why is a cardiovascular system an indispensable necessity in larger animals such as humans?

three essential components of a cardiovascular system
1) a flowing fluid
2) tubes carrying the flowing fluid
3) a pump helping to move the fluid through the tubes

why is a cardiovascular system an indispensable necessity in larger animals such as humans?

Cardiovascular System: Heart
Heart Structure, Part 1
four chambers: atria  ventricles
two septa (walls)

from figure 13.1
seen from the front side

simplified view
seen from the front side
Heart Structure, Part 1
major blood vessels, heart valves, myocardium

veins carry blood ___________________

inferior vena cava (IVC) carries blood from to

superior vena cava (SVC) carries blood from to

pulmonary veins (PVs) carry blood from to

arteries carry blood _______________
pulmonary trunk --> pulmonary arteries carry blood from to

aorta (Ao) carries blood from to

valves

semilunar valves
pulmonary SL (PSLV) located between and

aortic SL (ASLV) located between and

atrioventricular valves
right AV (RAVV) located between and

left AV (LAVV) located between and
Heart Structure, Part 1
major blood vessels, heart valves, myocardium

cut through the heart at the level of the valves
looking down on the valves
seeing flaps of heart valves
(all flaps partly opened - though that never happens in a functioning heart)

structures associated with atrioventricular valve flaps

chordae tendinae
papillary muscles

during contractions of ventricles - papillary muscles _______________
pull on chordae tendinae prevent ________________ of AV valve flaps
Heart Structure, Part 1

Heart valves - function

Passive valves: open and close on their own?

Valves open and close due to blood ______ and blood ______

Blood flow in heart: atria, ventricles, arteries

And a fundamental fact -

Blood flows from _______ blood pressure to _______ blood pressure

Blood flows through open heart valves from higher to lower blood pressure

Blood flowing from higher to lower pressure can __________ valves and __________ valves

AV valves

From figure 13.7

Atria

When blood pressure (BP) in atrium _______ than BP in ventricle

AV valves ______

Blood flows from ____ to ____

Ventricle relaxed

When BP in ventricle _______ than BP in atrium

AV valves ______

Blood cannot flow from ____ back to ____

Ventricle contacted

SL valves

From figure 13.8

Artery

When BP in ventricle _______ than BP in artery

SL valves ______

Blood flows from ____ to ____

Ventricle contacted

When BP in ventricle _______ than BP in ventricle

SL valves ______

Blood cannot flow from ____ back to ____

Ventricle relaxed
Heart Structure, Part 1

heart valves - function

heart valves - heart sounds, normal and abnormal

two easily heard heart sounds  first sound  second sound

first sound: when _______________  second sound: when _______________

note: not the sounds of valve flaps ______________________
actually, S1 and S2 are the sounds of ___________ in blood flow
caused by ______________________

abnormal sounds associated with heart =
produced by unusual patterns of ____________

some murmurs are due to problems with valves:

normal valves

stenotic valve

insufficient valve

in these cases - hearing ________________ of unusual blood flow
Heart Structure, Part 1

myocardium
bundless of cardiac muscle
in walls of atria and ventricles

bundles in atria largely __________
from bundles in ventricles

contraction of bundles helps force blood
in the “correct” direction

contraction
atra

force blood
into

in atria

ventricles

force blood
into

a slice through the lower part of the heart shows
amount of cardiac muscle in ventricular walls

RV
thicker
in walls of

LV

thickest
in walls of

from figure 13.6
Path of Blood Flow

two sides of heart

two circuits ____________ circuit ____________ circuit

two circuits meet in the heart

continuous flow of blood through both circuits

blue arrows = blood carrying _____ oxygen

red arrows = blood carrying _____ oxygen

air spaces in lungs

pulmonary

circuit

pulmonary

circuit

systemic

circuit

systemic

interstitial fluid

surrounding body cells

from figure 13.2
Path of Blood Flow

**systemic circuit**

contains many “subcircuits”

includes coronary circulation

coronary blood vessels supply myocardium

all the blood flowing through the atrial and ventricular chambers

does **NOT**

blockage (partial or complete) of blood flow along coronary arteries

ischemia

angina

myocardial infarct

some treatments for blood supply problems to the heart itself

drugs

surgery

from figure 13.4

**major coronary arteries**
Heart Function

Blood flows due to action of heart - it’s a muscular pump to pump blood effectively, the heart beats ...

i)

ii)

First -

Then -

Each heart beat includes **electrical** and **mechanical** events.

Heart muscle cells are the source and focus of the **electrical** and **mechanical** events.

Two types of heart muscle cells:

1) Striated (“striped”), branching cells form specialized for cells are attached by intercalated disks contain gap junctions.

2) Form communication/coordination system cells are linked by specialized for:

i) Beginning

ii) Carrying

iii) Coordinating

All muscle cells in heart are linked electrically by...
Heart Function - **Electrical Events**

*conduction system of the heart*

pacemaker cells in:

#1

______________________________

initiates __________
establishes ____________

**strings of myocardial conducting cells**

*conduct _______________ rapidly through heart in coordinated way*

#2

______________________________

pathways

#3

______________________________

pathways

#4

______________________________

#5

______________________________

#6

______________________________
Initiation and Spread of Excitation Through Heart

step 1

SA node depolarizes

cells in SA node ____________

SA node depolarizes

step 2

depolarization spreads through R and L atria

step 3

depolarization spreads through AV node and AV bundle __________

following depolarization ...... contractile cells in atria ________

depolarization spreads through R and L atria

step 4

AV node and AV bundle __________

100 msec ________

carry signals from ________ to __________

AV node and AV bundle depolarize

step 5

bundle branches and Purkinje fibers __________

carry signals down into __________

depolarization spreads along bundle branches and Purkinje fibers

step 6

wave of depolarization begins in _____ ventricles

spreads __________ through ventricles

following depolarization ...wave of __________

passes through contractile cells in ventricles

depolarization spreads through R and L ventricles
Electrical Activity in Cardiac Muscle Cells

1) action potentials in pacemaker cells of SA node

from figure 13.12

important ions
Ca++ more outside cells
Na+ more outside cells
K+ more inside cells

SA node action potential

Ca++ channels
Ca++ diffuses

K+ channels
K+ diffuses

K+ / Na+ channels
Na+ diffuses

SA node action potential
2) action potentials (APs) in contractile cardiac muscle cells must fire APs in order to contract. APs are similar to APs in nerve cells and skeletal muscle cells but a major difference – in nerve cells, APs last in skeletal muscle cells, APs last in cardiac muscle cells, APs last.

contraction process in cardiac muscle cells - like the process in skeletal muscle cells (page 374 and figure 13.14; Stanfield, fifth edition)

**IMPORTANT** effect of long AP duration in contractile cardiac muscle cells

refractory period __________ sustenance contraction (tetanus) __________

depolarization and AP followed by _____________, and then cardiac muscle _____________

from figure 13.13
electrocardiogram (ECG) or electrokardiogram (EKG)
on-invasive monitoring of ________ activity in heart
__________ electrical activity of ________ heart muscle cells
measure voltage changes as contractile cells ________ and
__________ during their action potentials

why is QRS wave larger than P wave?
when do atria repolarize?

ECG recording shows ______________ of many APs
NOT __________

P-Q interval
conduction time

P-Q interval
conduction time

Q-T interval
ventricular contraction

T-Q segment
ventricular relaxation

R-R interval
time between heart beats
cardiac arrhythmias

(sinus) bradycardia: heart rate

(sinus) tachycardia: heart rate

heart block

AV block

(normal)

(unsafe)

AV block

fibrillation

atrial fibrillation

ventricular fibrillation “V fib”
Heart Function - Mechanical Events

Cardiac _________

two major phases
i) ventricular _____________

ii) ventricular _____________

when are the ventricles most full of blood?
when are the ventricles least full of blood?
how much blood is pumped out of a ventricle?
what fraction of the blood in the ventricle is pumped out?
ejection fraction
Pressure - Volume relationship

blood pressure in left ventricle

60 milliliters

130 milliliters

volume of left ventricle

Pressure - Volume relationship

from figure 13.22

where is systole?

where is ESV?

where is diastole?

where is EDV?

SV at rest

SV during exercise
Aspects of Heart Function

#1 _________________ (CO)

definition CO = ______ volume pumped by a __________ in ____ minute

equation CO = _______________ (beats/minute) X _______________ (ejected)

table

example CO = ___ BEATS/MIN  X ___ ML/BEAT  = _____ ML/MIN

about _____ ML/MIN about _____ L/MIN

several factors affect cardiac output

act on __________ and/or on __________

factor affecting **heart rate**

depends on ___________________________  see figure 13.24

\[
\text{sympathetic autonomic } \quad \text{parasympathetic autonomic}
\]

\[
\text{sympathetic} \quad \text{parasympathetic}
\]

\[
\text{SA node} \quad \text{AV node}
\]

\[
\text{HR}
\]

\[
\text{CO}
\]

\[
\text{from figure 13.31}
\]

heart rate

neurotransmitter

targets

sympathetic autonomic

parasympathetic autonomic

conduction system

SA node

AV node

conduction system

SA node

AV node
action of autonomic nervous system on SA node from figure 13.25

influence

<table>
<thead>
<tr>
<th>12 seconds</th>
</tr>
</thead>
</table>

HR

why different # of APs in the same amount of time?

parasympathetic influence

sympathetic influence

sinoatrial node sets __________ rhythm of heart beats

"natural frequency" of heart beats

why 60 – 70 APs per minute at resting heart rate?

Cardiac Output  \[ \text{CO} = \text{HR} \times \text{SV} \]

factors affecting heart rate act on HR or SV

factor affecting stroke volume

force of ventricular contraction

if force of ventricular contraction __ , then SV __ and CO __

if force of ventricular contraction __ , then SV __ and CO __

force of ventricular contraction =

sympathetic autonomic influence can __________ contractility
Summary for Control of Cardiac Output
via Autonomic Action on Stroke Volume and Heart Rate

- Sympathetic activity makes contractile cardiac muscle cells contract ________________
- More Ca++ in cytoplasm of cardiac muscle cells
- More interaction between ________ and ___________
- Faster myosin ATPase
- More ______________ cycles
Cardiac Output

Cardiac Output \( \text{CO} = \text{HR} \times \text{SV} \)

autonomic factors affecting **heart rate**

autonomic factors affecting **stroke volume**

a factor (within heart) affecting **stroke volume**

also involves contractility of ventricular muscle

filling of ventricles with _______ blood (_______ blood volume)

ventricles contractions are _________; SV _________

(when other factors remain the same)

diastolic volume (EDV)

if EDV _____, contractility _____, SV and CO _______

explanation:

ventricular filling

__________ ventricular muscle cells

__________ overlap of myosin actin filaments in sarcomeres of cardiac muscle cells

__________ cross-bridge link actin and myosin during contractions

__________ force produced during contractions

from figure 13.28

called ________________________

stroke volume

EDV

larger

smaller

stroke volume

EDV

larger

smaller

from figure 13.28
too much stretch is not good

chronic ventricular ________________

stroke volume __________ and cardiac output __________

Cardiac Output

EDV affects contractility

EDV is source of end-diastolic pressure
- ventricular blood pressure at end of diastole

end-diastolic pressure is called ____________

factors related to EDV

- time for filling of ventricles with blood

- amount of blood returning to atria
- and movement of blood from atria into ventricles
Cardiac Output
factors affecting stroke volume
ventricular filling
ventricular contractility

and now, the force the muscle works against - known as __________
cardiac muscle “pushes” against arterial blood pressure

if arterial BP _____, afterload ______ and SV ______

Summary for Stroke Volume and Cardiac Output

danger of chronic high blood pressure

how can heart compensate for high afterload?

and if it does this for year after year after year ....

...eventually  SV       EDV
problem in Systemic Circuit affects

heart _____________ ___________ heart failure

BP in pulmomary Circuit
fluid leaks from pulmomary capillaries into
what is the initial shape of the “pressure - volume loop” for someone who has high blood pressure (initial shape = shape before a response to high blood pressure)

what is the initial shape of the “pressure - volume loop” for someone who has ventricular weakness (initial shape = shape before a response to ventricular weakness)