Unit 1 Psychomotor

1.1 Motor control

The Field of Psychomotor Behaviour

Psychomotor

- All motor functions and their relationship to mental activities (thinking, brain function, etc.) Three interconnected areas 1. Motor Control 2. Motor Development 3. Motor Learning Today's class: Motor Control

3 interconnected areas

- Motor Control
- Motor development
    - Change of motor control over a lifetime
- Learning
    - Change in motor control with practice

Defining Motor Control

Motor Control

- Refers to the nervous system's control of muscles to permit skilled and coordinated movement

Two main aspects of motor control

- Stabilizing the body in space; postural and balance control
- Moving the body in space.

Why study motor control

- Improving motor performance
- Generating and building theory
- Improving movement capability following injury to guide clinical
- How psychology and physiology of the brain influences motor control
- Link diseases to

Where motor control fails us

Amyotrophic lateral sclerosis (ALS)

- Nerve cells slowly die off
- Therefore no message going from brain to muscles
- No control over movement
- Paralysis
- Eventual death

Spinal cord injury

- Severs the nerves giving the signal to muscles
- Paralysis and lose of muscle control

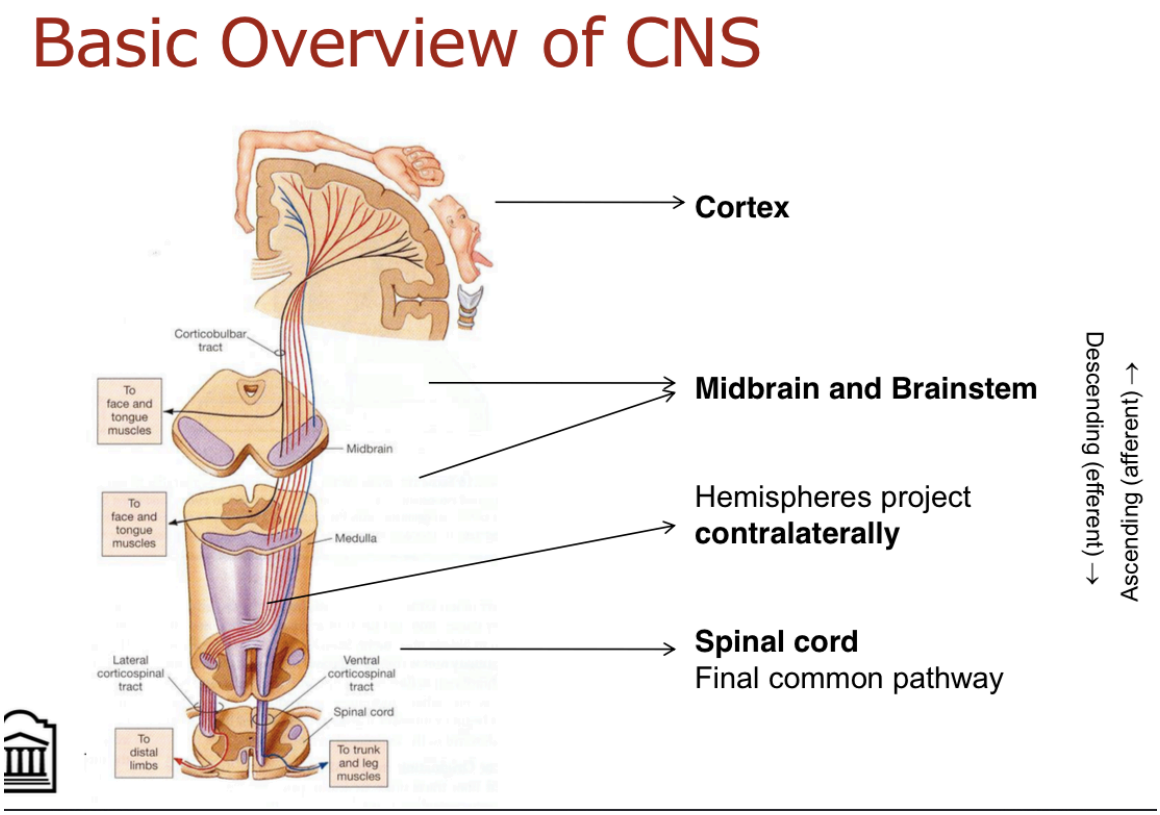
Parkinson disease

- Basodagila doesn't produce dopamine
- There is a gap in the neuron transmitter and dopamine is lacking
- Igniting or changing movement is very difficult
- Can give dopamine in form of medication in order to treat symptoms

The Central Nervous System

Basic overview

- Consists of the brain and the spinal cord
- Higher parts- execute and create patters
- Middle-
- Lower- execute movements
- Cortex
    - Sends signal down through the mid brain and brain stem
    - Medulla
- Contralateral cross over
    - Hemispheres project contralateral



The spinal cord

- Receives and processes sensory information from receptors in the skin or muscles
- Controls the movement through central pattern generators (CPG
- May control movements without signals from the brain
- Leads into the brain stem, which contains the medulla oblongata, the pons and the midbrain.

Medulla Oblongata:

- Contains several centers responsible for autonomous life support
- Responsible for involuntary movement

Pons:

- Transmits information regarding movement from the brain hemisphere to the cerebellum and spinal cord
- Responsible for arousal levels

Cerebellum

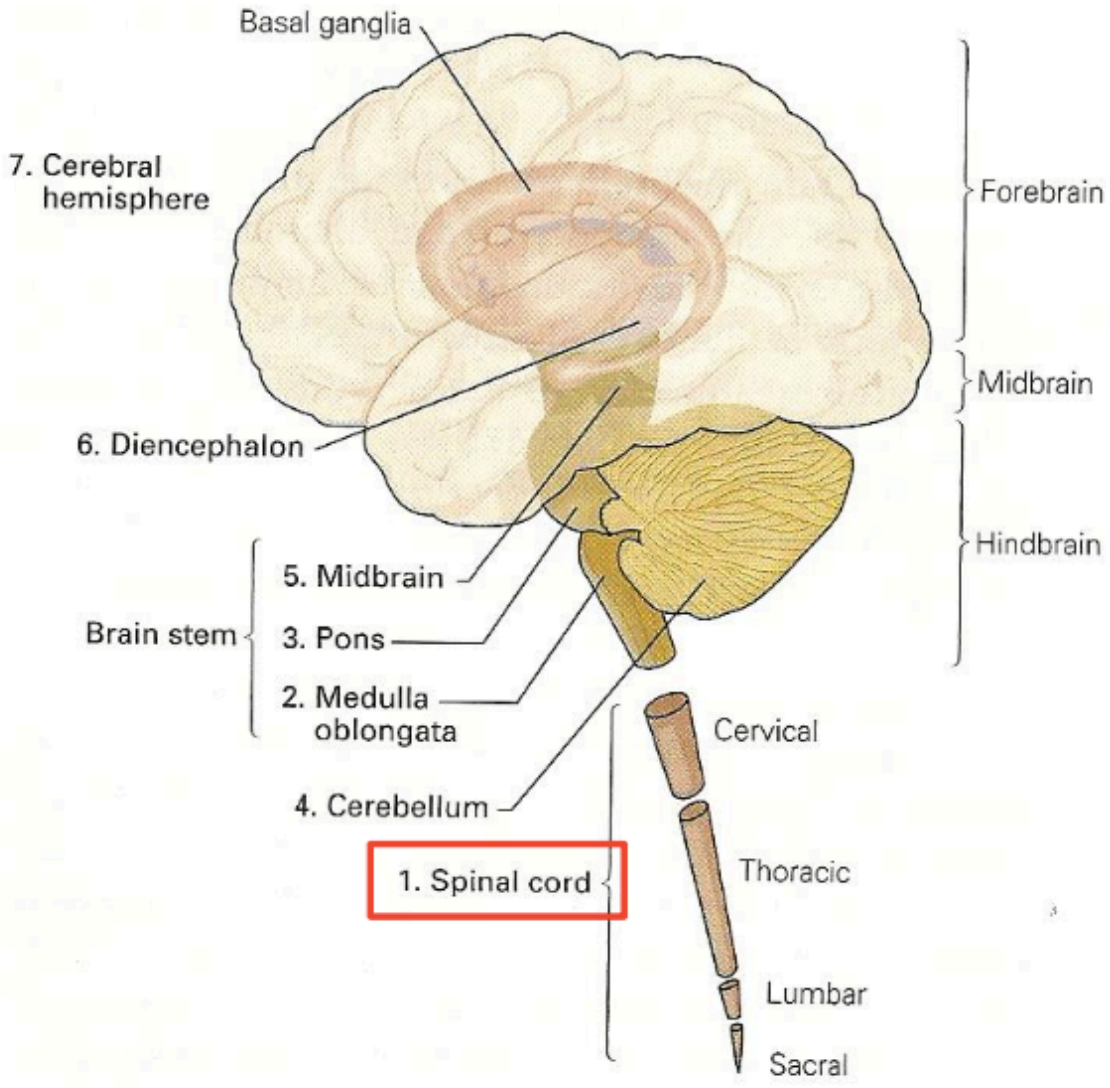
- Involved in motor learning, coordination of movement
- Modulates the strength and range of motion
- Vestibulocerebellum:
    - Vestibular System in inner ear
    - Gives you information about your surrounding
    - Gives equilibrium and provides Balance and Stability
- Spinocerebellum:
    - Receives sensory information from the spinal cord
    - Important for the control of movement (smooth)
    - Coordinates and fine-tunes movement
    - Especially the coordination of the trunk
- Neocerebellum:
    - Does not receive information from the spinal cord r
    - Receives projections from the cortex receive information from cortex in the eye that gives information about the world around us
    - Internal model/representation of our world
    - Laceration of neocerebellum from intoxication cause ataxia which
        - Leads to clumsiness
        - Influences coordination
        - No fine tuned movement at the end of a movement requires more control and fine tuning

Midbrain

- Connection between brain and spinal cord
- Controls several motor and sensory functions
    - Eye movement
    - Movement from or reaction to stimulus
    - Coordination of visual and auditory reflexes. \

Diencephalon

- Thalamus
    - Handles most of the information which reaches the cerebral cortex from the rest of the CNS
    - Door to the brain
    - All information must go through before going to the brain
- Hypothalamus
    - Regulates autonomic, endocrine and visceral functions
        - Temp control
        - Regulates thirst hunger
        - Maintenance of homeostasis
    - Located below the thalamus
    - Receives information from body and the brain


Basal ganglia
7. Cerebral hemisphere
Forebrain
Midbrain
6. Diencephalon
Hindbrain
5. Midbrain
Brain stem
3. Pons
2. Medulla oblongata
4. Cerebellum
1. Spinal cord
Cervical
Thoracic
Lumbar
Sacral

The cerebral hemispheres

The cerebral cortex

- The wrinkled outer layer
- Folded to store maximal information
- Contains 4 lobes and 3 internal structures

<table>
<tr><td colspan="3">4 lobes of the cerebral cortex</td></tr>
<tr><td>Frontal</td><td colspan="2">Contains the motor cortex

• Planning, voluntary movement and some aspects of language
• Gives signals for muscles to move</td></tr>
<tr><td>Parietal</td><td colspan="2">Sensory integration

• Managing proprioceptive information’s of the skin (heat, cold, pressure, pain)

Relationship in real time with the motor areas</td></tr>
<tr><td>Occipital</td><td colspan="2">Visual cortex and visual projection and interoperates and manages visual information</td></tr>
<tr><td>Temporal</td><td colspan="2">Speech, hearing and memory</td></tr>
<tr><td colspan="3">3 internal structures</td></tr>
<tr><td>Basal ganglia</td><td>Hippocampus</td><td>Amygdala</td></tr>
</table>

Cerebral palsy
- Cannot control movements involuntary movement, spasticity
- Treatment- stretching to avoid muscle shortening
- Occurs in different degrees

Brain mapping by electrical stimulation
- Took note of where in the brain the each body part is controlled through electrical simulation
- More of brain responsible of face, hand tongue, etc. due to more coordination and sensory ability
- Brain will adapt to circumstances (no hand, a larger portion of the brain will represent the feet)

Reflex vs. voluntary movement

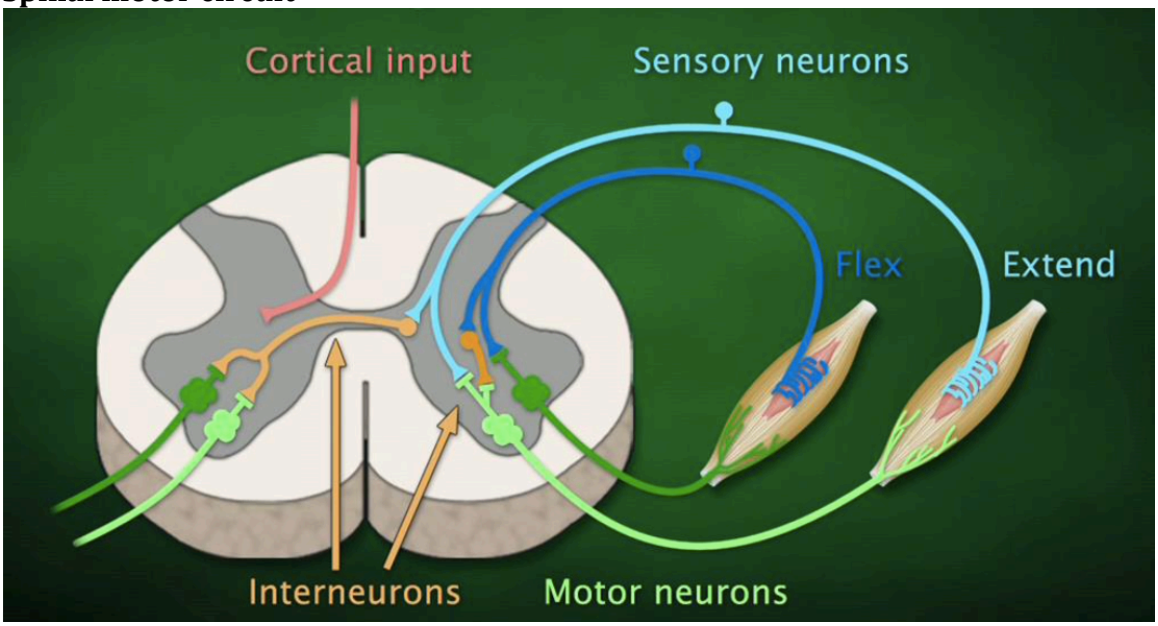
Reflex

- Involuntary response to a stimulus

Voluntary

- Initiating by the brain and sent to muscles

Spinal motor circuit



The Reflex Theory by Sir Charles Sherrington

Reflex arc has 3 components

- Receptor
- Conductor
- Effector (muscle or organ that performs task)

Monosynaptic

- Stimulus leads to response
- Simple response
- One synapse between nerves
- Sensory neuron sends signal directly to the motor neuron and back
- No control over movement
- No learning involved in movement
- Latency is 30-50ms
- Ex patellar tendon reflex
    - Tap on the patellar tendon
    - Stretch receptors tell spinal cord (dorsal root)
    - Spinal cord activates alpha motor neuron (ventral root)
    - Quadriceps extends

Polysynaptic reflexes

- More than one synapse is involved
- More complex movement generated via the reflex control

- More than one synapses involves (interneurons involved that can influence the degree of the reaction)
- Latency is 50-80ms
- Examples
    - Reaction to painful stimulus

Latency of response

- Refers to the time between the stimulus and a muscle activation response
- Is the delay between the stimulus and the response
- This is measured through electromyography (EMG)
- In laboratory session reaction time is sometime used as an index for response latency

Sherrington's Chaining of Reflexes

Sherrington's work

- With decorticate cats/dogs/apes
- Cut the information from the cortex off and let the animal walk on a treadmill
- Observed that the muscles were still working together so that the cat could still walk (agonist/ antagonist working in sink)

His argument

- Movement can be controlled at the level of the spinal cord through chaining of reflexes
- A movement done in a rhythmic pattern is a reflex
- Ex chicken will continue running with its head cut off

Limitation of Sherrington's theory

- Voluntary movement can be activated without a stimulus triggering the movement (outside active agent)
- Research has shown that movement can occur in the absence of sensory input (Taub and Berman, 1968)
- Cannot explain rapid movement sequences
- A given stimulus can result in different responses depending on context and descending commands
- Reflex chaining does not explain the ability to produce a novel movements

Voluntary movements

Defining voluntary movements

- Are goal-directed movements, initiated by the individual
- Cortical level control
- Longer pathway

Voluntary response latency

- About 120-180 msec
- Dependence on task and circumstances
- Require the person to pass through three stages of information processing and requires attention
- Can be affected by several factors

Comparison Reflex Movement vs. voluntary movement

Reflex	Voluntary
• Initiated by stimulus • Involuntary • Requires no conscious attention or information processing • Latency 40msec-80msec	• Initiated by intention • Requires attention and information processing • Latency 120msec-180msec

Factors Influencing Reaction time

Hick's law

- The time it takes to make a decision increases as the number of alternative increases

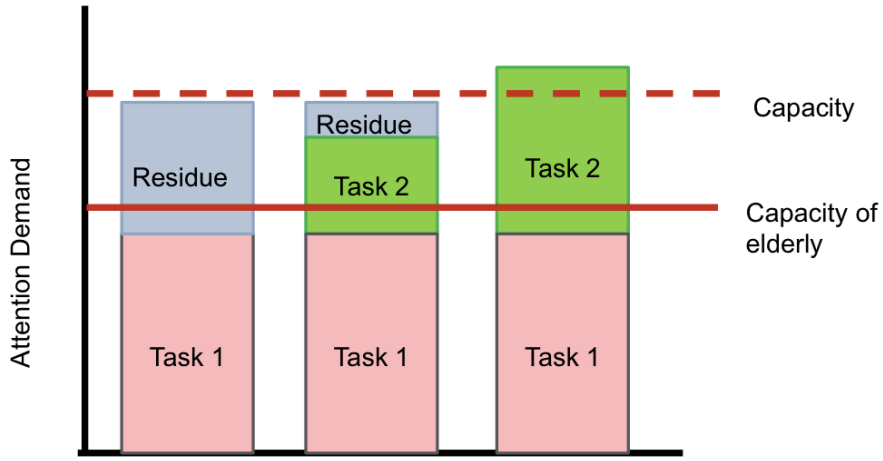
Factors

- Number of stimulus-response alternative
- Stimulus-response compatibility
- Complexity
- Practice
- Timing uncertainty
- Stimulus intensity
- Age, intelligence
- Stress

Attention

- Limitation in the ability of processing information
- Is limited in each individual

Limited Attention Capacity



Attention capacity is dependent on TIE constraints

- Task
- Individual
- Environment

Characteristics of voluntary movement

Flexible

- Same movement, muscles and various joints
- The motor equivalent

Unique

- The same moment is repeated in exactly the same manner

Constant

- Despites their uniqueness, the movements can be repeated in their spatial and temporal characteristic

Modifiable

- Ability to change a movement

Two types of motor control

Closed-loop system

- Movement based on sensory feedback
- Flexible, adaptable, precise and slow
- Ex: heating system

Open-loop system

- Structure to move forward (feed forward)
- Quick and powerful movement
- Less effective in unstable situations
- Ex: traffic lights

1.2 Motor development

Motor development

Defining Motor development

- The study of the changes in human motor behavior over the lifespan
- The processes that underlie these changes and the factors that effect them

Goals in studying motor development

- To determine common and characteristic changes in behavior, function and appearance across the life span
- The establish when the changes occur
- To describe what causes these changes
- To determine whether change can predicted
- To determine whether these changes are individual or universal

The Motor development continuum

<table>
<tr><td>Phase: Reflexes/Spontaneous movements</td><td colspan="2">Approximate Age: conception - 12 months</td><td>Stage: prenatal and infancy</td></tr>
<tr><td colspan="2">Spontaneous movements</td><td colspan="2">Reflex movements</td></tr>
<tr><td colspan="2">• Not stimulus driven
• Not voluntary but not a reflex
• Ex: baby flinging limb</td><td colspan="2">• Involve a stimulus and associated response
• Ex: palmar grasp, suckle,
• Some are survival and some are primitive
• Ex: rooting reflex; struck of cheek baby with turn to find food,</td></tr>
<tr><td colspan="4">Infantile reflexes</td></tr>
<tr><td>Primitive reflexes

Birth to 4 months

Occur in lower brain centers

For survival</td><td colspan="3">• These reflexes have been studied when they appear and disappear has been documented
• If primitive reflexes don’t disappear or appear at appropriate times in lifespan this may indicate a problem
• Reflexes don't actually disappear they’re over ridden but superior structures this is why no disappearance may= problem
• Ex: rooting, suckle, palmar, Babinski (stocking of bottom of foot= dorsi flexion,) startle reflex (dropping of arms= flexion,) asymmetric tonic reflex (move head to left, left arm down, right arm up, and vise versa, high correlation if baby has tendency to turn to left, left handed and vise versa,) stroke back on one side baby curls to that side, drop head backward= throw of arms back and startled look</td></tr>
<tr><td>Postural reactions

Appears after about 2 month</td><td colspan="3">• Help maintain posture in a changing environment
• Appears after about 2 months
• Ex: parachute reflex (baby keeps head elevated to ensure passage of air, lift arms up if tilted forward)
• Some don’t disappear</td></tr>
<tr><td>Reflex locomotion</td><td colspan="3">• Resemble the voluntary movement
• Disappears for months before the child is trying to do the movement voluntarily.
• Ex: Walking, swimming, and crawling
o Baby may lift legs if held up= reflexive walking reflex
o Will make movement resembling swimming and hold breath under water</td></tr>
<tr><td colspan="4">• Evaluation of the appearance and disappearance of reflexes can give us ideas of the development of the infant
• Recurrence may indicate injury to the central nervous system
• Reflexes appear and disappear at particular ages</td></tr>
</table>

• Newborn examinations include reflexes • Reflexes are only present at birth because we don't have the motor patterns yet, and we can't perform voluntary movement, they are also for survival •

Phase: Rudimentary Motor Skills	**Approximate Age: Birth-2 years**	**Stage: infancy**
Cephalocaudal	proximodistal	
• form head to tail • baby will first have to have head control before control of the truck	• control of truck before hands and feets • limb movements appear unique of movement of the truck and unique of each other	
• first form of voluntary movement- done with a purpose		

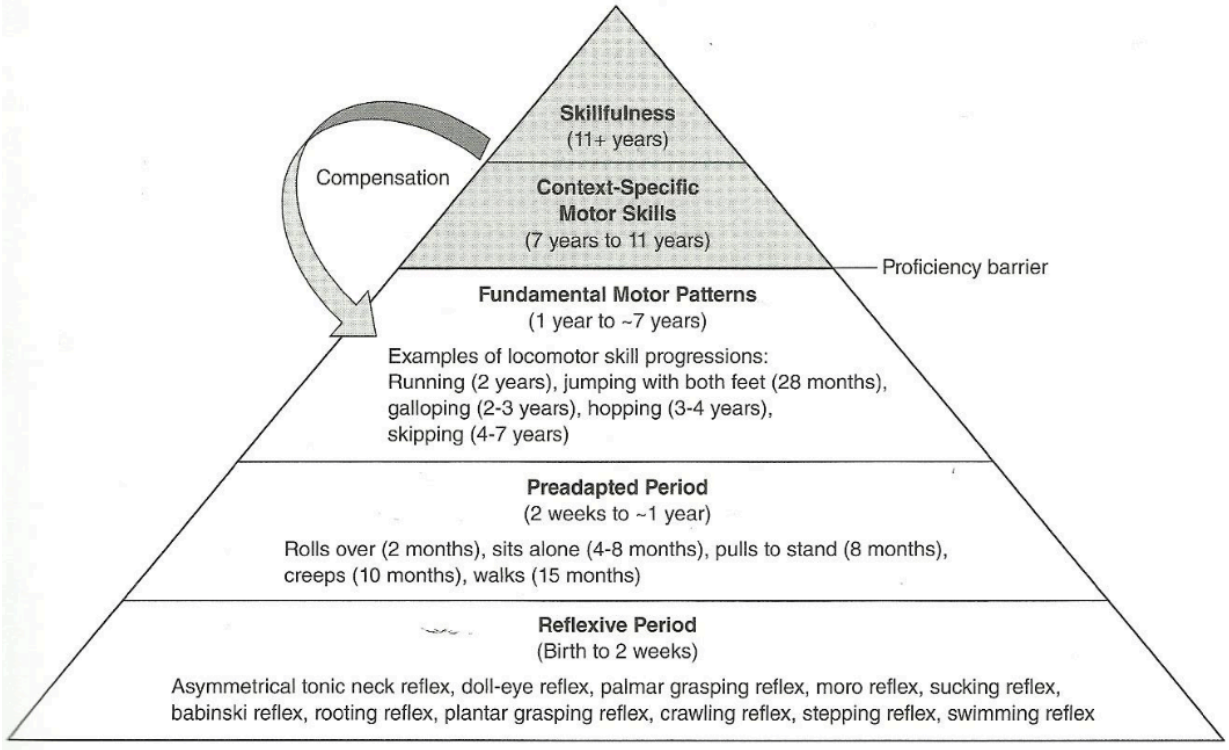
Phase: Fundamental Motor Skills	**Approximate Age: 2 years- 6 years**	**Stage: early childhood**
• Movements are due to development and environment may influence the speed of maturity but not the sequence • Walking, running, skipping, throwing, catching, striking, jumping, swimming • Fundamental movement skills are required before participation in s port •		

Phase: Sport/specialized skills and growth and refinement	**Approximate Age: 6 years- 12 years and 13 years – 18 years**	**Stage: late childhood, teen**

Phase: Peak performance	**Approximate Age: 19 years- 30s**	**Stage: Adulthood**

Phase: Regression	**Approximate Age: 40s and up**	**Stage: Mid-older adulthood**

Motor development pyramid



Ecological Perspective

Dynamical Systems Approach (Kugler, Kelso, Turvey – Bernstein)

- Organization of physical and chemical systems constrains behavior
- Structure of the adult human hip joint encourages (constrains) upright walking
- Motor skill development is the product of many underlying systems (nervous, skeletal, muscular, etc.)

Tenets of Dynamic Systems Theory

- All systems have their own rate of development
- The skill will emerge when all systems are at the level needed to perform the skill
- The last system to "kick in" is called the rate limiting system

Constraints

Karl Newel

- "Movements emerge from interactions between the organization, the environment in which the movement taking place, and the task. If any of these factors change, the resulting movement will change. "
- Constraint Limits or discourages the movement BUT permits or encourages other movements
- They "restrict" and guide the movement in a certain direction: they give it shape
- If any of the constraints are altered the movement will change

Types of constraints

Task	• Rules, equipment used, goals, etc. • Ex: Play hockey with a wooden stick vs. composite stick
Individual	Functional: • Changes quickly • Emotional state: motivation, fear, motivational focus • Ex: running in cold weather vs. warm and humid Structural: • Changes slowly with growth and age • Height, weight, muscle mass, etc. • Ex: swimmer with an amputated leg
Environment	They are outside the body, the properties of the world around us: • Physical • Sociocultural

Abilities vs. skills

Ability

- Genetically defined traits (innate)
- Stable
- Base for different skills
- Not modifiable by practice or experience

Skills

- Ability to perform with maximum certainty, and a minimum of energy or time
- Developed and changed with practice and over time
- Dependent on ability
- Look at skills in motor learning because ability cannot be altered

1.3 Motor Learning

Motor learning

Defining Motor Learning

- The relatively permanent gains in motor skill capability associated with practice or experiences

The purpose of motor learning

- To be able to do the task with
    - Maximum certainty
    - Minimal energy (physical or mental)
    - Minimum time

Learning vs. Performance

Learning	Performance
• Observable behavior • Temporary • May not be due to practice • Influenced by performance variables	• Not observable, inferred from performance • Relatively permanent • Due to practice • Not influenced by performance variables

Learning

- "Learning is a change in the capability of a person to perform a skill that must be inferred from a relatively permanent improvement in performance as a result of practice or experience" (Magill, 2010, p.249)

5 Learning Characteristics

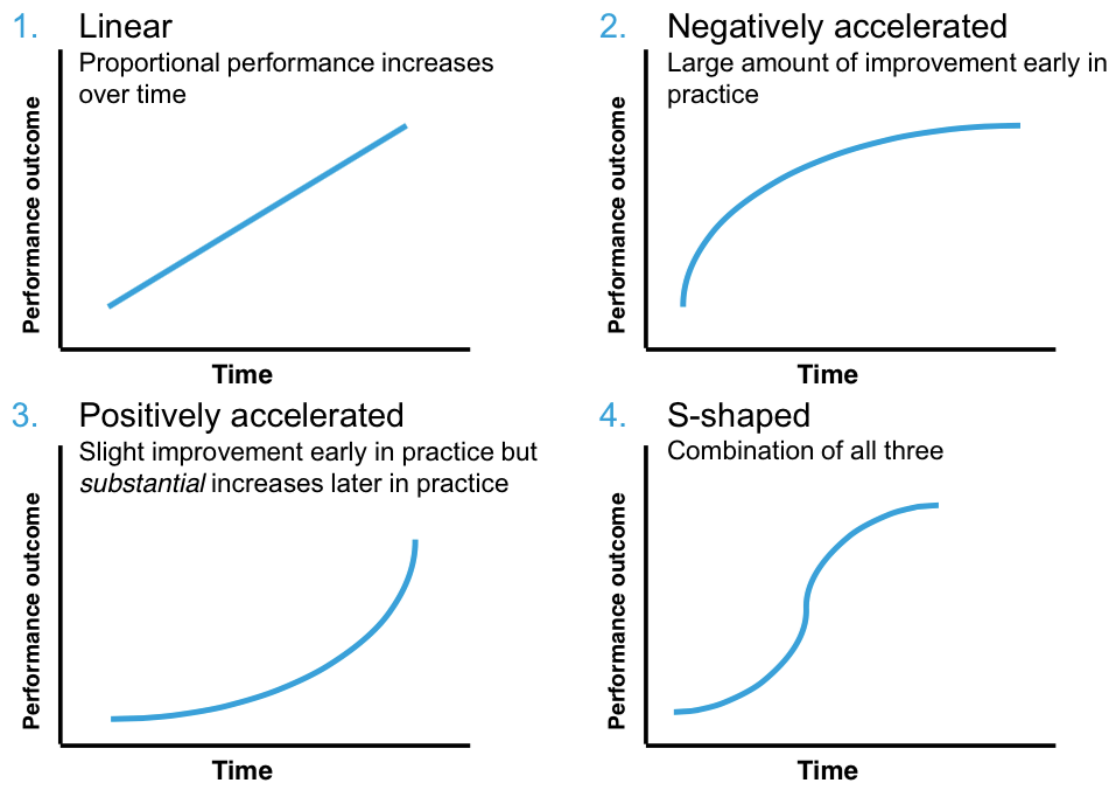
- Improvement
    - Increased level of skill at a later time compared to an earlier time
- Consistency
    - As learning progresses, performance is more consistent
- Stability
    - Skill not affected so much by perturbations
    - Internal condition: stress
    - External condition: weather, obstacles
- Persistence
    - Increased amount of persistence of performance capability over a longer period of time
    - (Today tomorrow next week)
- Adaptability
    - Increased capability to adapt to a variety of performance and context characteristics

Performance

- Affected by performance variables but not necessarily learning variables.
- Performance variables are factors that affect the person's immediate performance but not the degree of learning that is being achieved
- Ex: alertness, anxiety of the situation, fatigue

Assessing Learning by Practice Performance

- Performance curves
    - Record levels of performance
    - Error measures
        - Constant error (bias, always making the same or similar error)
        - Variable error (consistency, random)
    - Performance outcome over time



Kinematic Performance Curves

- Kinematic measures are performance production measures.
- Three common kinematic measures are
    - Displacement
    - Velocity
    - Acceleration
- Plot a sample of the trials at different points in acquisition

Inferring learning from performance

- Transient effects of the "instruction feature"
    - Artificial inflation
    - Artificial deflation

Assessing Learning by Tests

- Pre-test – practice – post test
- Retention test
    - Interval of time passes after practice and the person is asked to perform same task again.
    - Remove manipulation
- Transfer Tests
    - Novel situations adapted to the characteristics of a new situation
    - Novel context characteristics
        - Change physical environment
        - Change performance situation

    - Novel variation of skill
        - Perform a variation of the skill

Uses of Motor Learning

Practical considerations

- Motivation
    - Goals
    - Self-regulation of practice- Giving the individual control over their own practice helps with motivation
    -
- Instructions
    - Structure of instructions
        - Simple, direct
        - Verbal instructions- should be focusing on external focus (outside the body) for best performance
        - Demonstration
        - Given a lot of information may start relying on in, slowly reduce amount of information/instructions
    - Directing attention focus
        - Person who is more skills requires a more narrow focus
- Mental practice
    - Visualization- watch yourself doing a task in 3rd person
    - Imagery- watching yourself doing a task as though you're actually doing it (1st person)

Organization of practices

Types of Practice

- Physical
    - Simulator
    - Partial
        - Divided, segmented, simplified
    - In slow motion
    - Error detection
- Mental

Practice Structure

- Blocked practice
    - Practice same task in blocks
    - Better for beginners
- Random practice
    - Practice different tasks in random order
    - Better for experiences- start doing the skill without thinking about, constantly initiating a different motor pattern involves more cognitive

attention
    - Better transfer of learned skills

Practice Variability

- Constant
    - Practice on variation of task
    - Same skill same way
- Variable practice
    - Practice a number of variations of the task
    - Same skill different way
    - Better transfer of learned skills

Factors to consider when planning a practice
- Characteristics related to the task
- Characteristics of the person
- Level of experience
- Intellectual capacity
- Learning style (impulsive vs. thoughtful)

Feedback
- Intrinsic feedback
    - Which comes from all the sensory systems of the body during movement
    - Exteroception of proprioception
    - Ex intrinsic: Throw a ball and see where it lands, what you perceive yourself, during movement
- Extrinsic feedback
    - Additional information provided by an external source
    - Ex: what someone else tells you, after movement

Knowledge of Results (KR)	Knowledge of performance (KP)
• Information about outcome in terms of environmental goal • Often redundant with intrinsic feedback • More useful in the laboratory	• Information about movement production of patterning • Usual distinct from intrinsic feedback • More useful in real-world

Types of feedback
- Based on the errors
    - Helps guide the proper movement pattern
    - For beginners
- Corrective
    - Feedback on the correct aspects of the movement pattern
    - For those who are not motivated or interested in the activity.
- Combination
    - Best Method

Quantity of feedback

- Optimum level of information to include decreases with the level of complexity of the task
- Providing a summary can reduce dependency on feedback (optimal level)

Affective Extrinsic Feedback

Accuracy	• More specific feedback can improve learning • General feedback better for beginner, more precise feedback for • The more advanced learner • The direction vs. the magnitude of the error
Timing	• More frequently in the beginning, and less when the performance improves • Instant feedback affects learning, because it interferes with the intrinsic feedback of the learner and his development of error detection capabilities

Unit 2 Biomechanics

2.1 An Overview of Biomechanics

Biomechanics

- The science that examines the internal and external forces acting on the human body

Sports biomechanics

- The scientific study and evaluation of sports techniques and skills.

Examples of questions biomechanics asks

- Why do people walk the way they walk?
- How can mobility impairment be improved?
- How prosthesis can aid a person with an amputation?
- How can we optimize performance?

Applications of biomechanics

- Sport and exercise:
    - To improve sports performance through technique and equipment
        - Ex: swimmers pushing off the wall go rly fast but a lot of resistance, compression suits reduce resistance
        - Ex: clap skate allows athletes to keep blade on the ice longer and utilization of the calf muscles, and therefore more power
    - To avoid sports injury by identifying safer techniques,
    - In the development of protective equipment.
- Occupational injury prevention (ergonomics)
    - Low back pain, injury rehabilitation
    - Reduction of physical strain or when functional capacity declines
        - Ex: adjusting a work station/environment so that its better for the body/ more efficiency
    - Improve product design

The Nine fundamentals of biomechanics

Inertia	Newton's first law
Force-Motion principle	• For motion to occur, first there have to act forces on the object (person) Force= mass × acceleration F = m × a • Based on newton's three laws of motion
Force-Time	• Not only the amount of force but also the amount to time the force is applied to an object will affect the change in motion Impulse = Force ×time (in Newton seconds) I = F × **Δ**t (in Ns)
Range of Motion	• Increasing the Range of motion (ROM) in a movement is an effective way to increase speed or to gradually slow down form a high speed. • Related to the force-time principle Work = force × distance (joules) W=F× Δd (J)
Balance	• Ability to control the body position relative to some base of support • Mobility is the ability to perform functional movement patterns with no restrictions in the ROM
Coordination Continuum	• Optimal timing of muscle actions or segmental motions depends on the goal of the movement.
Segmental Interaction	• The body is made of rigid segments that are interconnected. This allows the force generated by the muscles to be transferred by the joints. • Terms used: transfer, summation, sequential
Optimal Projection	• For most human movements involving projectiles there is an optimal range of projection angles for a specific goal. • The optimal projection is a compromise between the vertical velocity (determines time of flight) and horizontal velocity (determines range given the time of flight)
Spin	• Rotations imparted to projectiles o Stabilizes flight o Create a fluid force called lift o Lift force is used to create a curve or to counter gravity affecting the trajectory and bounce of the ball.

2.2 Forces

Newton's laws

Newton's 1st Law

- "An object either remains at rest or continues to move at a constant velocity, unless acted upon by an external force"
- Inertia is the property of all objects to resist changes in their state of motion.

In a state of equilibrium

- $\Sigma F=0$
- $\Sigma M=0$

Linear inertia depends on

- The mass

Angular inertia depending on

- Mass
- Shape
- Distribution of mass
- Axis of rotation

Moment of Inertia

- Centre of mass vs. Turning radius
- $I = m k^2$

Factors that influence the moment of Inertia

- Mass
- Distribution of mass (in relation to the axis)
- The position of the axis of rotation

Turning radius

- Distance where the entire mass of the object could concentrate to
- Produce the same resistance to angular motion as the original object

Moment of Inertia of the Body

- The human body is not a rigid body
- Movements of segments induces a different distribution of
- Mass about an axis of rotation
- Therefore, the movement of inertia varies around said axis of rotation

Newton's 2nd Law: Acceleration

- "The acceleration (a) of a body is directly proportional to, and in the same direction as, the net force (F) acting on the body, and inversely proportional to its mass (m)."
- $F = ma$
- A force is something that has the ability to accelerate an object or a body; causing an increase or decrease in velocity of an object, or a change in direction.
- The unit of force is the Newton (N), which is defined, as the force required producing an acceleration of 1 m/s^2 on a mass of 1 kg.

Newton's third Law of Motion: Action= – Reaction

- "When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction to that of the first body."

Weight, mass, force levers

Characteristics of a force: e.g., Weight

- A magnitude (ex: 686N)
- Line of action/orientation (vertical)
- A direction (downwards)
- A point of application (Come)

Mass vs. weight

- Mass
    - Amount of material (kg)
- Gravitational acceleration
    - Gravity (g) = 9.81 m/s2 ≈ 10 m/s2
- Weight
    - Force of gravity

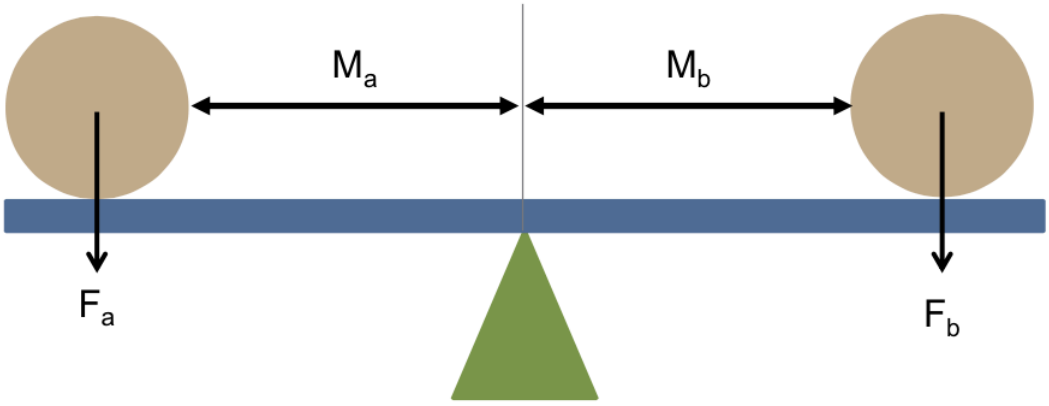
Moment of Force

- Force applied at a perpendicular distance from the axis of rotation.
- The rotational movement is modulated by the magnitude of the applied force and the length of the lever arm
- The cause of motion is an internal or external force
- Newton's first Law of Motion:
    - If an object is not accelerating or decelerating it experiences a state of constant velocity
    - No motion is the state of a constant 'zero' velocity!
- Forces that act through the body's center of mass will cause linear motion
- Forces that do not go through the center of mass or pivot point of an object cause a rotation or angular motion (about an axis of rotation)
- When a force causes angular motion the effect is known as a moment of force or torque

Moment of Force = Moment Arm x Force

For balance

$M_a \times F_a = M_b \times F_b$

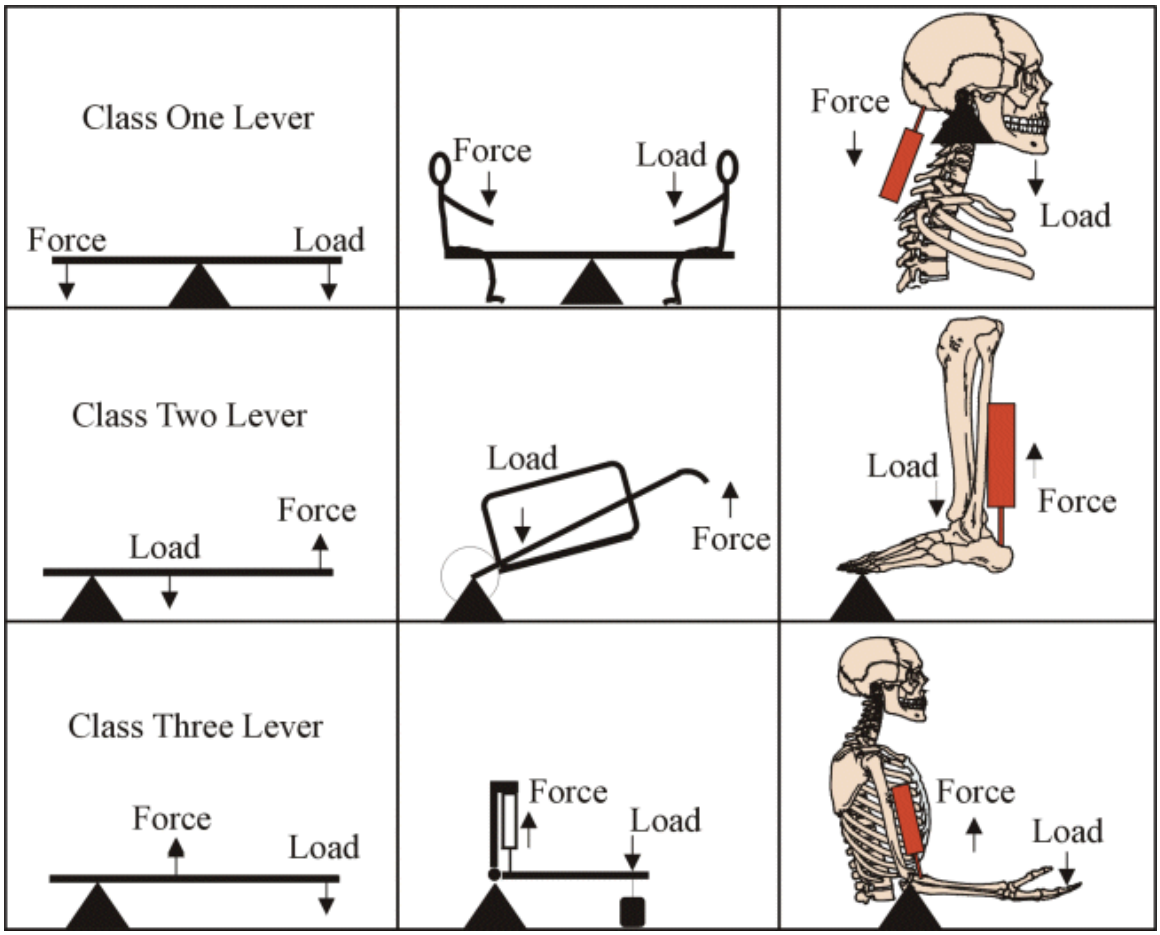


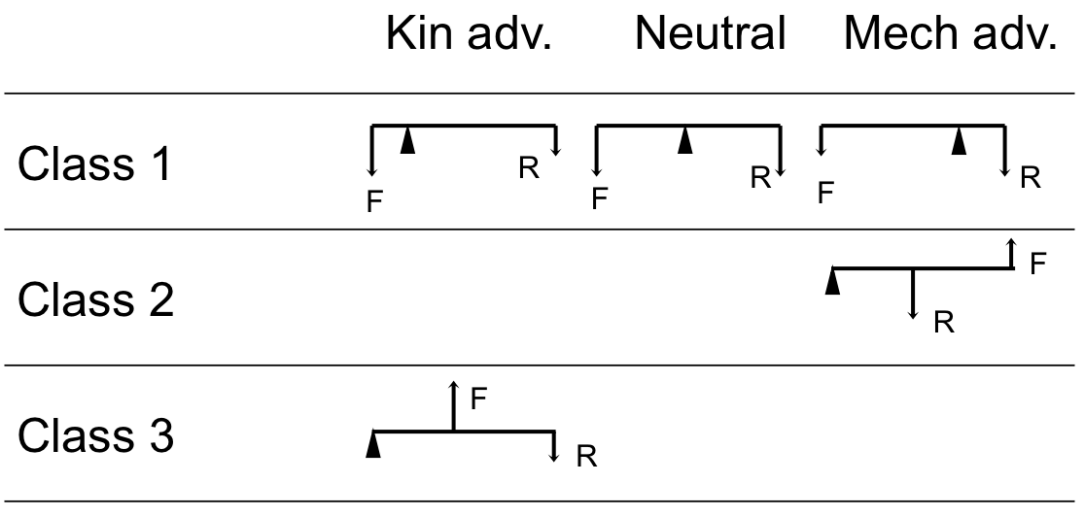
if Ma x Fa < Mb x Fb
no balance

Types of levers

Mechanical Advantage= $\frac{\text{Lever arm of the force}}{\text{Lever arm of the resistance}}$

Mechanical Advantage= $\frac{A_F}{A_R}$





Unit 3 Exercise Physiology

3.1 Cardiovascular System

Roles of the cardio system

The cardiovascular system has important roles in maintaining life and homeostasis

- Provide oxygen and nutrients to the working muscles and organs to function properly
    - Ex: to organs and muscles
- Remove "metabolic waste" from the production site to the site of excretion
    - works with other organs: lungs and kidneys
- Thermoregulation
    - Too hot
    - Too cold
- Immune function
    - white blood cells
- Acid base balance

Cardiovascular Circuits

The Pulmonary Circuit

- Carries blood to and from gas exchange surfaces of lungs

The Systemic Circuit

- Carries blood to and from the body

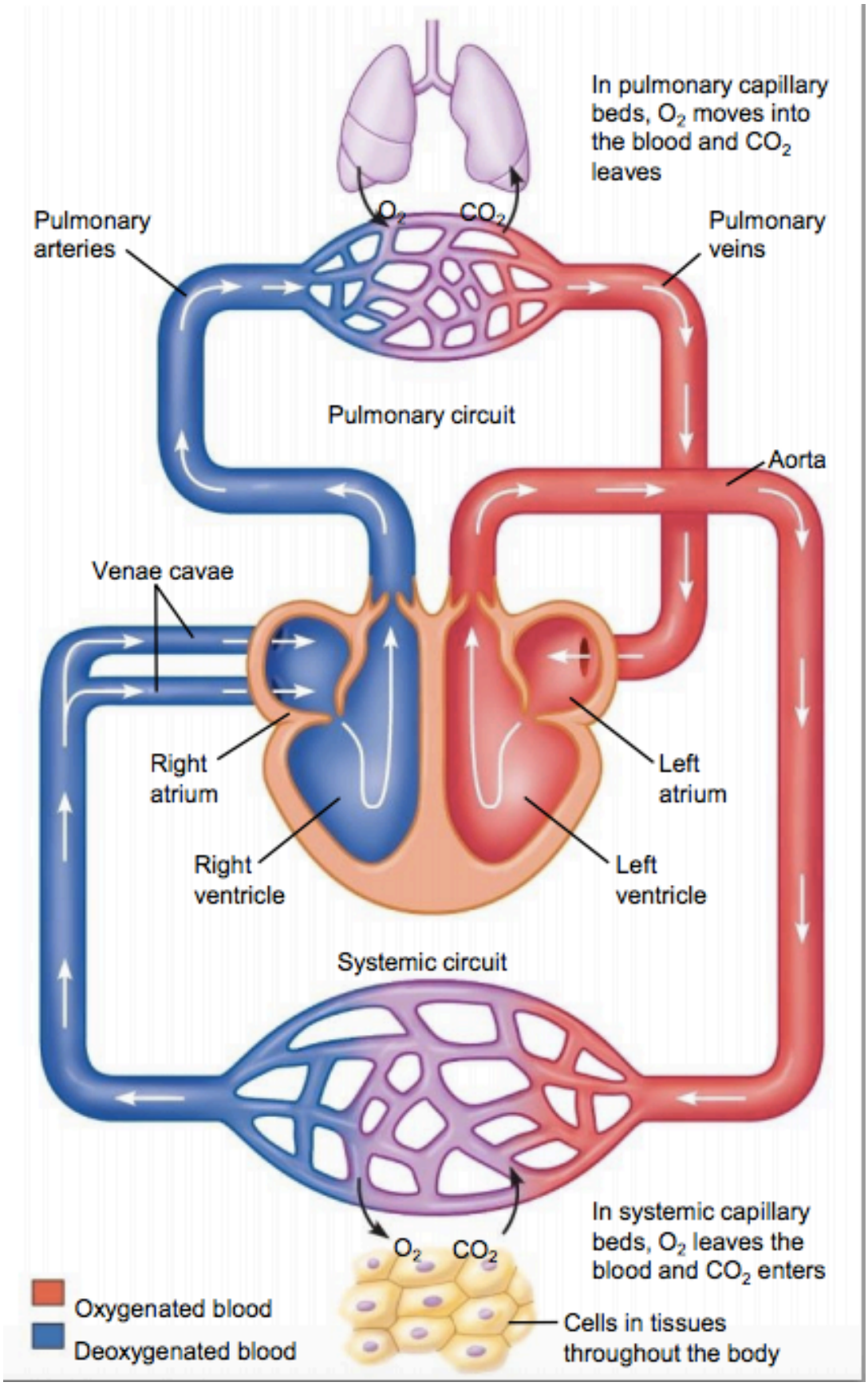
Systemic and pulmonary circulation (from body to heart to lungs to heart to body)

1. Superior and inferior vena cava
2. Right atrium
3. A-V tricuspid valve
4. Right ventricle
5. Pulmonary semilunar valve
6. Left and right pulmonary arteries
7. Pulmonary arterioles
8. Lungs
9. Pulmonary capillary beds
10. Pulmonary venuoles
11. Right and left pulmonary veins
12. Left atrium
13. A-V bicuspid valve
14. Left ventricle
15. Aorta semilunar valve
16. Aorta followed by systemic arteries
17. Systemic arterioles
18. Systemic capillary beds
19. Systemic venuoles
20. Systemic veins

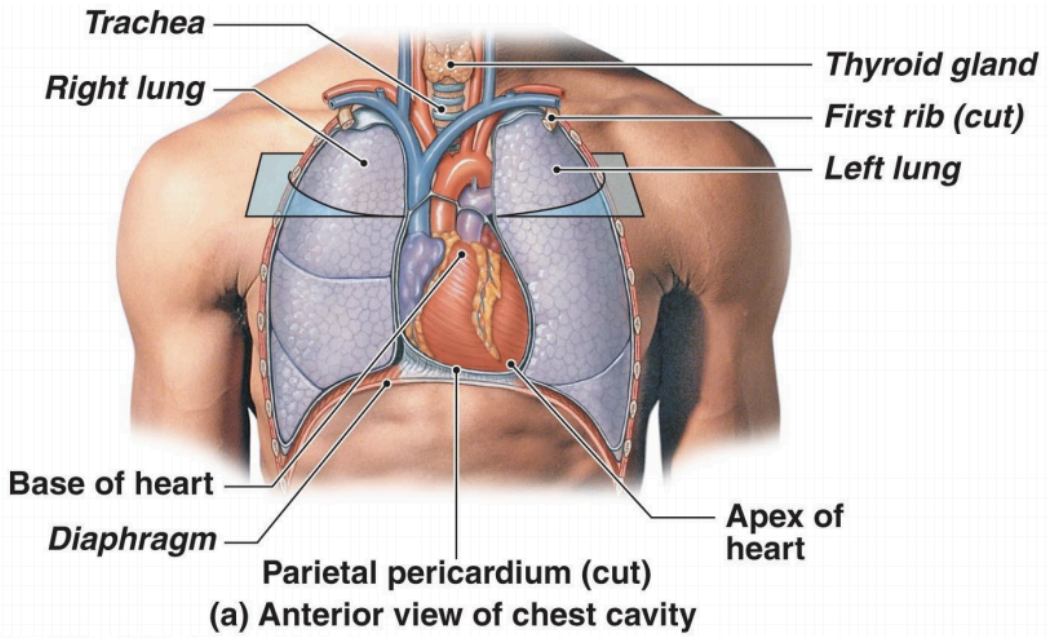
Coronary circulatory (how blood feeds the heart muscle)

- Aorta
- Coronary arteries
- Coronary arterioles
- Coronary capillary beds
- Coronary venuoles

- Coronary veins
- Drains into right atrium


In pulmonary capillary beds, O_2 moves into the blood and CO_2 leaves
O_2
CO_2
Pulmonary arteries
Pulmonary veins
Pulmonary circuit
Aorta
Venae cavae
Right atrium
Left atrium
Right ventricle
Left ventricle
Systemic circuit
In systemic capillary beds, O_2 leaves the blood and CO_2 enters
O_2
CO_2
Cells in tissues throughout the body
Oxygenated blood
Deoxygenated blood

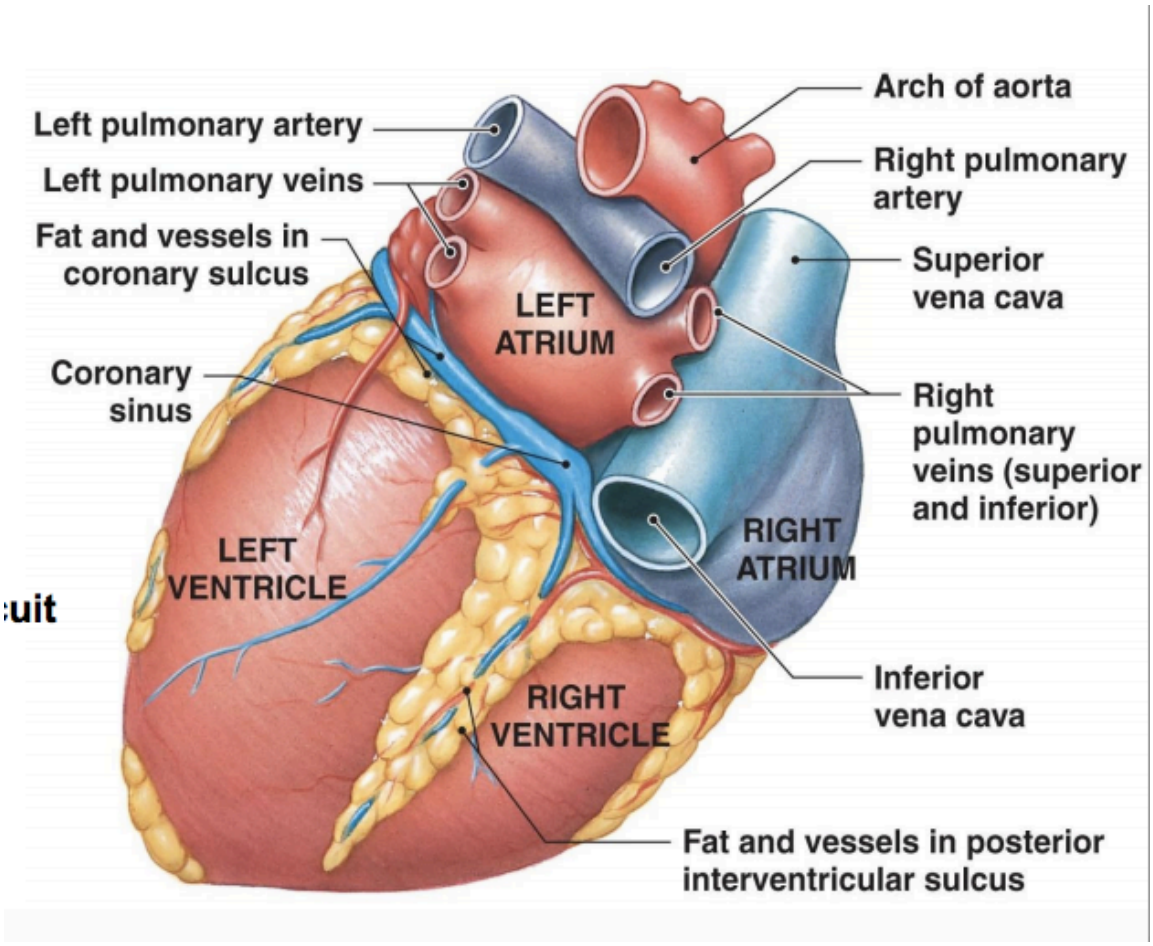
Location of the Heart
The Thoracic Cavity



Anatomy of the heart
Heart= pump
Closed circuit piping system= blood vessels
Fluid= blood
Factors that determine rate of flow throught a system

- Pressure is the driving force that pushes blood through the system
- Resistance
    - Length of tube (more length= more resistance)
    - Radius (big radius= more resistance)
    - Viscosity (large viscosity = more resistance)

Images and labeling (Know anterior vs. posterior side)


Left pulmonary artery
Left pulmonary veins
Fat and vessels in coronary sulcus
Coronary sinus
LEFT ATRIUM
LEFT VENTRICLE
RIGHT VENTRICLE
RIGHT ATRIUM
Arch of aorta
Right pulmonary artery
Superior vena cava
Right pulmonary veins (superior and inferior)
Inferior vena cava
Fat and vessels in posterior interventricular sulcus

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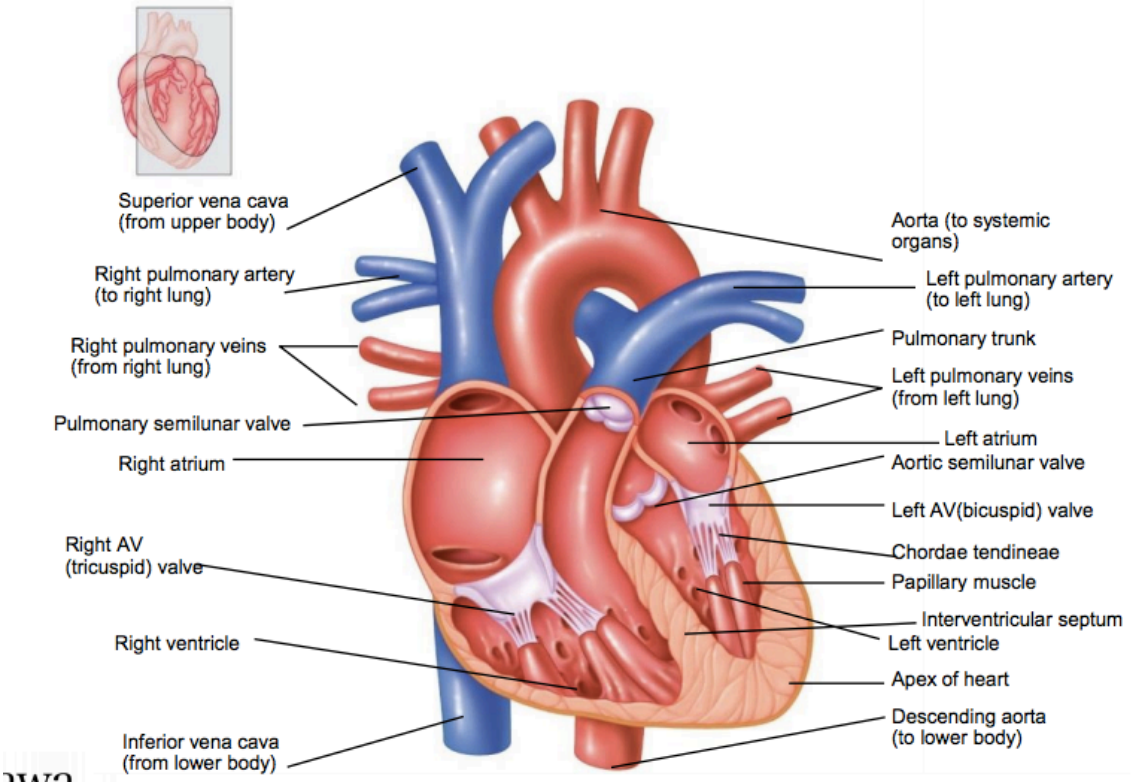
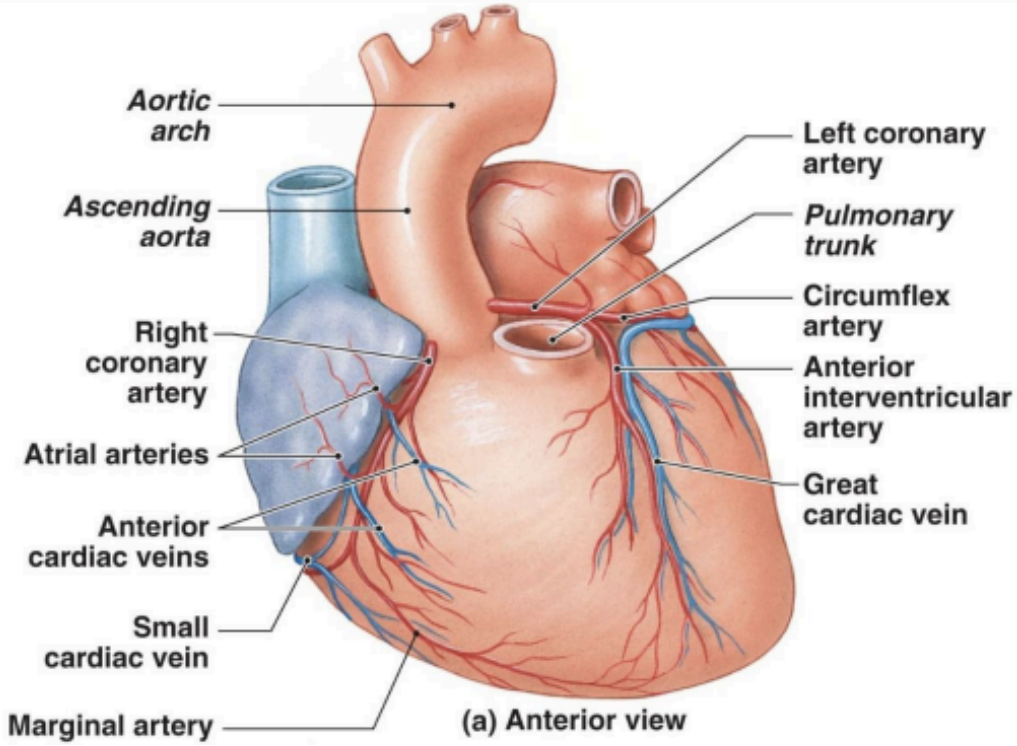




Functions of each part

Layers	
Pericardium Or Epicardium	• A membrane encovering the fluid-filled cavity called the pericardial in which the heart sits • Lubricates the heart and prevent friction between the ever beating heart and its surrounding organs
Myocardium	• The muscular middle layer of the heart wall that contains the cardiac muscle tissue. • Makes up the majority of the thickness and mass of the heart wall • Part of the heart responsible for pumping blood
Endocardium	• The simple squamous endothelium layer that lines the inside of the heart • Very smooth • Is responsible for keeping blood from sticking to the inside of the heart and forming potentially deadly blood clots
Cambers	
Right Atrium	• Deoxygenated blood enters the right atrium through three major veins: the superior and inferior vena cava and the coronary sinus. •
Right Ventricle	• Pumps the deoxygenated blood received from the right atrium into the lungs
Left Atrium	• Collects oxygenated blood from the pulmonary vein and fills the left ventricle
Left Ventricle	• Forces oxygenated blood from the left atrium to all other parts of the body against a great flow of resistance •
Valves	
Tricuspid	• Composed of three cusps • Permits blood to move from the right atrium into the right ventricle and prevents it from moving back the other way. •
Bicuspid	• Composed of two cusps • Permits blood to move from the left atrium into the left ventricle and prevents it from moving back the other way. •
Pulmonary Semilunar	• Made up of three leaflets or cusps • Located at the base of the pulmonary trunk. This valve opens when the right ventricle contracts • When the right ventricular muscles relax, blood starts back up the pulmonary trunk, causing the valve to close to prevent the flow from returning into the ventricular chamber.

	•
Aortic semilunar	• Aortic semilunar valve has three leaflets or cusps. It is located at the base of the aorta. It opens to allow blood to leave the left ventricle as it contracts. When the ventricular muscles relax, the valve closes to prevent blood from backing up into the ventricular chamber. •
Conducting system	
Senatorial (SA) node	• Small bundle of cells located in the wall of the right atrium inferior to the superior vena cava • Responsible for setting the pace of the heart as a whole and directly signals the atria to contract. • The signal from the SA node is picked up by another mass of conductive tissue known as the atrioventricular (AV) node.
atrioventricular (AV) node	• Located in the right atrium in the inferior portion of the interatrial septum • Picks up the signal sent by the SA node and transmits it through the atrioventricular (AV) bundle
Atrioventricular (AV) bundle	• a strand of conductive tissue that runs through the interatrial septum and into the interventricular septum. • splits into left and right branches in the interventricular septum and continues running through the septum until they reach the apex of the heart
Purkinje fibers	• carry the signal to the walls of the ventricles, stimulating the cardiac muscle cells to contract in a coordinated manner to efficiently pump blood out of the heart.

By-pass
- If someone has a heart attach place a side road so blood can pass around the clot and feed the heart

Septum
- Separates right and left heat

Subvalvar apparatus
- System to keep heart tight

There are no valves between the atria and the veins since
- The veins themselves have large valves, there for no valve is needed in this location

Hypertrophy

Hypertrophy
- Increased heart size and strength due to training

Hypertension
- Caused by high blood pressure, ventricle has to work harder to overcome the pressure, this increases the size of the heart too much and its harder for individual to contract efficiency

Hypertrophy In athletes (good)
- Increase of up to 60% in V-mass!
- Increase in performance

Hypertrophy in people with hypertension (bad)
- Increase of up to 150% in V-mass!!!
- No increase in performance

Effects of Training on the Heart
- Heart is a muscle, if heart is trained it has to work harder to pump blood to the body and becomes stronger and more efficient

Endurance training can cause an enlargement of the heart
- Increased thickness of the heart (hypertrophy of the heart muscle) allows for better contractility
- Larger atria and ventricles allow for a larger blood volume to be pumped out every heart beat (increased stroke volume)

Cardiac Muscle Cells

Conducting system
- Controls and coordinates heartbeat
- Located in AV bundle and pukije fibers

Contractile cells
- Produce contractions that propel blood
- Gap junction allows signal to travel 6 times as fast as normal contraction
- Need controlled and coordinated contractions

Intercalated discs
- Interconnect cardiac muscle cells
- Linked by gap junctions
- Convey force of contraction
- Propagate action potentials
- Conducting system

Pace making cells
- Cells that are self depolarizing
- Beat by its self without nervous system
- Located in SA not and AV node

Heart Rate

SA node
- Generates 80–100 action potentials per minute

AV node
- Generates 40–60 action potentials per minute

Regulated by
- Central nervous system innervation during normal rest and exercise

Athletes heart rate

- In rest an athletes heart rate is lower, heart is enlarged to accommodates for greater volume of blood in the heart, heart is more efficient and stronger, enlargement of ventricles and aritia= increase stroke volume

Heart rate may increase by stimulating the SA node pace maker cells

- The parasympathetic nervous system decreases heart rate, sympathetic increases.

Endocrine system also has an effect on HR

- Adrenaline

Intrinsic HR= 100 beats/minute

The Conducting System Step by Step

Step 1

- Depolarization of right atria SA node full of modified cardiac muscle cells created an action potential

Step 2

- Action potential generated at the SA node spreads to both atria by cell to cell contact
- Stimulus only affects the atria because they are isolated from the ventricles
- AP spreads fast enough that both atria contract at the same time

Step 3

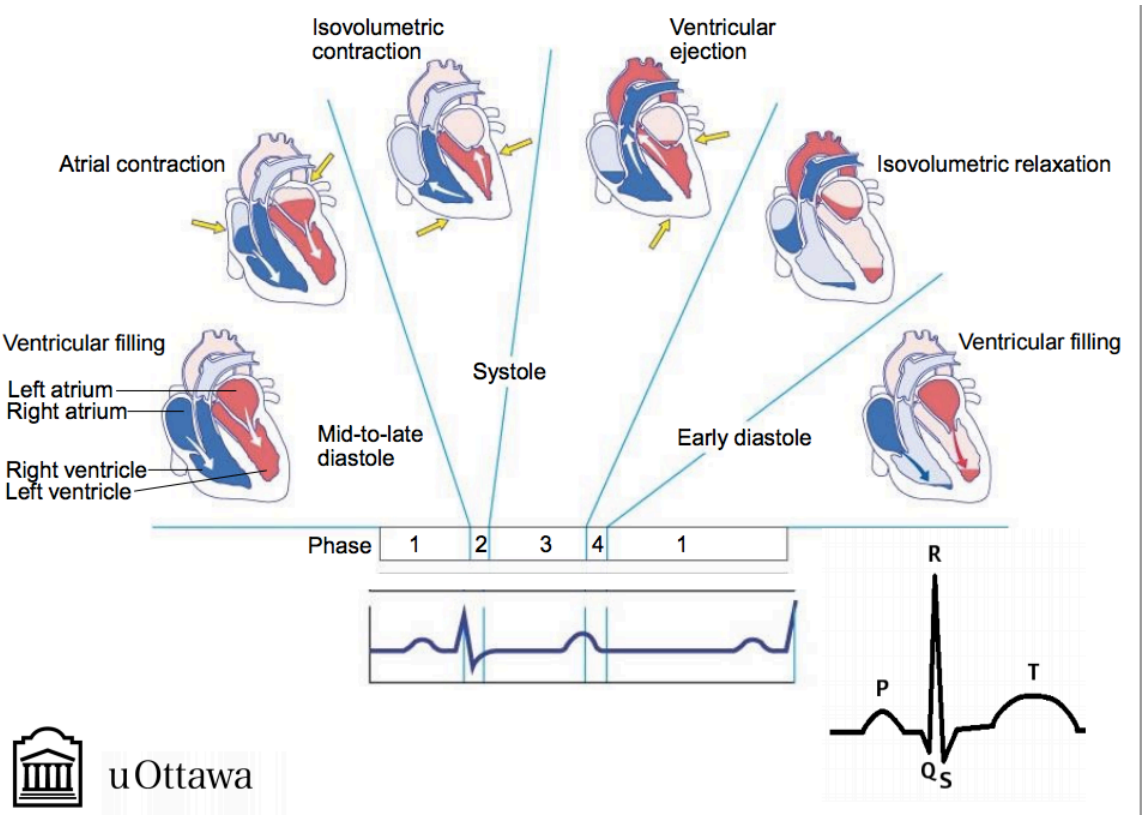
- Delay through the AV node is due to:
    - Nodal cells are smaller in diameter than the conducting cells
    - Connection between conducting and nodal cells is less efficient than between conducting cells
- Importance:
    - Allows sufficient time to the atria to contract before the ventricles do, which would close the AV valves

Step 4

- The impulse travels along the interventricular septum with the AV bundle and the bundle branches to the purkinje fibers and via the moderator band to the papillary muscles of the right ventricle

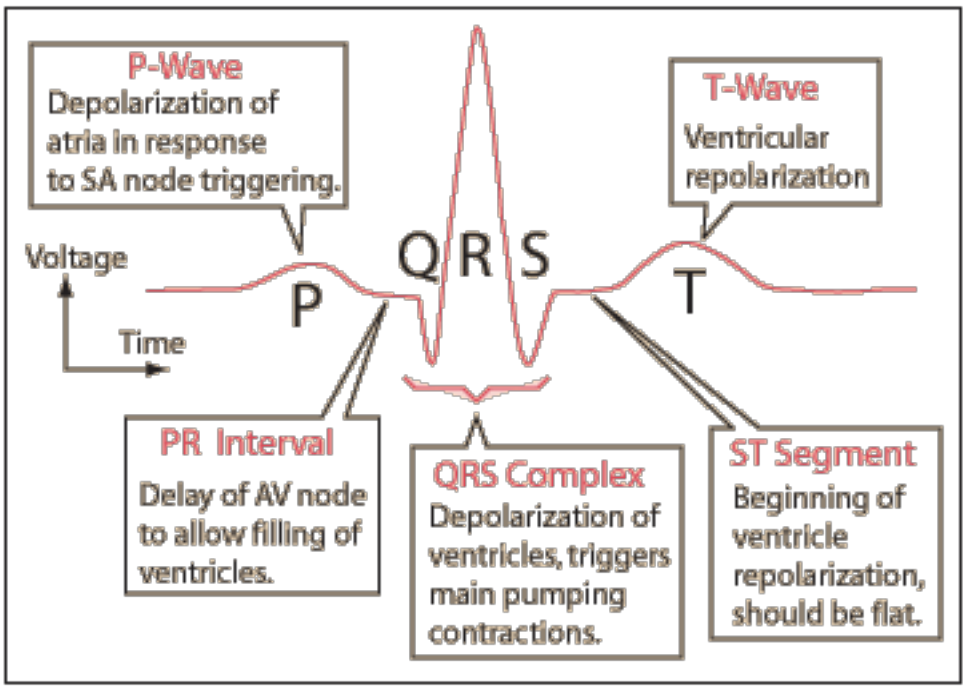
Step 5

- The impulse is distributed by purkindje fibers and relayed throughout the ventricular myocardium
- Atrial contraction is completed and ventricular contraction begins



ECG

- Electro cardiogram can pick up signal of contraction of the heart muscle



Cardio dynamics

Variables

Stoke volume (SV)	Volume of blood being pushed out of the heart in one beat
Ejection faction (EF)	Stroke volume as percentage or fraction
Cardiac output (Q)	Volume of blood being pushed out per minute
Heart Rate (HR)	Beats per amount of time
Blood pressure (BP) expressed as mean arterial Pressure (MAP)	

Equations

- Cardiac output

$$Q\ (mL/min) = HR\ (beats/min) \times \text{Stroke Volume}\ (mL/beat)$$

  - If not specified choose a reasonable resting heart rate (around 80)

- Max Heart Rate

$$HR_{max} = 220 - age$$

- Flow

Flow **α** Driving force / resistance

F **α** D/R

$$F = (P_2 - P_1)\ \pi\ r^4 / 8\ L\ \mu$$

F= change in pressure π **(**radius)^4/8 (length) (viscosity)

Pressure difference increases so does driving force

- Blood pressure

MAP= DP [(SP – DP)/3]

3.2 Energy Metabolism

Adenine Triphosphate (ATP)

- The chemical form of energy storage

Energy contained in food

- The energy the human body uses is derived from the breakdown of carbohydrates, fats and proteins

  Food + O2 → H2O + CO2 + heat

- Food molecular bonds are weak and when they break they release a little energy
- The chemical energy from food is used to convert adenosine diphosphate (ADP) to adenosine triphosphate (ATP)

  ADP + heat + P → ATP + H2O

- ATP is the energy currency and energy reserve of t he cell

The unit of energy is calorie

- 1000 calories = 1 kcal
- The energy on food labels is measured in kcals
- 1 calorie= heat required to raise the temperature of 1 gram of water by 1 degree
- 1 kcal=4.19 kJ

Glucose	$C_6H_{12}O_6$	4.1 kcal/g
Palmitic acid	$C_{16}H_{32}O_2$	9.4 kcal/g
Protein		4.1 kcal/g
Alcohol		7 kcal/g

Energy in macromolecules

- Carbohydrates and proteins 4 kcal/g
- Fats 9 kcal/g
- Can use these values to calculate the total kcal in foods given the amounts of each of the macromolecules

Adenosine triphosphate is used for

- Na+ / K+ ATPase (sodium-potassium pump)
- Synthesis other molecules such as DNA and RNA
- Transport of macromolecules
- Enzymatic reaction
- Muscle contraction

Exercise

3 types of Athletic Activities

- Power
- Speed
- Endurance

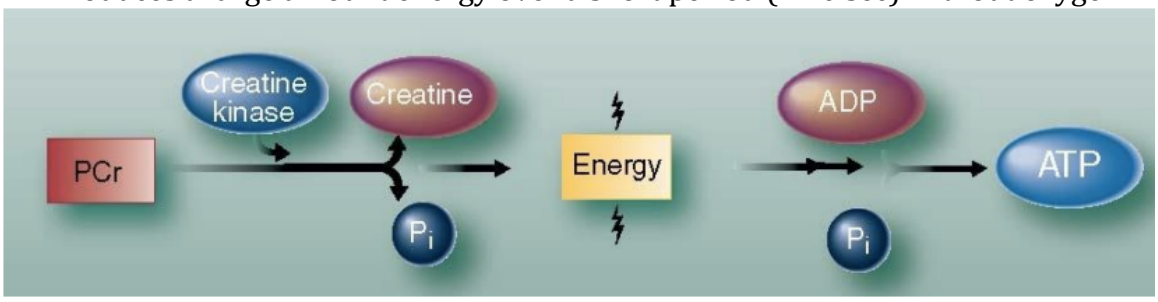
Bioenergetics

- Chemical processes that break down food substrates to produce ATP

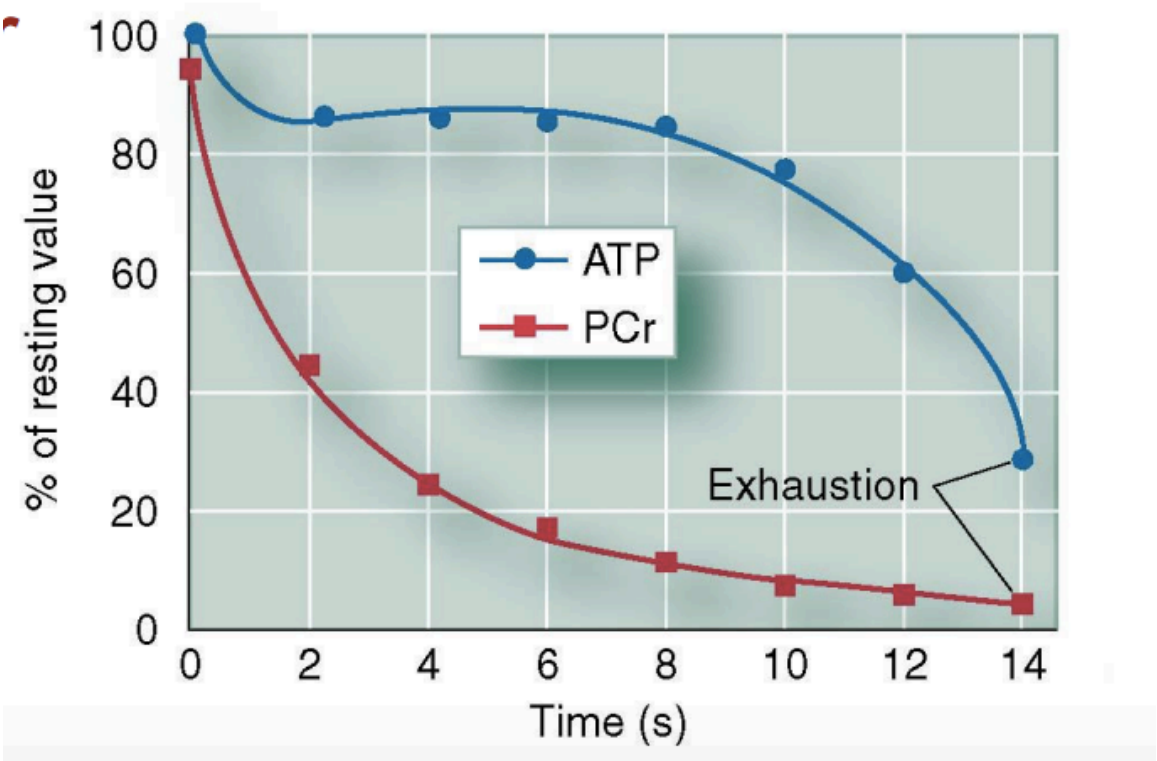
Three systems that produce ATP

ATP-Phosphocreatine System

- Produces a large amount energy over a short period (± 10 sec) without oxygen



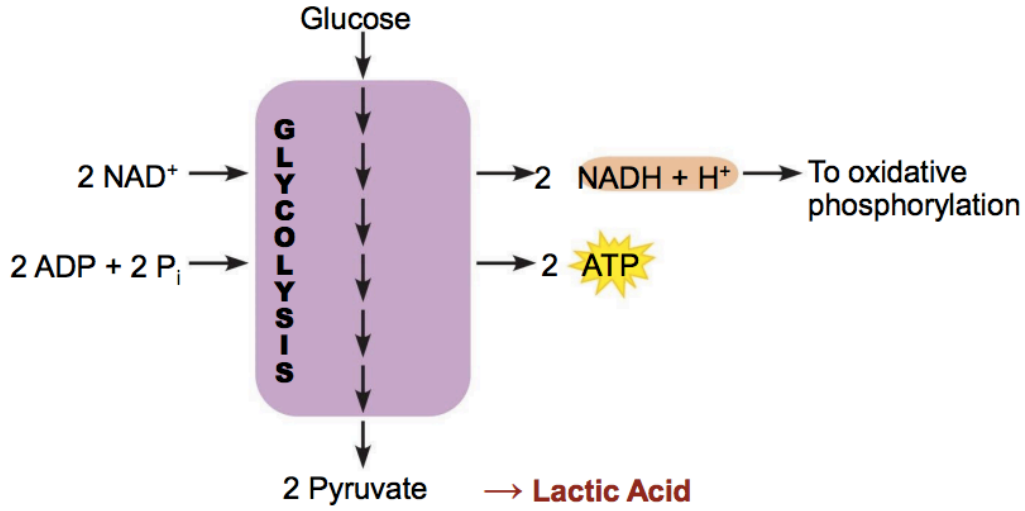
- Two main sources:
  - ATP in the muscle fibers (cytosol)
  - Creatine phosphate (CP) a.k.a. phosphocreatine (PCr) in the same muscle fibers (cytosol)
- Although ATP is being used at a very high rate, the energy from PCr is used to resynthesize ATP, preventing the ATP level from decreasing. At exhaustion, both ATP and PCr concentrations are low.



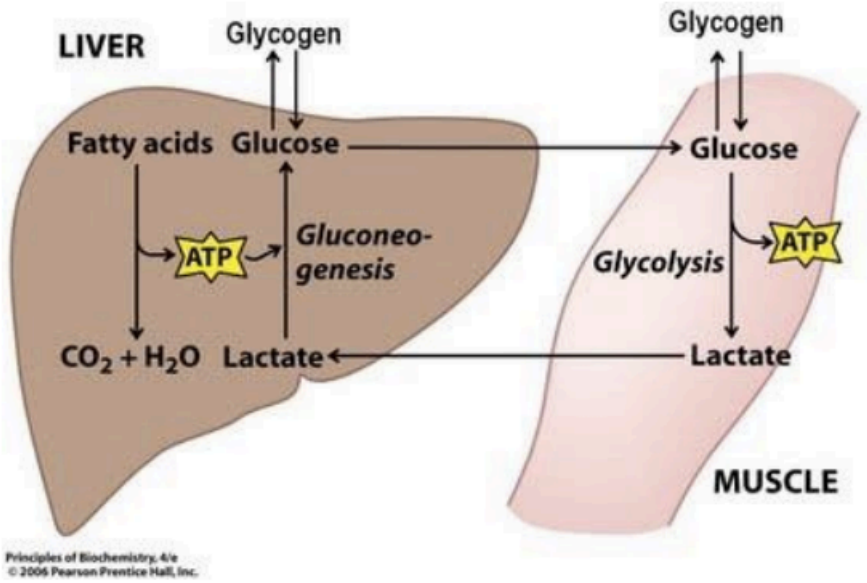
Glycolytic System

- Formation of ATP from glucose or glycogen via glycolysis (without oxygen)
- 1 molecule of glucose produces 2 ATP
- 1 molecule of glycogen produces 3 ATP
- At very high intensity, the final product of glycolysis is lactic acid
- Mostly used during very high intensities that last from 15 s to 2 min
- Fuel:
    - Blood Glucose
    - Muscular and liver glycogen
- Glycolysis
    - Process by which a glucose molecule is broken down without oxygen into pyruvate, by specific enzymes.

$$\text{Glucose} + 2NAD^+ + ADP + 2P_i \rightarrow 2 \text{ pyruvate} + 2 NADH + 2 H^+ + 2 ATP$$



- Lactic acid builds up if the intensity remains high
  - Increase acidity (decrease in pH)
  - Alters enzymatic function of glycolysis
  - Inhibits the breakdown of glycogen
  - Discomfort and burning sensation in the muscles
  - The body is unable to sustain the effort
- Lactic Acid Lactic Acid vs. Lactate
  - Lactic Acid = Acid (C3H6O3)
  - Lactate = lactate salt
  - When lactic acid releases H+ ion, the residue is combined with Na+ or K+ to form a salt
- Lactic acid removal
  - During cool-down lactic acid is converted into glucose by the liver (Cori cycle) and can be used again in glycolysis to produce energy



- Effect of training the glycolytic system
    - The rate of lactic acid accumulation decreases in a trained subject working at the same effort
        - Production rate of lactic acid decreases and effectiveness of aerobic system increases
        - Elimination rate of lactic acid increases muscle blood flow increases and the ability to metabolize lactate by the heart, liver and muscle fires is increased

Transition between the glycolysis and oxidative system

- Oxidative phosphorylation
- Krebs cycle
- Electron Transport Chain

Oxidative system

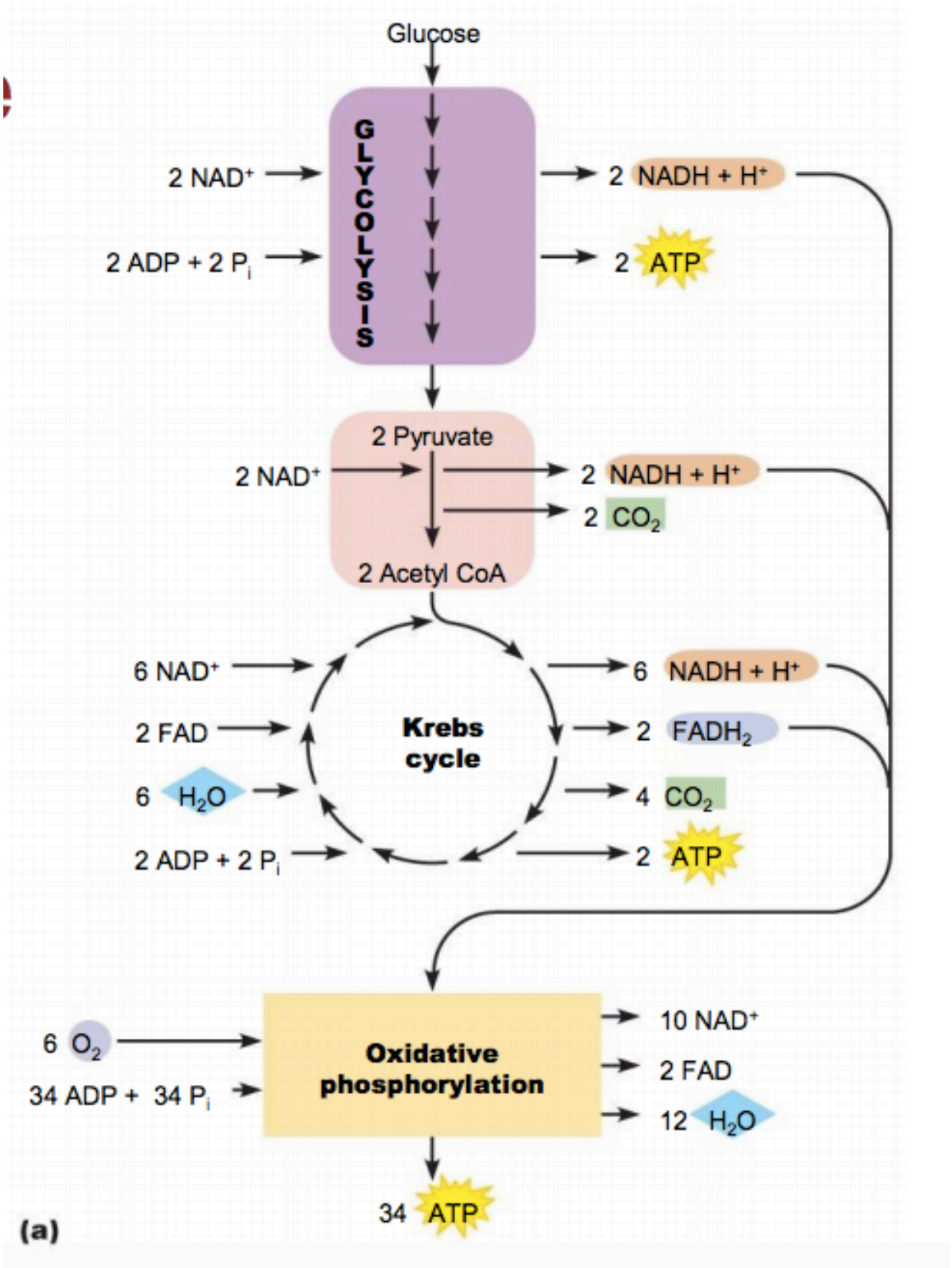
- The most important energy system of the human body
- For activity lasting from over 2 min to 2-4 h
- For mild to moderate intensity
- Breakdown of fuel in the mitochondria by oxidative phosphorylation
- Uses oxygen to produce ATP
- Fuel Types:
    - Blood glucose
    - Muscle and liver glycogen
    - Intramuscular and subcutaneous triglycerides
    - Proteins
- Effects of trains on oxidative system
    - Endurance training leads to:
        - Increased vascularity within the muscle
        - Increase in number and size of mitochondria in the muscle fibers.
        - Increased activity of enzymes (i.e., Krebs cycle)

        - Preferential use of fat over glycogen during exercise
        - Endurance training increases maximal aerobic power of a sedentary person by 15-25%
    - An elderly person can improve aerobic power but the adaptation will be slower

Summary Glucose Oxidation

- Anaerobic
    - Glycolysis:
    - Glucose = 2 ATP
    - Krebs Cycle = 2 ATP
- Aerobic
    - An additional 34 ATP!!
    - Total: 38 ATP per 1 molecule glucose

• PCr = 1 ATP per molecule
• Glycolysis: Glycogen = 3 ATP



Only a percentage of the energy is concerted to ATP the rest is lost in the form of heat

Ex: Energy calculation

Given: $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + \text{Energy (686 kcal)}$
Calculate: 60% of energy converted to heat
Solution:

1) Convert energy to mol from kcal

   686kcal ÷ 7 kcal/mol = 98 mol

2) Divide useable ATP by Total ATP

   38 mol ÷ 98 mol × 100% = 39% of ATP produced is usable

   100% - 39% = 61% of ATP converted to heat

Summary of the 3 Energy systems

- Phosphagen System
  - ≈ 180 ATP roughly available
  - ≈ 840 ATP by the ATP-CP system

Small reservoir

High flow rate

- Non-oxydative System
  - 1 molecule of glucose = 2 ATP

Medium reservoir

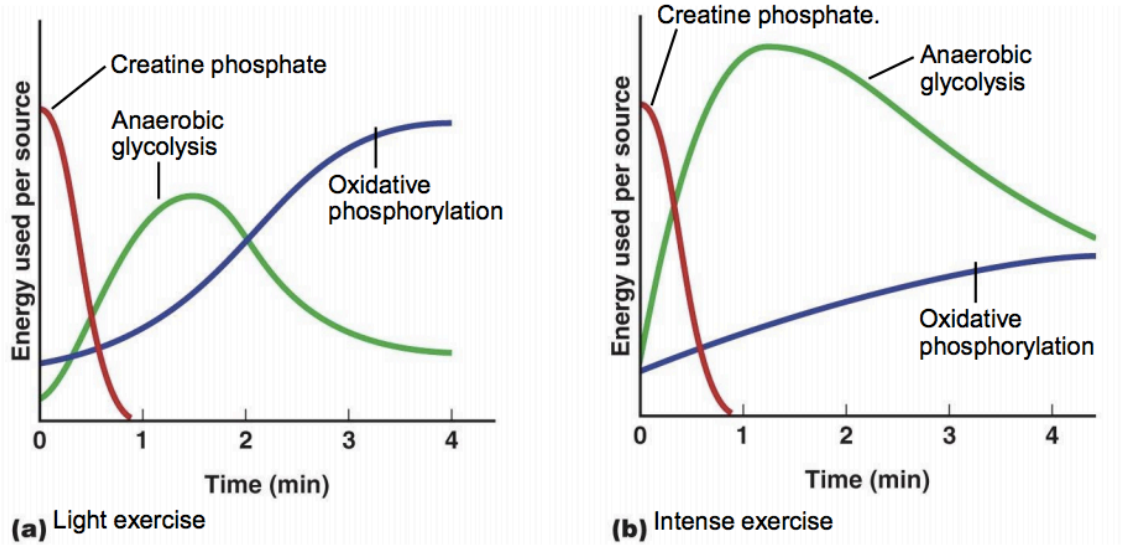
Medium flow rate

- Oxydative System
  - The system produces ATP by demand
  - (great potential)

Big reservoir

Low flow rate

Energy Sources of Skeletal Muscle during Light and Heavy Exercise



Metabolism

- The sum of all chemical reactions that occur in the body

Basal Metabolism

- The minimum amount of energy needed to sustain life functions during the day
- Ranges from 1,100 to 2,500 kcal/day
- 60% of total energy expenditure
- Typically 5% to 10% lower in women.
    - Women have more body fat than men in general.
    - Adipose tissue is metabolically less active than muscle tissue.

Factors that influence metabolism

- Cold
- Heat
- Altitude
- Pregnancy
- Nursing

Thermic Effect of Food

- Energy required for digestion, absorption and processing food
- 10% of the total energy expenditure

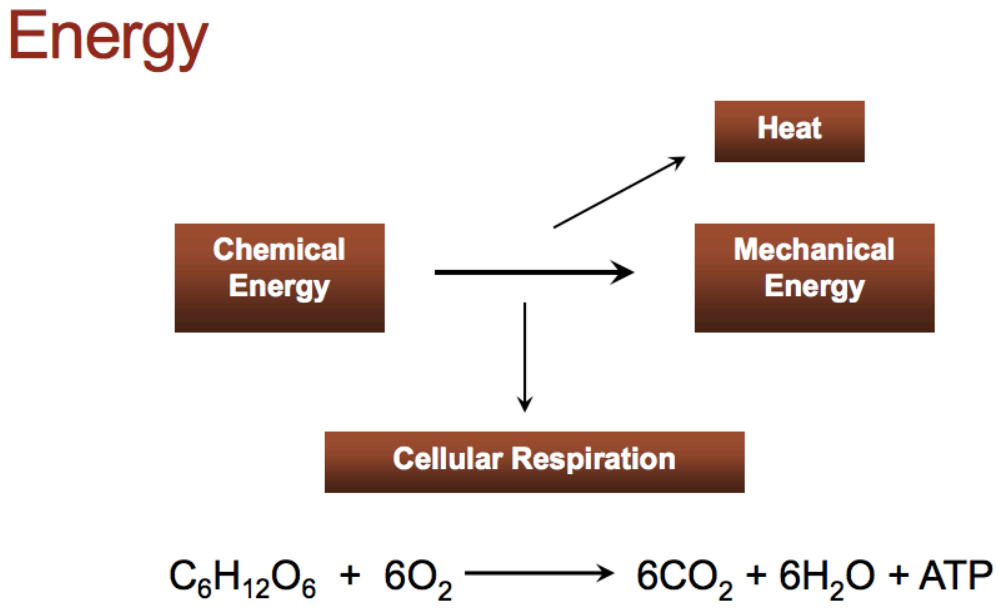
Exercise

- Structured exercise (power, strength or endurance)
- Non structured physical activity (walking, gardening, lifting groceries)

Energy

The law of Energy Conservation

- Energy can not be created or destroyed
- Energy can only be converted from one type to another



Methods of Measuring Metabolism

Calorimeter

- Uses direct measurement of body heat dissipation
- Sealed and fully insulated room. The walls contain copper pipes in which water circulates. The temperature of the water and air that enters and leaves the room is measured.

O_2 consumption

- Energy consumption is estimated using gas analysis
- Measuring oxygen and carbon dioxide
- Measures energy expenditure by measuring O2 consumption
- Assumes ~ 5 KCal / 1 L O2 consumed (depends on RER)
- Much more commonly reported in O2 values

Respiration Exchange Ratio (RER)

- The ratio between volume of CO2 released (VCO2) and the volume of oxygen consumed (VO2)
- The RER value at rest is usually 0.78 to 0.80

$$RER = \frac{VCO_2}{VO_2}$$

RER: Determining Substrate Utilization

- Carbohydrate

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + 38ATP$$

$$RER = \frac{6 \text{ mol of } CO_2}{6 \text{ mol of } O_2}$$

RET= 1.0

- Fat

$$C_{16}H_{32}O_2 + 23O_2 \rightarrow 16H_2O + 16CO_2 + 129ATP$$

$$RER = \frac{16 \text{ mol of } CO_2}{23 \text{ mol of } O_2}$$

RET= 0.70

Summary: Energy Metabolism

- Adenosine Triphosphate (ATP) is the energy exchange currency for the body to use and store.
- ATP is used for cellular processes and physical activity
- We can produce ATP using food as fuel
- There are 3 systems by which ATP can be produced; the type of exercise dictates which system will contribute the most amount of ATP to the working muscles.

- Total energy expenditure is composed of resting metabolism, thermal effect of food and physical activity.
- Energy expenditure can be measured directly or indirectly
- The indirect measure is measuring oxygen consumption and is mostly used in exercise physiology.