**Cardiac Physiology**

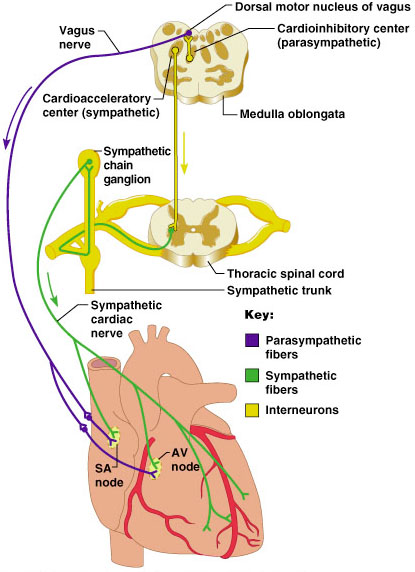
**Dr. Gary Mumaugh**

**Introduction**

* Vital role of the cardiovascular system in maintaining homeostasis depends on the continuous and controlled movement of blood through the capillaries
* Numerous control mechanisms help regulate and integrate the diverse functions and component parts of the cardiovascular system to supply blood in response to specific body area needs

**Cardiac Muscle Contraction**

* Heart muscle:
  + Is stimulated by nerves and is self-excitable (automaticity)
  + Sympathetic increases heart rate
  + Parasympathetic decreases heart rate
  + Contracts as a unit
* Cardiac muscle contraction is similar to skeletal muscle contraction



**Extrinsic Innervation of the Heart**

* Heart is stimulated by the sympathetic cardioaccelerator center
* Heart is inhibited by the parasympathetic cardioinhibitory center

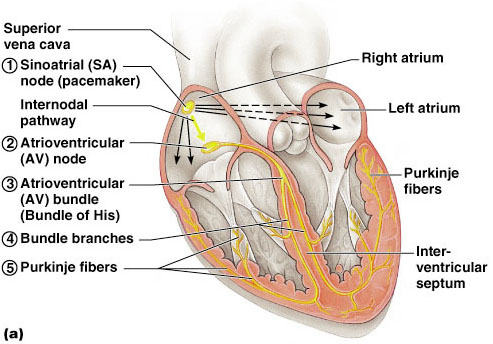
**Heart Physiology: Sequence of Excitation**

* Sinoatrial (SA) node generates impulses about 75 times/minute
* Atrioventricular (AV) node delays the impulse approximately 0.1 second
* Impulse passes from atria to ventricles via the atrioventricular bundle (bundle of His)
* Heart Block - the only route for impulse transmission from the atria to the ventricles is through the AV node, and damage to the AV node is called heart block

**Defects in the Intrinsic Conduction System**

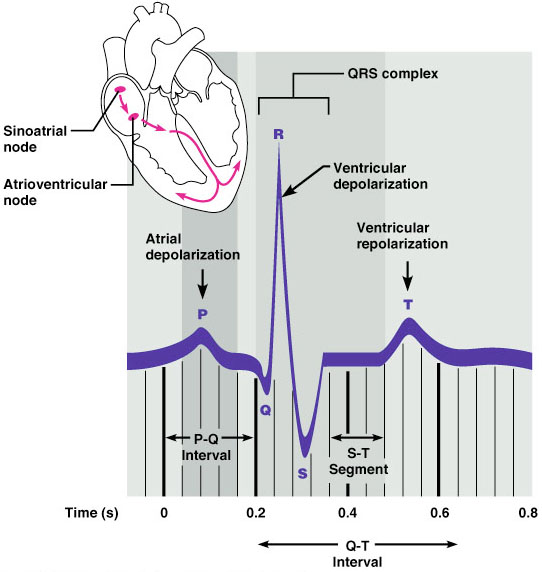
* Arrhythmias
  + Irregular heart rhythms
  + Uncoordinated atrial and ventricular contractions
* Fibrillation
  + A condition of rapid and irregular or out of phase contractions
  + The heart rhythm is taken away from the SA node by fast activity in other heart regions

**Heart Physiology: Sequence of Excitation**



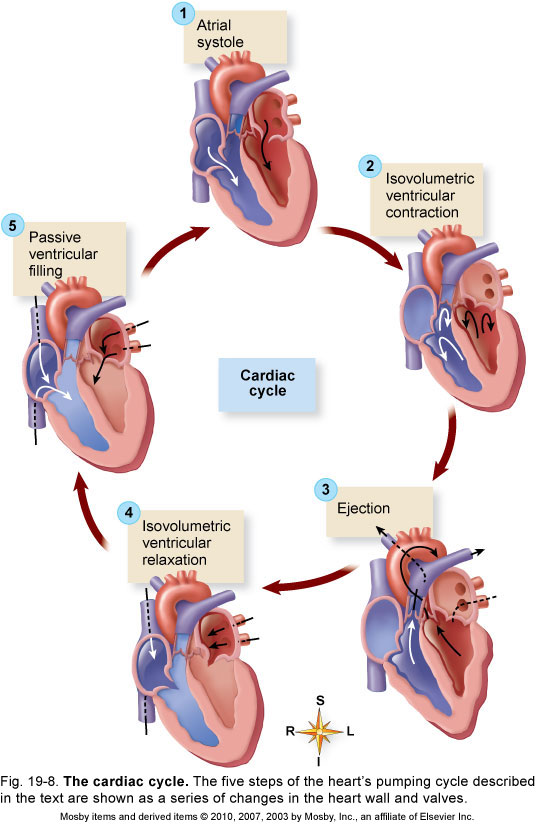
**Electrocardiogram (ECG)**

* Graphic record of the heart’s electrical activity, its conduction of impulses
* A record of the electrical events that precede the contractions of the heart
* Producing an ECG
* Electrodes of an electrocardiograph are attached to the subject
* Changes in voltage are recorded that represent changes in the heart’s electrical activity

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**Cardiac Cycle**

* Cardiac cycle: a complete heartbeat consisting of contraction (systole) and relaxation (diastole) of both atria and both ventricles
* When the heart muscle contracts (pushes in) it is called systole
* When the heart muscle relaxes (stops pushing in), this is called diastole
* Both atria do systole together
* Both ventricles do systole together
* But the atria do systole *before* the ventricles
* Even though the atrial systole comes before ventricular systole, all four chambers do diastole at the same time
  + This is called cardiac diastole
* The order is: atrial systole > ventricular systole >cardiac diastole
* When this happens one time, it is called a cardiac cycle

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**Heart Sounds**

* Heart sounds (lub-dup) are associated with closing of heart valves
  + First sound occurs as AV valves close and signifies beginning of systole (start of the heart contraction)
  + Second sound occurs when SL valves close at the beginning of ventricular diastole (relaxation of the heart muscle)
  + Clinically significant because they provide information about the functioning of the heart valves

**Heart Murmurs**

* Abnormal heart sounds are called murmurs
* Blood flows silently as long as the flow is smooth and interrupted
* If there is an obstruction, the flow becomes turbulent and generates a detectable sound
* Common in young children and some elderly
  + Probably because the heart walls are thinner and vibrate more

**Arterial Blood Pressure**

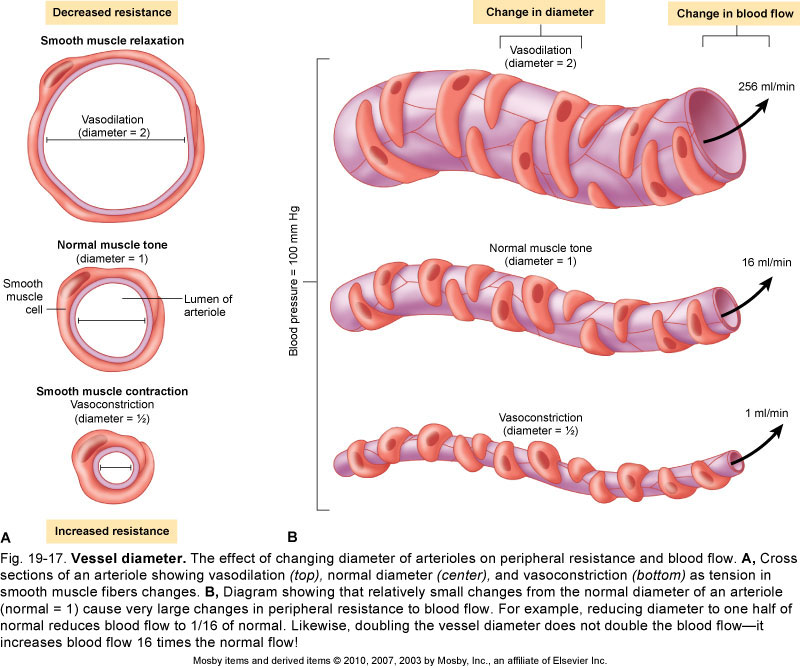
* Primary determinant of arterial blood pressure is the volume of blood in the arteries
* A direct relation exists between arterial blood volume and arterial pressure
* Cardiac output (CO) is the amount of blood pumped by each ventricle in one minute
* CO is the product of heart rate (HR) and stroke volume (SV) – Normal adult volume is 5L/min
* Heart rate (HR) is the number of heart beats per minute
* Stroke volume (SV) is the amount of blood pumped out by a ventricle with each beat

**Starling’s Law of the Heart**

* States that the force of contraction depends on the length of muscle fibers of the heart wall
* The greater the stretch of cardiac muscle, the greater the force of contraction
* This means that when there is an unusual increase in volume of blood entering the heart, the ventricular wall stretches causing the cardiac muscle to contract more forcefully
* Since there is an increase of the load experienced by each muscle fiber the result is greater heart contraction and beat

**Factors That Affect Heart Rate**

* Cardiac pressor receptors
  + Aortic baroreceptors & carotid baroreceptors affect the autonomic cardiac control center
* Other factors
  + Anxiety, fear, and anger often increase heart rate
  + Exercise normally increases heart rate
  + Grief tends to decrease heart rate
  + Emotions produce changes in heart rate
  + Increased blood temperature or stimulation of skin heat receptors increases heart rate
  + Decreased blood temperature or stimulation of skin cold receptors decreases heart rate
* Peripheral resistance
  + Resistance to blood flow imposed by the force of friction between blood and the walls of its vessels
  + Factors that influence peripheral resistance
    - Blood viscosity: the thickness of blood as a fluid
      * High hematocrit (percentage of red blood cells) can increase blood viscosity
      * Anemia, hemorrhage, or other abnormal conditions may also affect blood viscosity
    - Diameter of arterioles
      * Muscles in walls of arteriole may constrict
      * Small changes in blood vessel diameter

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**Arterial Blood Pressure**

* Systolic pressure – pressure exerted on arterial walls during ventricular contraction
* Diastolic pressure – lowest level of arterial pressure during a ventricular cycle
* Pulse pressure – the difference between systolic and diastolic pressure

**Capillary Blood Pressure**

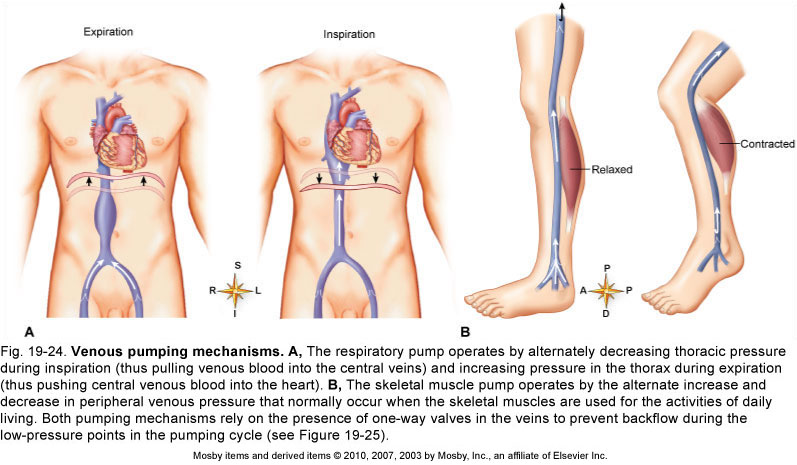
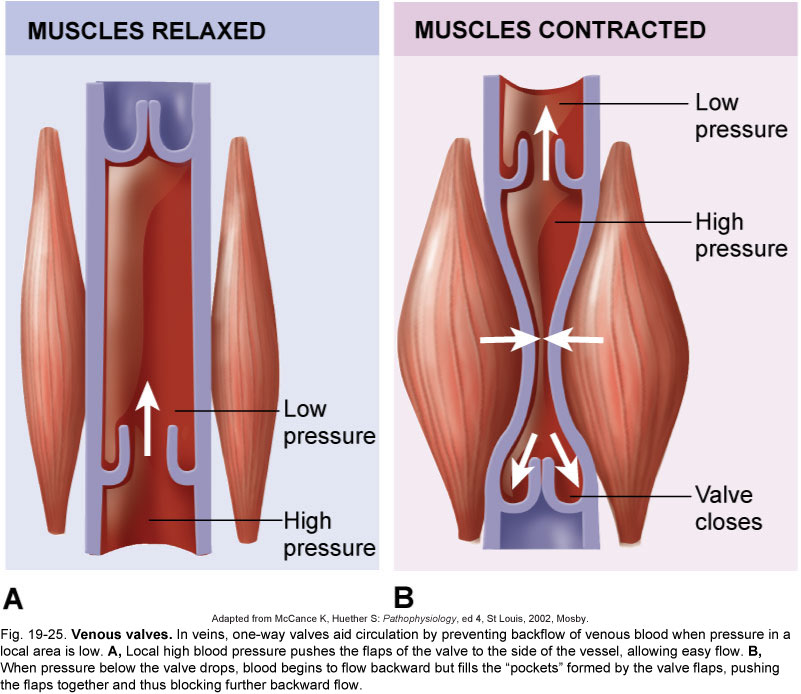
* Capillary BP ranges from 20 to 40 mm Hg
* Low capillary pressure is desirable because high BP would rupture fragile, thin-walled capillaries
* Low BP is sufficient to force filtrate out into interstitial space and distribute nutrients, gases, and hormones between blood and tissues

**Maintaining Blood Pressure**

* Maintaining blood pressure requires:
  + Cooperation of the heart, blood vessels, and kidneys
* Supervision of the brain
* The main factors influencing blood pressure are:
  + Cardiac output (CO)
  + Peripheral resistance (PR)
  + Blood volume

**Venous Return to the Heart**

* Venous return: amount of blood returned to the heart by the veins
* Gravity: the pull of gravity on venous blood while sitting or standing tends to cause a decrease in venous return (orthostatic effect)
* Venous pumps: blood-pumping action of respirations and skeletal muscle contractions facilitate venous return by increasing pressure gradient between peripheral veins and venae cavae
* Three main mechanisms of venous return to the heart:
  + Respiratory pump mechanism- pressure changes occur in the thoracic and abdominal cavities during inspiration and expiration. This compresses veins and assists blood return to the heart.
  + Skeletal muscle contractions: promote venous return by squeezing veins through a contracting muscle and milking the blood toward the heart
  + One-way valves in veins prevent backflow



**Localized Blood Flow**

* Blood flow to skeletal muscle
  + When muscles become active, hyperemia is directly proportional to greater metabolic activity of the muscle (active or exercise hyperemia)
  + Muscle blood flow can increase tenfold or more during physical activity as vasodilation occurs
* Blood flow to skin
  + Helps maintain body temperature
  + Provides a blood reservoir
* Blood flow to the brain
  + Is constant, as neurons are intolerant of ischemia
  + Brain is extremely sensitive to declines in pH
  + The brain can regulate its own blood flow in certain circumstances, such as ischemia caused by a tumor
  + The brain is vulnerable under extreme systemic pressure changes
    - MAP below 60mm Hg can cause syncope (fainting)
    - MAP above 160 can result in cerebral edema
* Blood flow to the lungs
  + Blood flow in the pulmonary circulation is unusual in that:
    - The pathway is short
    - Arteries/arterioles are more like veins/venules (thin-walled, with large lumens)

**Measuring Blood Pressure**

* Arterial blood pressure
  + Measured with a sphygmomanometer and stethoscope; listen for Korotkoff sounds as the pressure in the cuff is gradually decreased
  + Systolic blood pressure: force of the blood pushing against the artery walls while ventricles are contracting
  + Diastolic blood pressure: force of the blood pushing against the artery walls when ventricles are relaxed
  + Pulse pressure: difference between systolic and diastolic blood pressure
* The first sound heard is recorded as the systolic pressure
* The pressure when sound disappears is recorded as the diastolic pressure

**Variations in Blood Pressure**

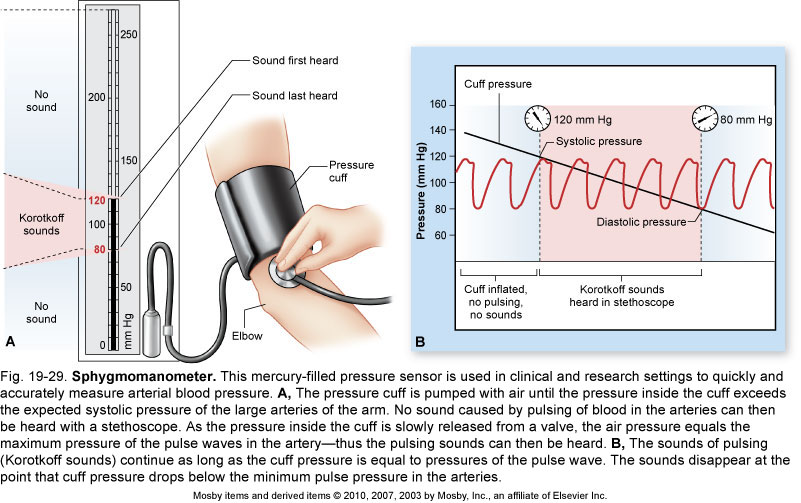
* Blood pressure cycles over a 24-hour period
* BP peaks in the morning due to waxing and waning levels of retinoic acid
* Extrinsic factors such as age, sex, weight, race, mood, posture, socioeconomic status, and physical activity may also cause BP to vary
* Alterations in Blood Pressure
  + Hypotension – low BP in which systolic pressure is below 100 mm Hg
  + Hypertension – condition of sustained elevated arterial pressure of 140/90 or higher

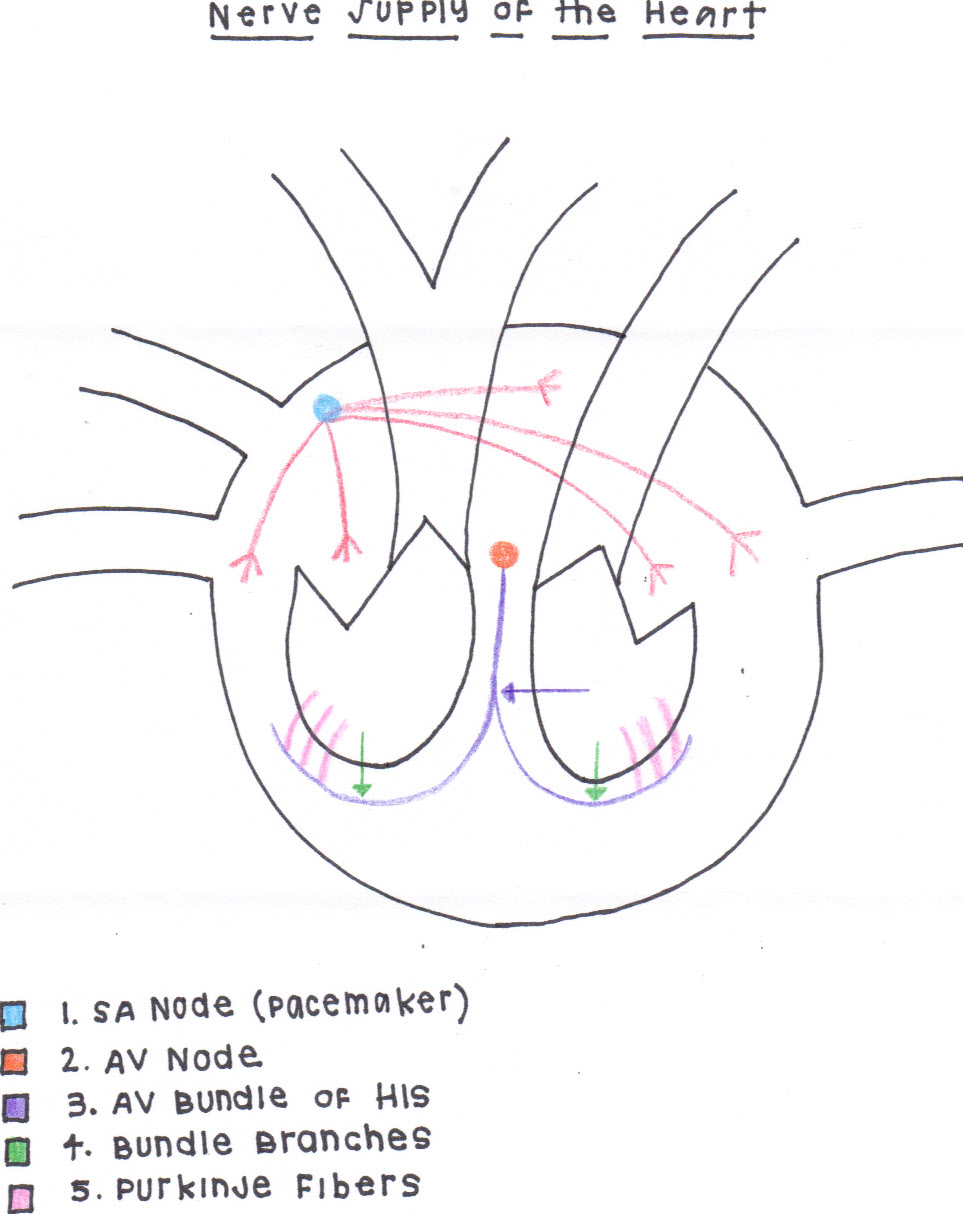
**Hypertension**

* Hypertension maybe transient or persistent
* Primary or essential hypertension – risk factors in primary hypertension include diet, obesity, age, race, heredity, stress, and smoking
* Secondary hypertension – due to identifiable disorders, including excessive renin secretion, arteriosclerosis, and endocrine disorders

**Developmental Aspects**

* Blood vessels are trouble-free during youth
* Vessel formation occurs:
  + As needed to support body growth
  + For wound healing
  + To rebuild vessels lost during menstrual cycles
* With aging, varicose veins, atherosclerosis, and increased blood pressure may arise





**By Kyla Kern – OTA Student**