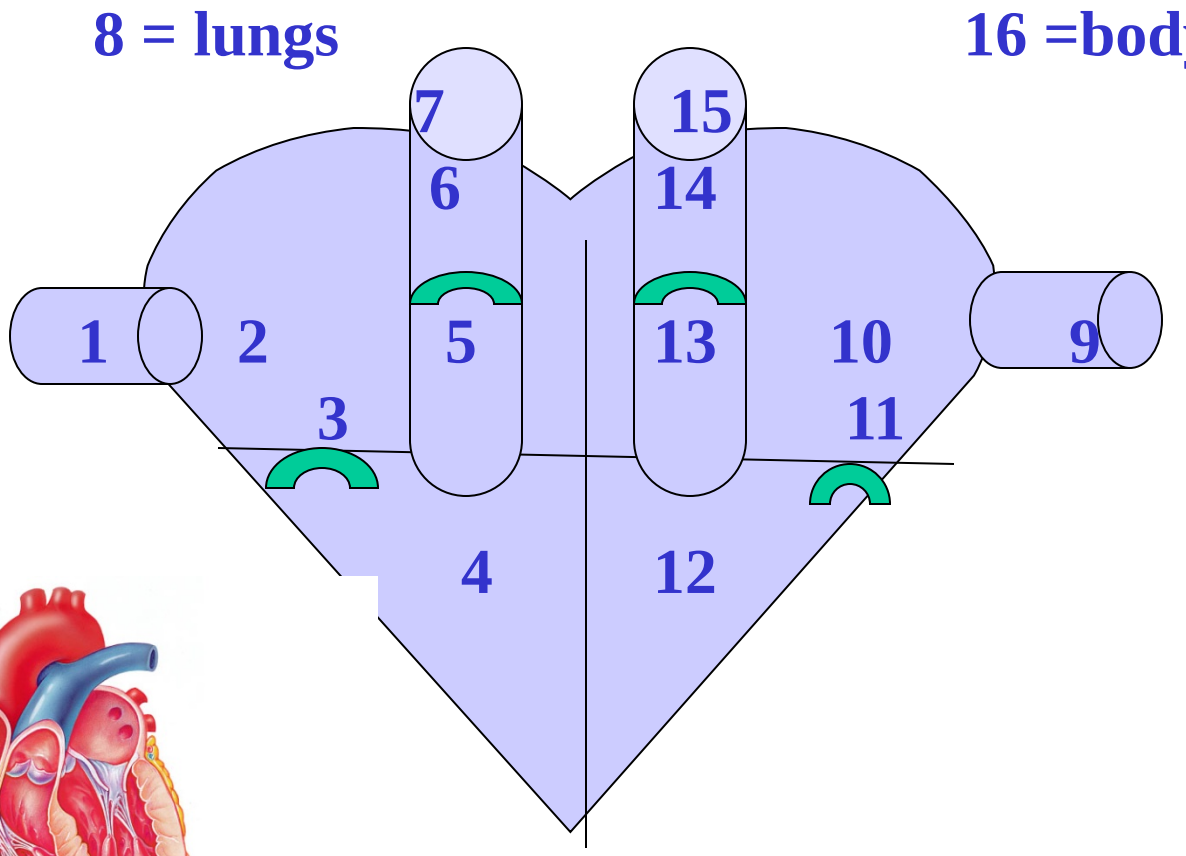
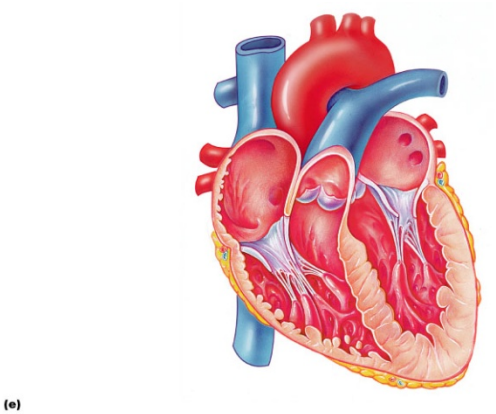
Engineer's Heart





(e)

Heart Flow

Oxygen-poor **Mixed** **Oxygen-rich** .

8. Pul. Circ.

1. vena cava (2)
2. RA
3. tricuspid valve
4. RV
5. pul. semi. valve
6. pulmonary trunk
7. pulmonary arteries (2)

9. pul. veins (4)
10. LA
11. bicuspid valve
12. LV
13. aortic semi. v.
14. aorta
15. aortic art. (4)

16. Sys. Circ.

Sequence

Diastole:

1. **E SA node: initiate heart beat**
2. **E atrial muscles (gap junction): receive SA signal**
   M atrial muscles contract (simultaneous)

Systole:

3. **E AV node: conduct SA signal**
4. **E Bundle of His: conduct AV signal**
5. **E Bundle Branches: conduct Bundle signal**
6. **E Purkinje fibers: conduct Branch signals**
7. **E ventricular muscles: receive Purkinje fibers**
   M ventricular muscles contract (simultaneous)

***E = electrical event; M = muscle event**

Neural Reg. Notes

1) SA node
   - several potential areas in atrial vicinity
   - prob. if in ventricular vicinity
2) pacemaker
   - artificial, battery powered SA node
   - initiate beat; hard to change tempo
3) ventricular contraction
   -> BP, more imp. than atrial contraction
4) atrial contraction
   - less critical; more imp. during exercise
5) left side of heart
   - more developed than right
     (thicker heart wall; larger chambers)
   -> systemic circuit

EKG - Waves

waves = electrical/neural events

- height = amount of neural excitation

α force prod. by cardiac muscle

- width = amount of time

3 waves:

1) P wave: atrial depol. (.08 sec)*

- ↓ height→↓PD→↓force

2) QRS wave: ventr. depol; atrial repol. (.08 sec)

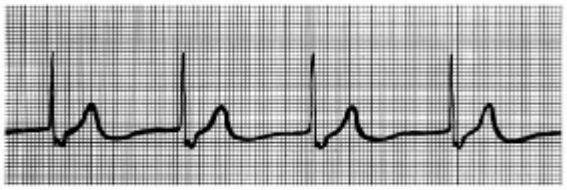
- ↑ height→↑PD→↑force

3) T wave: ventr. repol. (.16 sec)

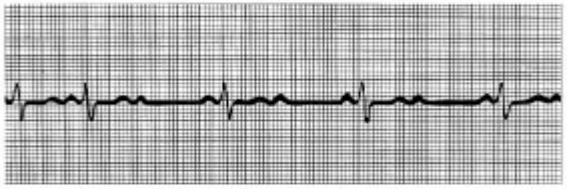
***based on HR=75 bpm, 1 cycle = .8 sec**

Arrhythmias

(a)



(b)



(c)

(d)

normal

atrial fibrillation
- no P waves
- slower HR

heart block
- #P wave > # QRS

vent. fibrillation
- erratic pattern
- heart attack

Preload

preload = stretch
-stretch in cardiac muscle α force cardiac contraction
-more blood volume -> stronger systole

length-tension relationship:
↑ stretch in muscle fibers
→ ↑ # cross bridge attachments
→ ↑force of contraction

heart: force of contraction matches volume of blood to be ejected
- more volume -> stronger contraction

Frank-Starling Law

- ↑preload thru exercise → ↑SV
- ↓HR → ↑venous return → ↑ EDV → ↑stretch
→ ↑contraction force → stronger systole → ↑SV

1) untrained individual
- @ rest:↓HR → more time for ventr. fill-up
→ ↑ venous return → ↑SV
- @exercise: ↑HR → less time for ventr. fill-up
→ ↓ venous return → ↓SV

2) trained individual:
- @ rest & exercise, ↓HR → ↑SV
- combine both benefits

Contractility

contractility = cardiac tone

- **healthy cardiac muscles → ↑ contractile strength**
- **independent of stretch and EDV**
- **↑tone → ↑ contraction force**

Factors:

1) **Sympathetic NS**
   ↑epinephrine/nor-epi. → Ca+ influx
   → ↑ contractility→ ↑blood ejection → ↓ESV → ↑ SV
2) **Ca+ ions**
3) **glucagon**
4) **thyroxine**
5) **digitalis (heart stimulant)**

***Fill in the functions of 2 thru 5**

Afterload

afterload = back pressure to open heart valves

- **onset of systole, to eject arterial blood**
- **aortic semilunar valve: 80 mm Hg**
  (→ afterload = 80+ mm Hg)
- **pul. semilunar valve: 8 mm Hg**

BP = opposing force to afterload

hypertension: 140/90 (mm Hg)

- **afterload = 90+ mm Hg**
- **↓ time heart valves open → ↓SV**

HR - ANS

HR: compensates SV when ESV & EDV changes

ANS - reg HR

a) stress → ↑symp. NS → ↑epineph. release
→ a) ↑HR
b) ↓EDV (less time for vent. fill-up)

b) grief → ↑ parasymp. NS → ↑ ACh release
→ a) ↓HR
b) ↑EDV (more time for vent. fill-up)

note: sustained stress or grief brings new problems
- compensations only temporary

HR - Chem.

Chemicals reg HR:

a) hormones

1) epinephrine (adrenal gland - ↑HR),

2) thyroxine (thyroid - sustained ↑HR)

b) ions

- too high or low levels

→ irritable heart (spastic, little rest)

→ contraction prob., heart block, cardiac arrest

- ion disorders (look up symptoms in text)

- hypo/hyper-calcemia (calcium)

- hypo/hyper-natremia (sodium)

- hypo/hyper-kalemia (potassium)

HR - Other Factors

1) **age : fetus (140 - 160 bpm), elderly < 60**

2) **gender: female adult (72 - 80), male adult (64 -72)**

3) **exercise: ↑symp. NS →↑HR**
   - **untrained people:↑HR →↓SV**
   - **trained athletes →↓HR →↑SV**

4) **temperature**
   - **heat:↑metabolism →↑HR**
   - **cold: opposite effect**

CHF

congestive heart failure:

1) coronary atherosclerosis

- clog coronary vessels w/ fat

→ heart muscle atrophy

2) ↑BP: →↑afterload → heart muscle hypertrophy

3) myocardial infarcts

- cartilage replaces cardiac muscle cells

→ ↓contraction force

4) DCM - dilated cardiomyopathy

- ventricles stretch, flabby, deteriorate

→ harder cardiac work w/ less results

Congestion

heart = double pump
- each side can fail independently → congestion of circuit

a) pulmonary congestion:
right side works → blood to pulmonary circuit
left side fails → blood remains in pul. circuit
→ pulmonary edema (lungs engorged w/ blood)
→ suffocation (fast death)

b) peripheral congestion:
left side works → blood to systemic circuit
right side fails → blood remains in sys. circuit
→ systemic edema (organs & muscles engorged)
→ extremities swollen → poor circulation (slow death)

Resistance

R = resistance to blood flow (F), friction
- 3 sources (η, l, r)

1) η (viscosity): fluid - thicker to thinner
- anemia: ↓η → ↓R
- higher altitudes: thicker blood → ↑R
2) l (BV length)
3) r (BV radius
- ↑ distance from heart
→ ↑ l & ↓r of blood vessels
→ ↑R → poorer circulation

Radius notes

a) type of blood flow dep. on location:

1) laminar flow: center, no walls, less friction (↓R)
2) peripheral flow: near walls, more friction, impeded flow (↑R)
3) turbulent flow: protruding objects, (↑R)

b) radius of BV:

- **large: mostly laminar flow (↓ R)**
- **small or objects: impeded, turb. flows (↑R)**
- **4th power: R = 1 / radius 4 (exponent)**

eg r doubled, R → 1 / 16 (↓↓R)
r halved, R → 16 (↑↑R)

BP

"BP" = <u>arterial</u> blood pressure (systemic)

2 factors:

a) stretch - arterial wall elasticity

b) volume - ↑ vol → ↑ BP

2 types of BP:

a) systolic pressure (adult 120 mm Hg)

- highest aortic pressure

- aortic semilunar valves open

b) diastolic pressure (adult 80 mm Hg)

- lowest aortic pressure

- aortic semilunar valves closed