Factors that affect the conductive velocity

↘First : Decreased by :

- Parasympathetic stimulation
- Cyclic Gmp muscarinic receptor agonist (Parasympathetic)
- Less blood supply : it damages the SA and AV nodes (Ischemia)
- Na and Ca channel blockers :
  - Blocking Na channel slow De-polarization
  - Blocking Ca channel decrease the plateau phase and then, the heart rate..
- When you cut Bundle of His :
  - SA and AV will not stop : because of the Pre-potential of the Purkinje fibers
  - The speed will decrease
  - There will be a mess (the atrium will contract at it's own speed, the ventricle will contract at it's speed) and that will decrease in the conduction velocity

↗Second : Increased by :

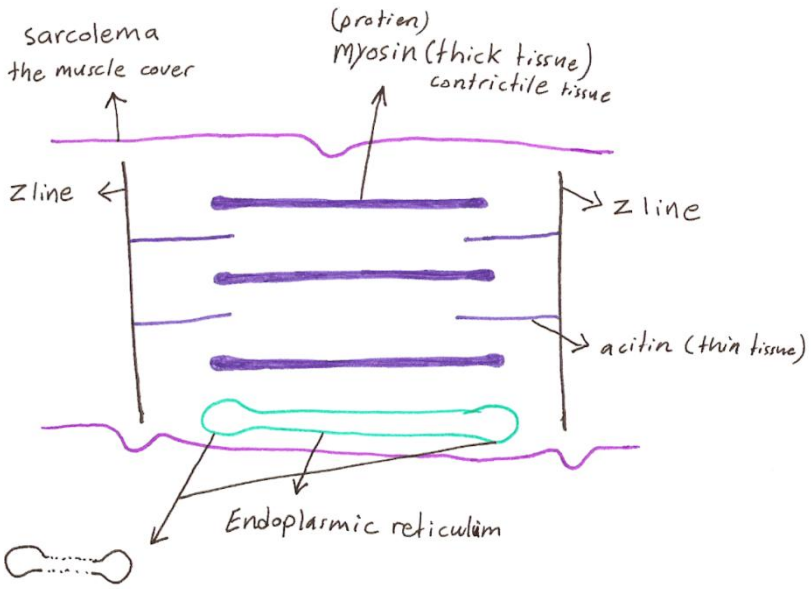
- Sympathetic stimulation
- Muscarinic receptor antagonist
- $\beta 1$ adrenoceptor agonist
- Circulating catecholamine (adrenalin, noradrenalin and Dopamine)
- Hyperthyroidism

▶Contractility

"The end product of Rhythmicity "

Remember !

Any muscle to contract needs Calcium storage



↗ The end part of the Endoplasmic reticulum ER called cisterna

- **Ca** is needed for contraction .

How could Ca get to the heart ?

❶ from outside the cell during the plateau phase
❷ from Endoplasmic reticulum (ER) 's cisterna

- When Ca is released , it's combines with troponin and tropomyosine , will be shifted and head of myosin will sticks and myosin will pull the actin and thetwo Z-line (sarcommere) come near and there the muscle contract

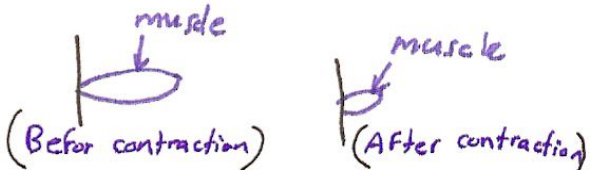
Heart contraction

There are **2** types of contraction :

❶ Isovolumetric or Isometric :
Increase in tension , but no decrease in length because the muscle is tied at 2 ends

This is called isometric contraction in skeletal muscles, and Isovolumetric in cardiac muscles .

❷ Isotonic :
Contract and decrease in length because on end of the muscle is free and the other is fixed .



Frank Starling law of contraction

❶ _____
❷ _____
❸ ___

The longer the length the more power contraction will be

Muscle ❶ has the strongest force of contraction because it's the longest
Muscle ❸ has the weakest force of contraction because it's the shortest

That's all :) ©