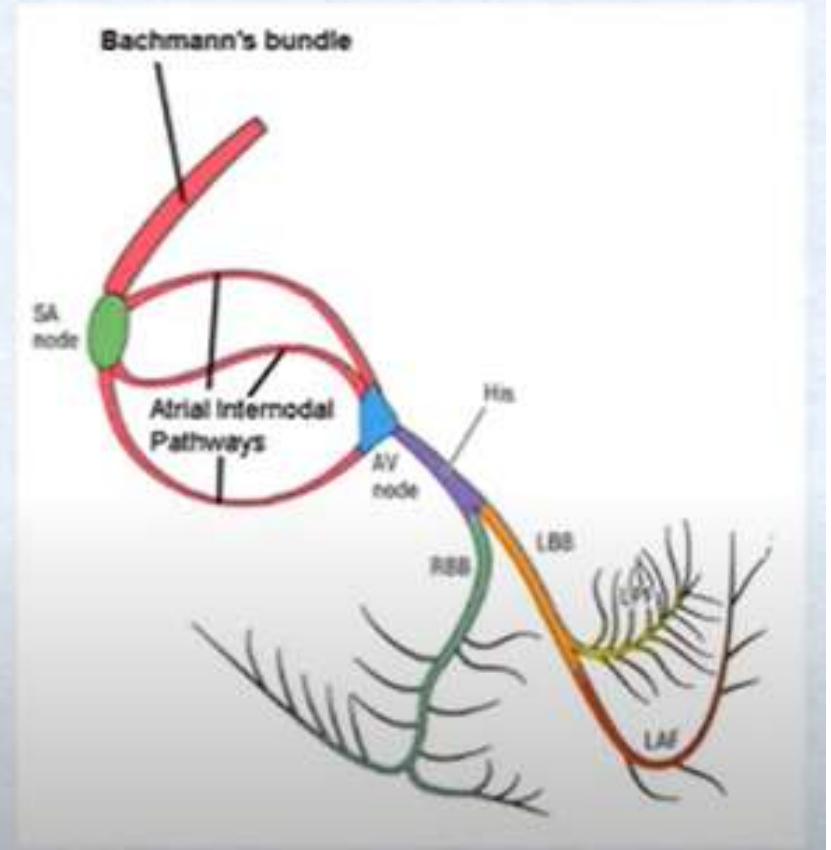


Pumping Action of the heart

Dr. Arwa Rawashdeh

Cardiac Conduction System

- The **heart beats over 3 billion times** in its lifetime.
- to do so there must be a **properly functioning electrical system**
 - called **the cardiac conduction system**



the action potential

- A key component is the **action potential**:
- is an **electrical wave of depolarization** that sweeps over the heart from atria to ventricles.
- akas: impulse, current, signals, electrical signals, wave of depolarization.

JUNCTIONAL REGION?

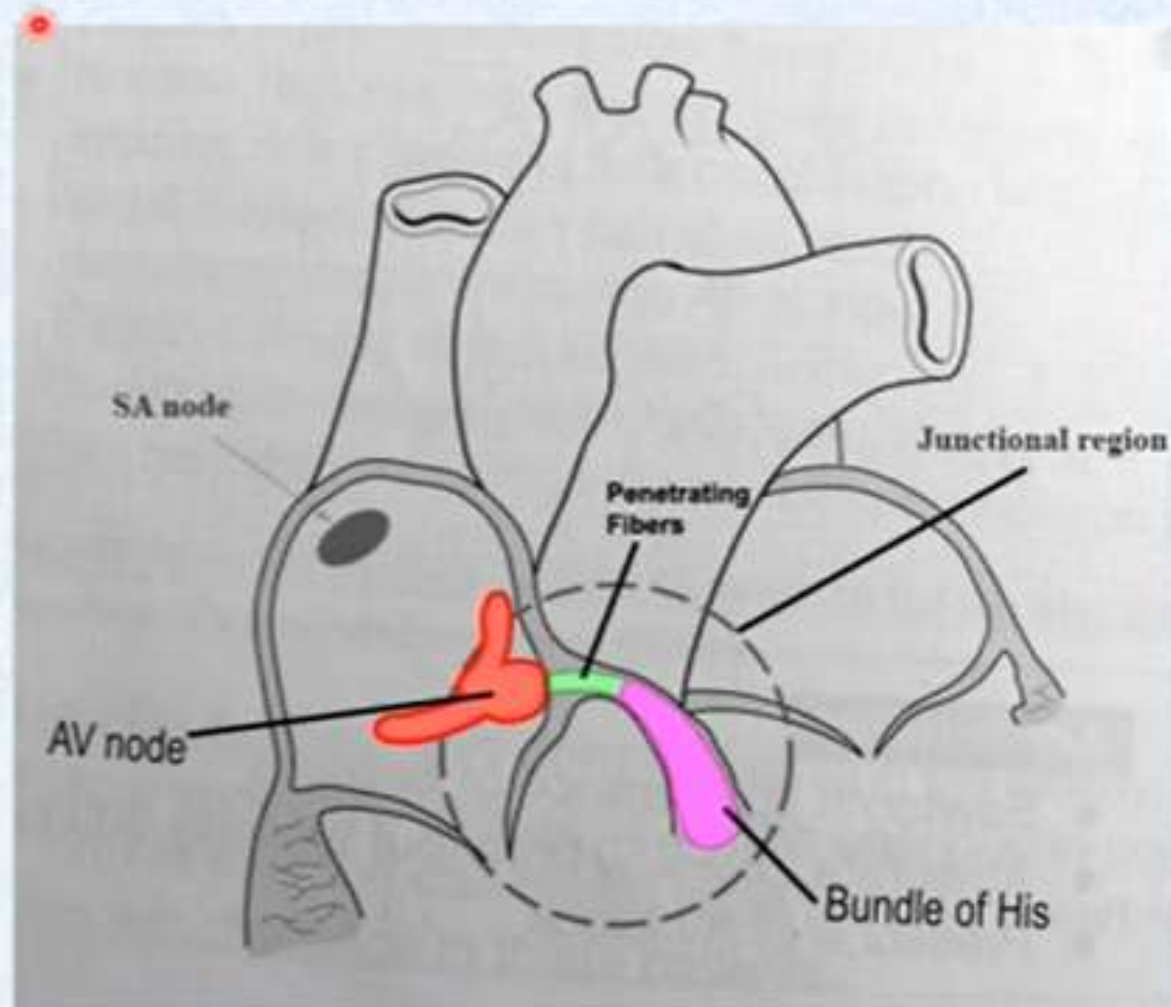
^ junctional region basically is the **AV node**, and **bundle of His**.

^ Some authors include the surrounding tissue as well.

^ **Junctional arrhythmias** arise from this area.

^ the **penetrating fibers** of the **bundle of His** is also where the current normally passes through the **fibrous skeleton**

– This is the beginning of ventricular depolarization.

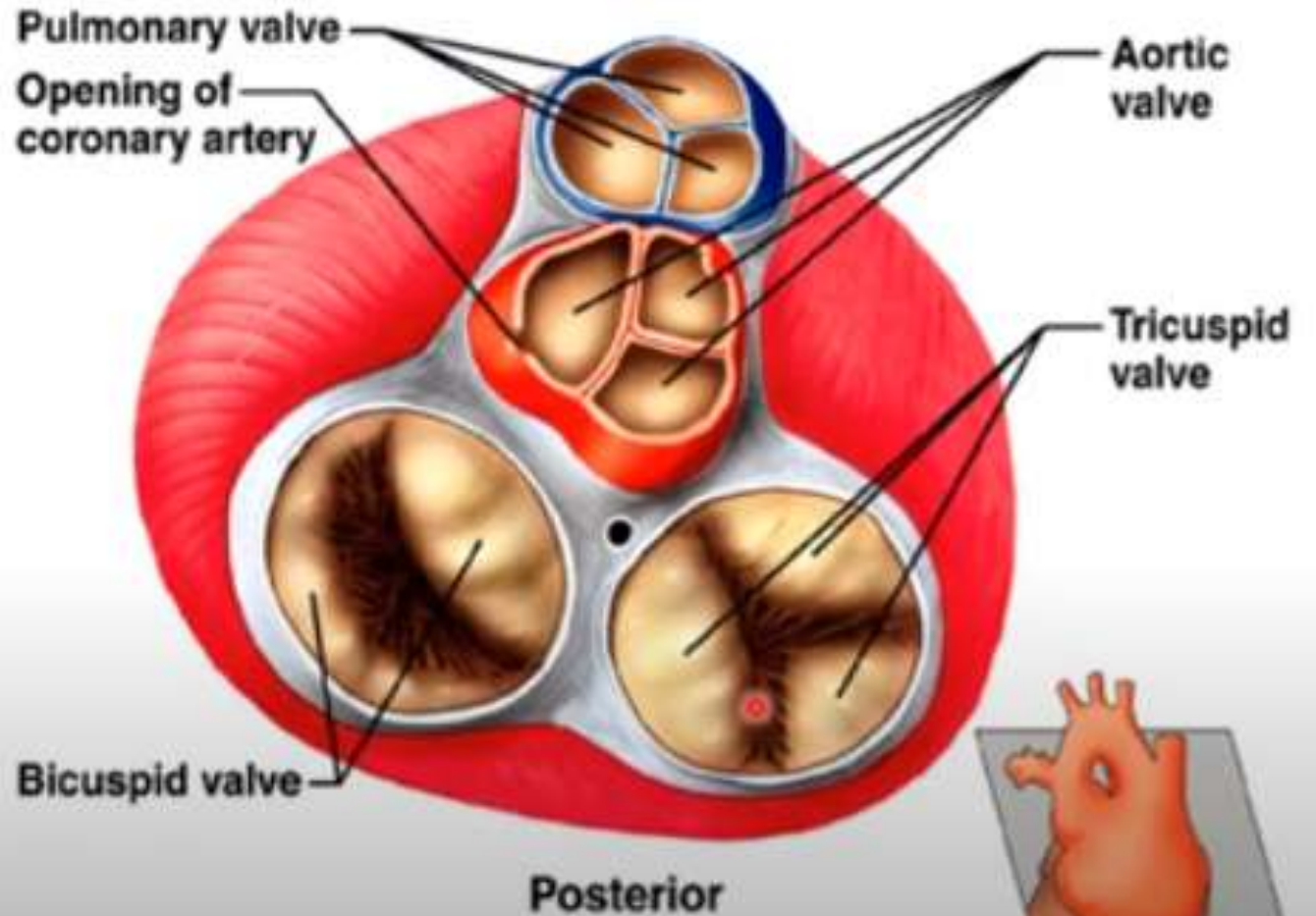


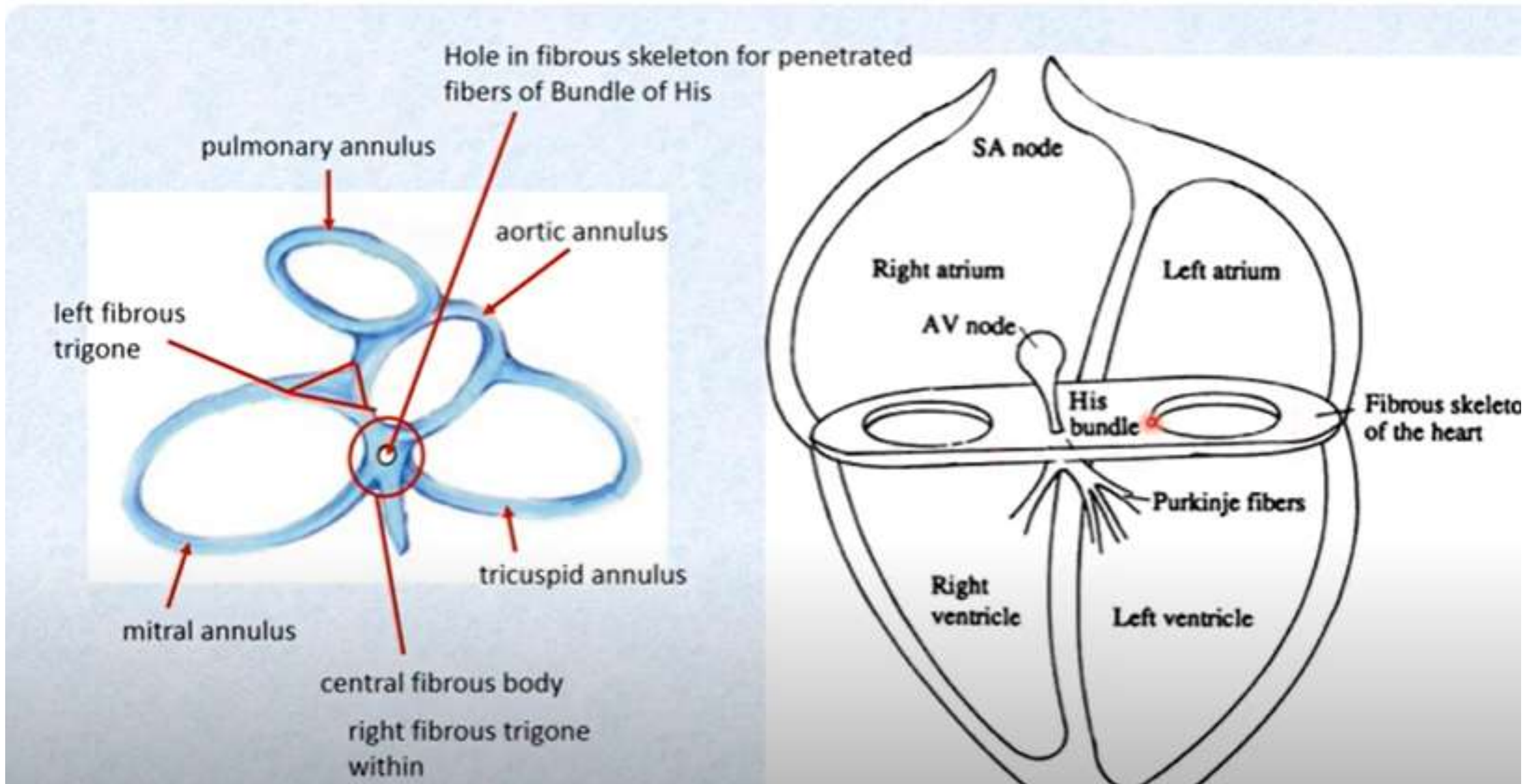
FIBROUS SKELETON?

^ **electrically insulates** the atria from the ventricles.

^ Normally there is a **hole** in the **right fibrous trigone** (and the central fibrous body which includes the right fibrous trigone)

^ **normally**, this is the only place that the **SA Node-generated current** can get from the atria to the ventricles.





Why is the atria need to contract first?

- contraction of the atrial is called **atrial systole**.
- atrial systole squeezes all the **blood out of the atria** which in turn “**tops off**” or completely fills the **ventricles**.
- **if there was no delay** between contraction of the atria and ventricles, the **ventricles would not be filled** to capacity.
 - **Decreased ejection fraction!**
- so that **delay is super important!**

Heart Cells: Contractile cells

- 99% of the heart's **myocardial cells** in the atria and ventricles perform mechanical work by contracting.
- These are the “**worker bees**” of the heart.
- Their contractions is what drives blood **through** and then **out** of the heart.



Worker bee

“I’m so tired! I never get much rest.”

Worker bees have a secret: they are autorhythmic!

- Under normal circumstances, most myocardial cells do not initiate action potentials
 - in other words, they do not “pace” the heart!
- However, they are “counting down,” just in case they get “the call” to run (pace) the heart!
 - which they occasionally do!
 - e.g., PVC, PAC



Worker bees: “normal?”



- so because of their slowness, they usually have nothing to do with “**pacing**” the heart
 - they are just slow worker bees following orders.
- However, sometimes they can **become** “**mischievous**”!
 - PVC
 - PACs
- when they do so, they can run the heart
- this is called an **arrhythmia**.
- e.g., **ectopia atrial tachycardia** or **ventricular tachycardia**





Worker bees: **another job**



- In addition to **contracting**, they also have to **spread the wave of depolarization** to their **neighbor cells**.
 - when the **current** hits them, **they depolarize** and then **spread** that depolarization **to their neighbors**.
 - This is called “**cell-to-cell spread**”
- Although **cell-to-cell spread** fairly fast, it is **not nearly as fast** as the **superhighways of conduction**, like **Bachmann’s bundle**, or the **bundle branches**

Overdrive suppression: the crushing of the worker bee's dream!

- when the wave of depolarization hits the worker bee it “**knocks out**” its *count down (depolarization)*.
- Makes them reset.
- This is why worker bees almost never get to pace the heart
 - they keep getting knocked out.





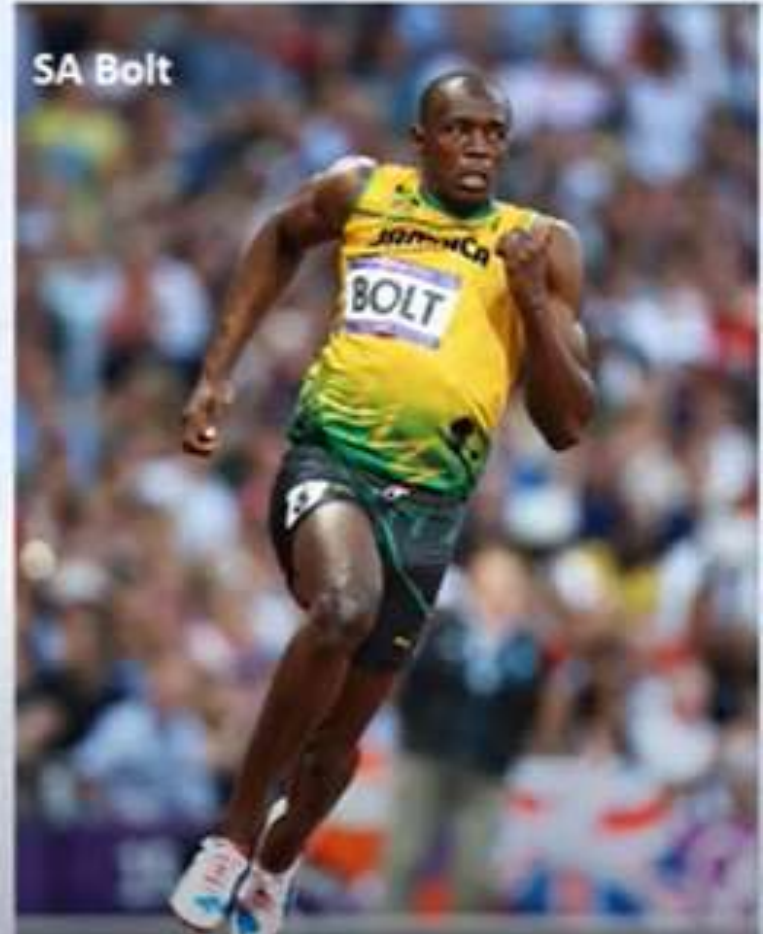
Pacemaker cells

- Although any myocardial cell has the “potential” to become a pacemaker, **some cells are born to pace the heart:**
 - **they are very fast depolarizers**
 - Much faster than worker bees.
- **Only the fastest depolarizer get to pace the heart!**
- These “quick depolarizers” are called the “**pacemaker cells**”, and include the ***SA node, AV node, and the bundle of His.**



Who's the fastest?

- The “**Champion**” of all cardiac autorhythmic cells (*i.e., the one that depolarizes the fastest*) are the cells of the **SA node**!
 - Aka, **Sinoatrial node**
- Normally, it “**paces the heart.**”
 - Starts the action potential that eventually sweeps over the entire atria and ventricles
 - Causes blood ejection.



The conduction system: a third type of heart cell

- a.k.a., **Purkinje system**
- About **1%** of the heart cells are neither “**worker bees**” nor “**pacemaker cells**”
- Their job specialty is to **carry/speed the electrical signal** generated by the **SA node** through the atria, interventricular septum, and ventricles.





the conduction system

- **Members include....**

- Bachmann's bundle
- Atrial internodal conduction pathways
- Bundle branches
- Purkinje fibers.

- **all members** are designed to **conduct action potentials**
very quickly!

AV node & bundle of His?



- Some authors include the **AV node** and **bundle of His** as **members of the conduction system** as well
 - In **addition to being pacemaker cells**
- **Have virtually no contractile function, though.**
- However, they are **still autorhythmic** and **can pace the heart** if need be.
 - In fact, they're **pretty good** at pacing the heart if need be.

Meet the entire team: the heart's electrical system



1. Sinus node (SA node)
2. Bachmann's bundle (interatrial conduction pathway)
3. Atrial internodal conduction pathways
4. Atrioventricular node (AV node) and its one or two entry-tracts.
5. Atrioventricular bundle (AV bundle, *Bundle of His)
6. Right and left bundle branches
7. Right and left Purkinie fibers (subendocardial plexuses)

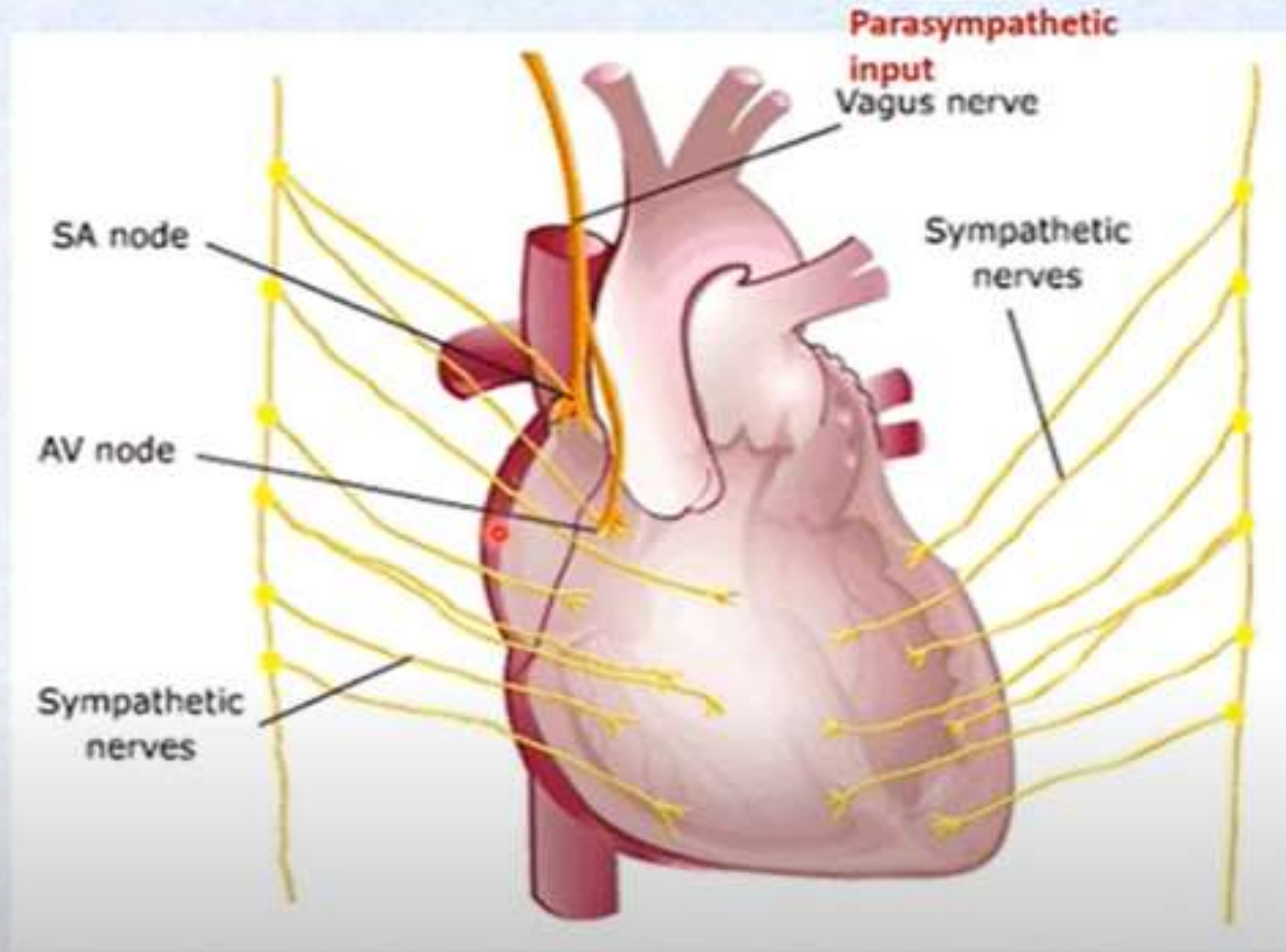
Sinoatrial Node



- Because of this **superficial positioning**, it **can be easily damaged by...**
 - atrial myocardial infarction
 - metastatic neoplasm
 - pericarditis
- Its “**countdown**” speed is also **greatly influenced by sympathetic and parasympathetic nerves** that plug into it or near it.

^notice only the SA and AV nodes have parasympathetic input.

^ is also affected by **angiotensin II** which is sparked via the R2A system.



Sinoatrial Node: **connections**

- Connects **directly** to ...

1. adjacent atrial myocardial muscle cells (fiber)

- Sparks cell-to-cell spread ◦

2. special right atrial conduction system, called the atrial internodal pathways

3. Another special, super-fast interatrial conduction pathway called Bachmann's bundle

Bachmann's bundle!

- is a “**superfast conduction highway**”
- it is so fast that the current comes out of the SA node and is **immediately transmitted to the left atrial!**
- Without Bachmann's bundle, the right atrium would contract well before the left, which would lead to big problems!
 - Arrhythmias
 - Compromised cardiac output

Other Autorhythmicity Tissues

Other cells can pace the heart, which include (in order):

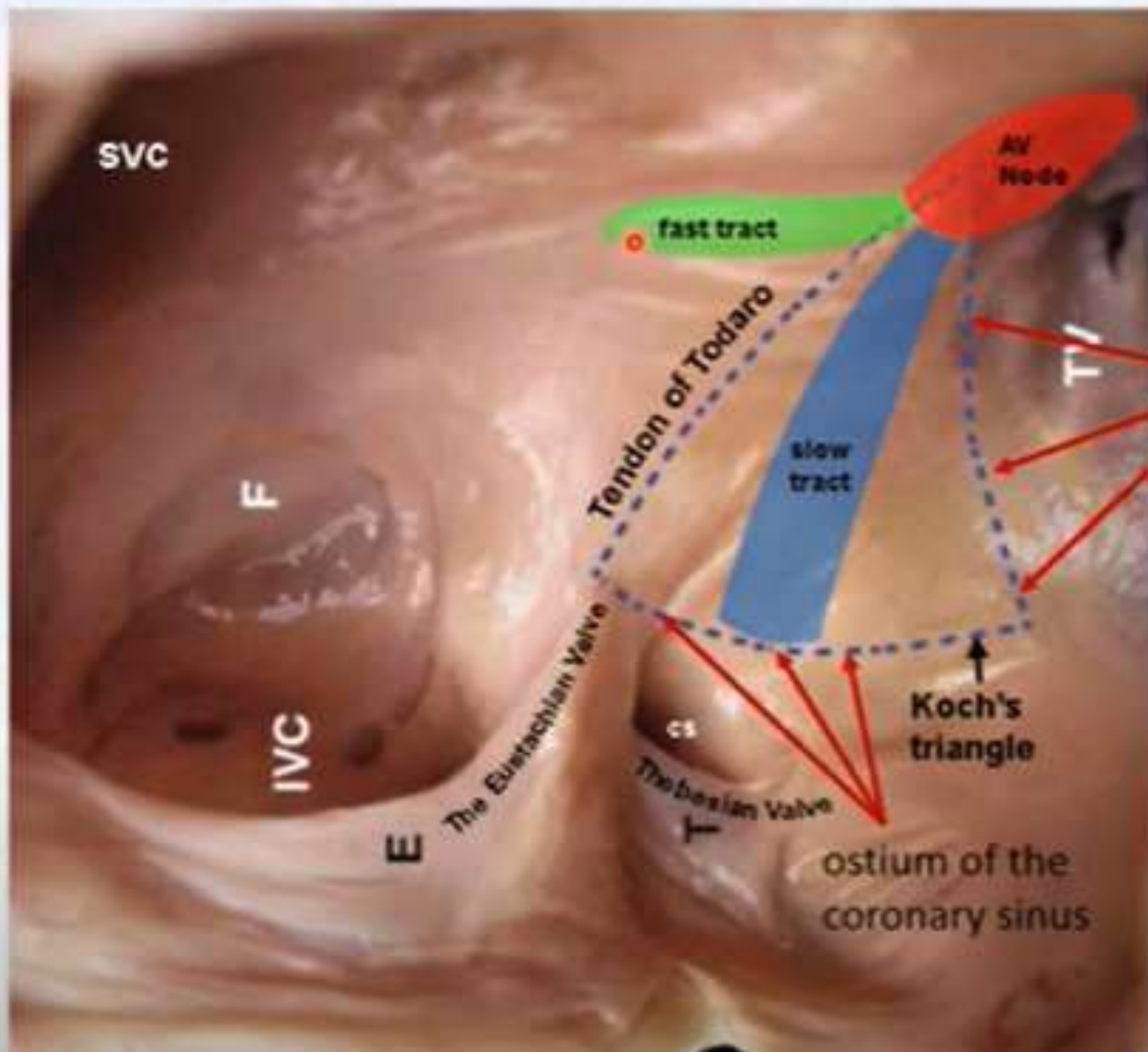
- **Atrioventricular node (AV node)**
 - Pacemaker activity rate = 40 – 60 b/m
 - Can permanently take over!
- **Bundle of His**
 - Pacemaker activity rate = 20 – 40 b/m
- **Bundle branches and distal Purkinje fibers**
 - 15 – 40 b/m
 - Do have pacemaker potential, but *typically not enough to sustain life very long!*.
- **Atrial myocardial cells (45-65 b/m)**
 - don't normally permanently take over pacing duties! [Garcia]
 - We'll talk about atrial fibrillation!

The **atrioventricular Node**



- A.k.a., AV node
- Located subendocardially (i.e., between the endocardium and myocardium) in the **inferomedially region of the right atrium**
 - **Much deeper than the SA node!**
- Electrophysiology speak, it's **located** in an area of the heart called the **junctional region.**
 - **Many authors say it is the junctional region!**

view through the right side of the atrium



tricuspid orifice

Koch's triangle

ostium of the coronary sinus

Function of the AV node?

Hey wave of depolarization, slow it down!

- Once the AV node receives the impulse, it's **job** is to **slow down the signal!**
- The slowdown is called **decremental conduction.**



AV node vs. ANS

- Like the SA node, it is also significantly **influenced by sympathetic and parasympathetic** nerve fiber which actually enters it!
 - So sympathetic and parasympathetic are connected to the AV node.
- **Parasympathetic stimulation** will increase the delay time (increases decremental conduction)
- **Sympathetic stimulation** will decrease the delay time (decreases decremental conduction)

Bundle of His



- Has a **dual blood supply**
 - Hard to take out of action
- made of **Purkinje cells** with a limited number of ventricular myocardial cells, arranged in parallel
- The **AV bundle has 2 components**:
 - A **penetrating portion**
 - A **distal portion**

Bundle of His: **accessory pathways**

- sometimes the fibrous skeleton can have **pathological holes** in it!
 - Remember, there is normally one hole for the penetrating fibers of the bundle of His.
- These holes are often filled with **superfast conduction fiber**
- these holes can allow the **wave of depolarization** from the atria to "**sneak**" into the **ventricle ahead of time!**
- This **screws up the heartbeat** and can be seen on EKG!
- **perfect breeding ground** for a **supraventricular tachycardias!**
 - we shall talk about AVRT (atrioventricular reentry tachycardia)

^ will learn about **Wolff-Parkinson-White syndrome** and how it can lead to a common type of supraventricular tachycardias: **atrioventricular reentry tachycardia**.

