BML 300: INTRODUCTION TO HEALTHCARE ENGINEERING

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What is Biomechanics?

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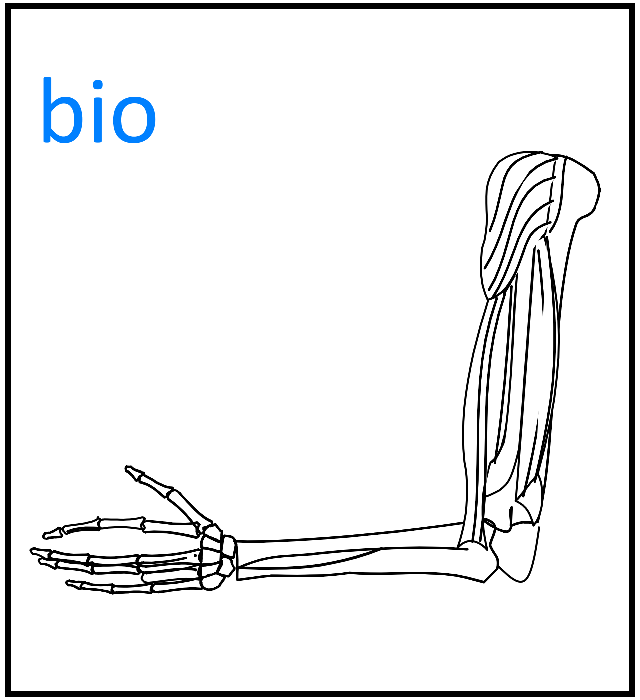
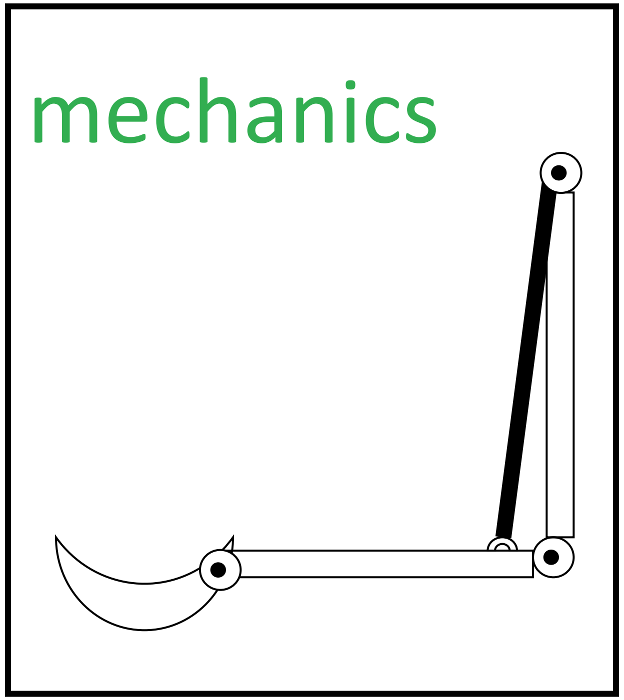




The term *biomechanics* combines the prefix *bio*, meaning "life," with the field of *mechanics*, which is the study of the actions of forces, (both internal muscle forces and external forces.) In biomechanics we analyze the mechanical aspects of living organisms.

Sub-branches of **biomechanics**:

- **statics**: study of systems in constant motion, (including zero motion)
- **dynamics**: study of systems subject to acceleration
- **kinematics**: study of the appearance or description of motion
- **kinetics**: study of the actions of forces (Force can be thought of as a push or pull acting on a body.)

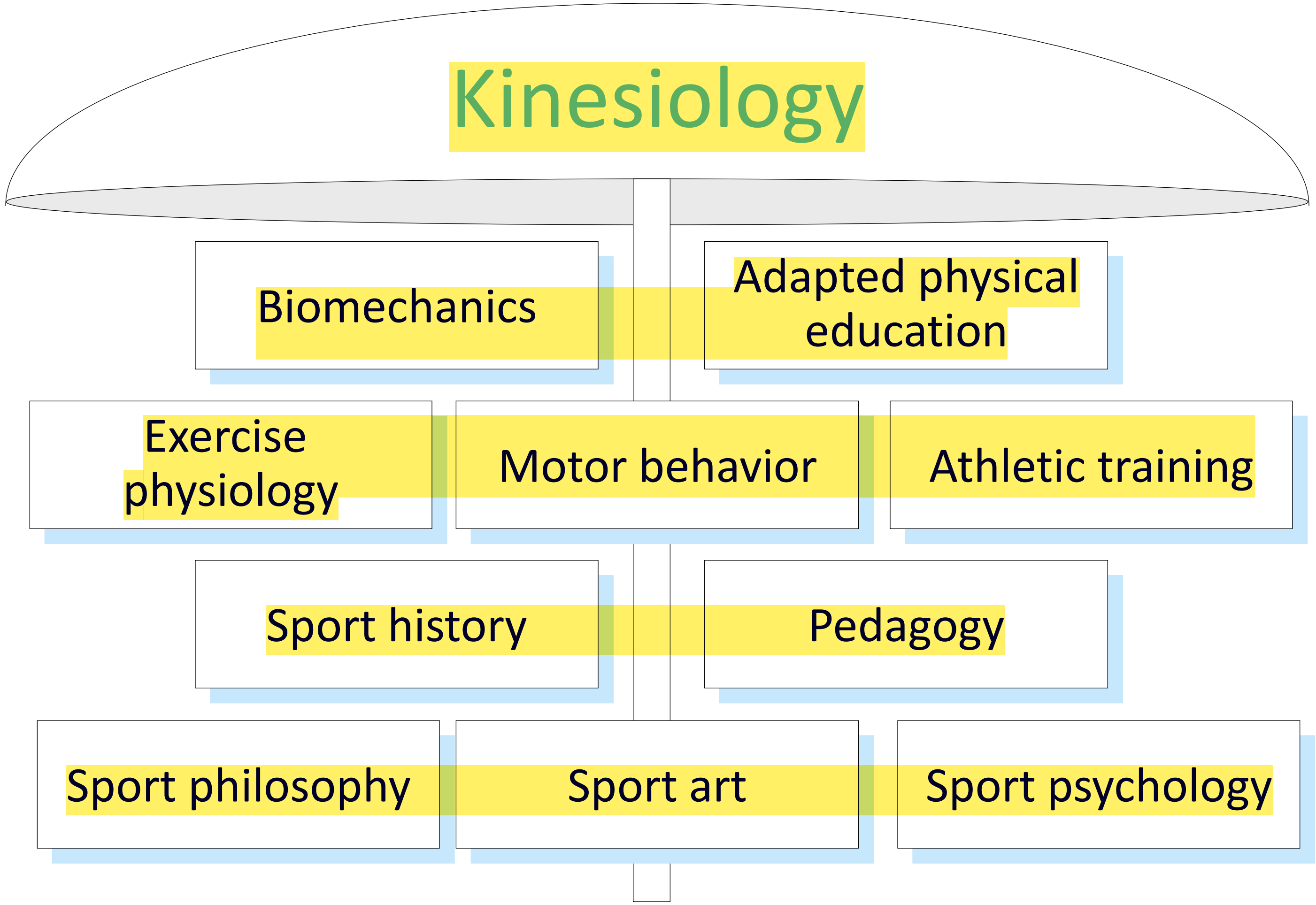
What is kinematics?

What we visually observe of a body in motion is called the kinematics of the movement. Kinematics is the study of the size, sequencing, and timing of movement, without regard for the forces that cause or result from the motion. The kinematics of an exercise or a sport skill is known, more commonly, as form or technique.

What is kinetics?

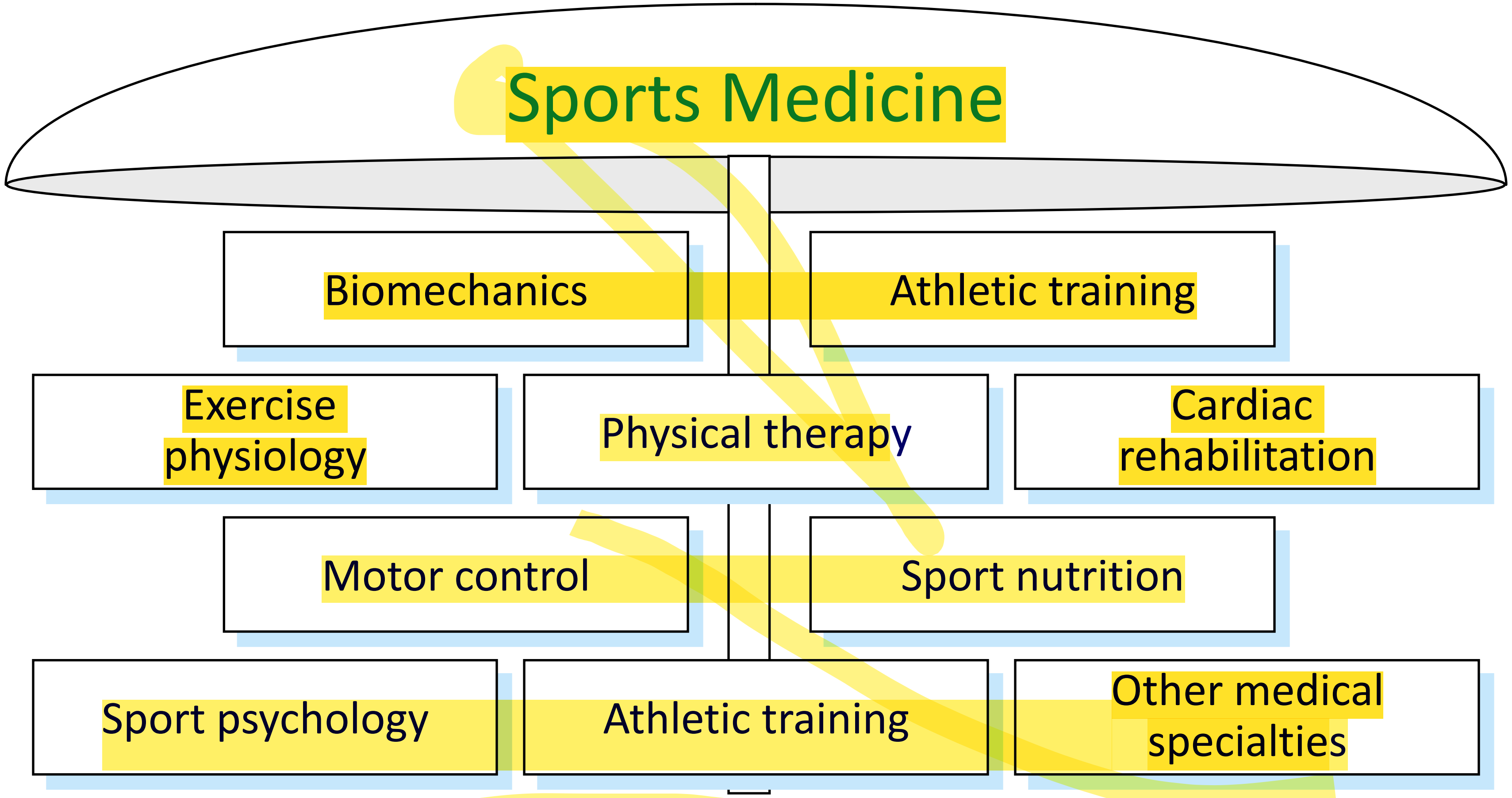
Kinetics is the study of forces, including internal forces (muscle forces) and external forces (the forces of gravity and the forces exchanged by bat and ball).

What is kinesiology?



Kinesiology is the study of human movement.

What is sports medicine?



Sports medicine is an umbrella term that encompasses both clinical and scientific aspects of exercise and sport.

What questions or problems are studied by biomechanists?

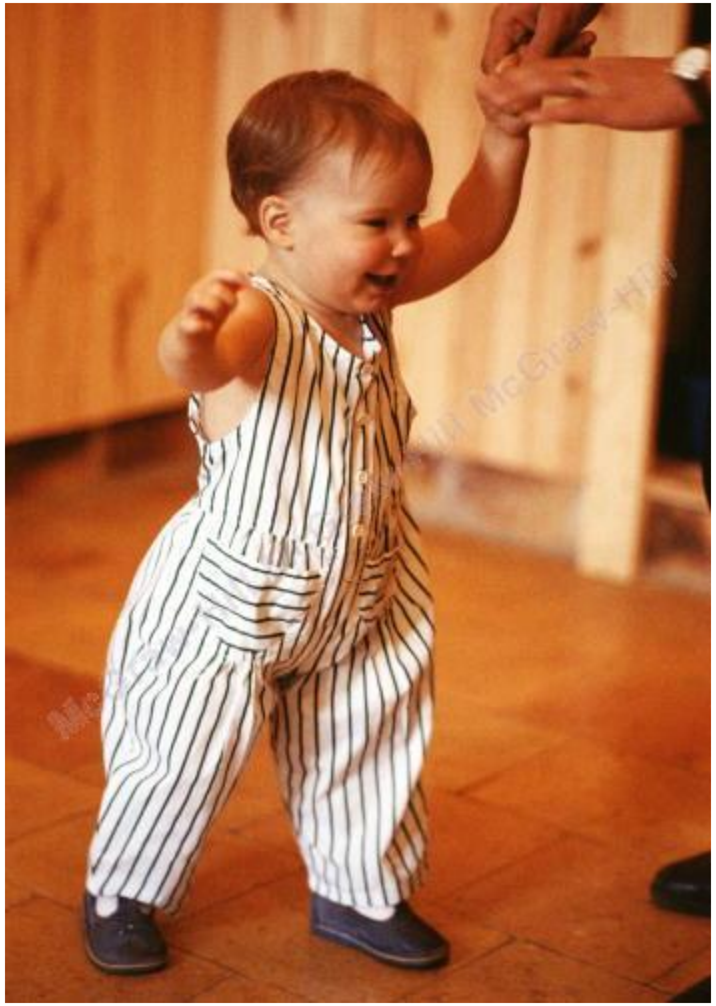
What questions are studied by biomechanists?

When not subject to gravitational force, astronauts lose significant amounts of bone mass. (Bone atrophies when not subjected to forces.) Exercise, however, is known to increase bone mass. So what kinds of exercise should astronauts do while in space in order to preserve as much bone as possible?

What questions are studied by biomechanists?

Whether lifting weights or lifting boxes in industry, the act of lifting places major mechanical stress on the low back. What lifting kinematics (techniques) can minimize this stress?

What questions are studied by biomechanists?



How do toddlers learn to balance their torsos on little legs unaccustomed to walking? (This question spans the fields of biomechanics, motor learning, and motor development.)

What questions are studied by biomechanists?

Pitching can lead to stress injuries of the elbow and shoulder joints. What pitching technique characteristics minimize the mechanical stresses to these joints?

What questions are studied by biomechanists?

Recreational runners, as well as athletes in many sports, often stretch before a work out. Does this actually help or hinder performance? (Increasing evidence suggests the latter…)

What questions are studied by biomechanists?

What biomechanical elements of running technique enable some sprinters to dominate over others who are just as well trained and have just as strong physiological attributes?

Qualitative vs. Quantitative:

- **qualitative**: pertaining to quality (without the use of numbers)

For example: strong, skillful, agile, flexible, fast

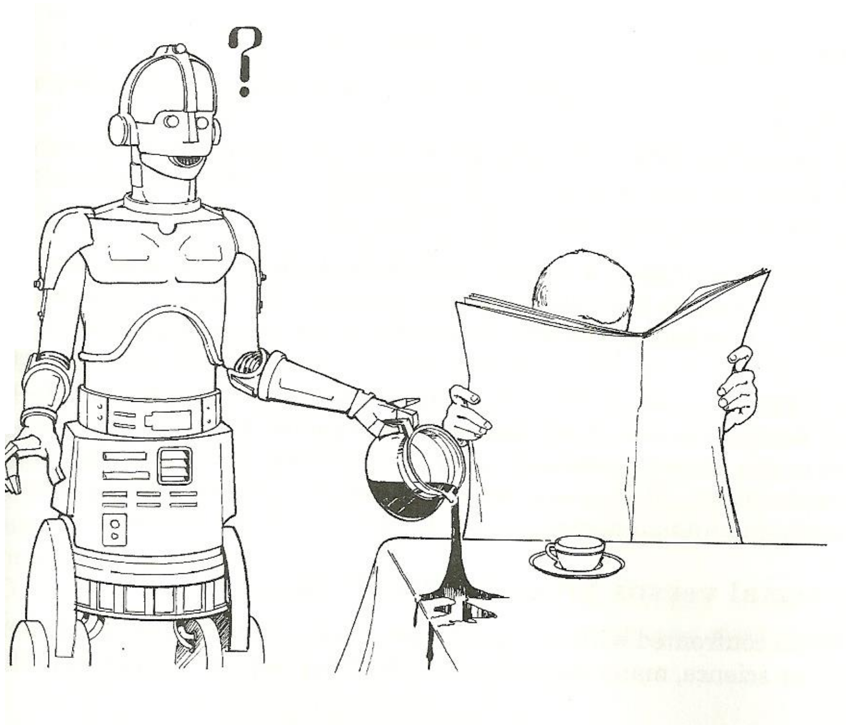
- **quantitative**: involving numbers

For example: running speed = 5 m/s

height = 1.75 m

mass = 68.2 kg

Qualitative vs. Quantitative:



Quantitatively, the robot missed the coffee cup by 15 cm.
Qualitatively, he malfunctioned.

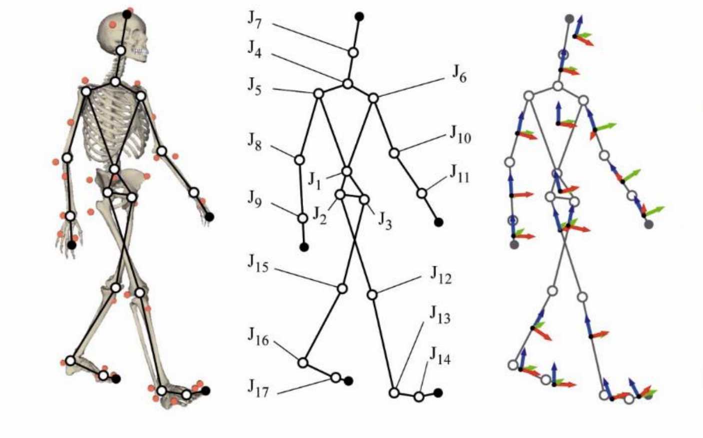
Qualitative vs. Quantitative:

Coaches rely heavily on qualitative observations of athletes' performances in formulating advice about technique.

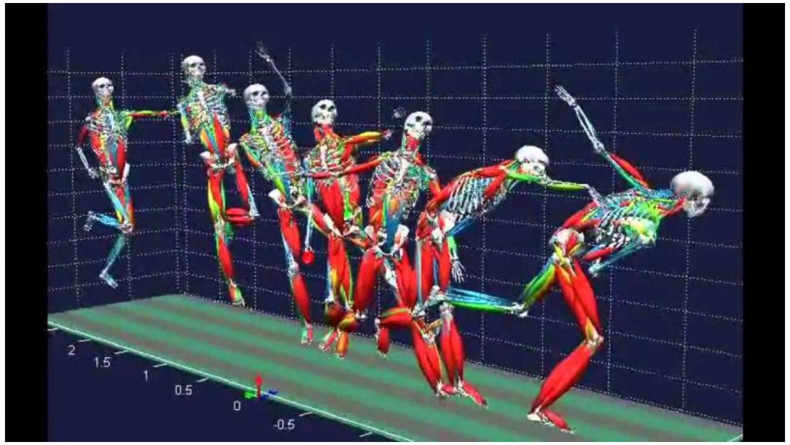
Introduction to Biomechanics

Biomechanics:

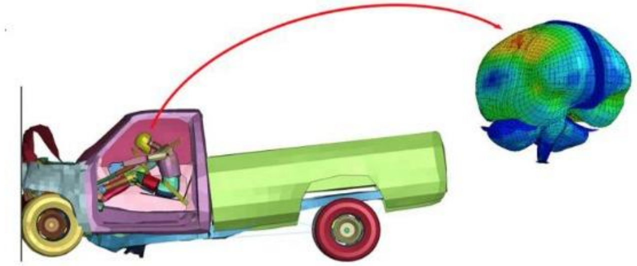
- Study of movement of living body (including bones, tissues, and organs)
- The **math** behind injury and tissue related disease-Doctors cannot tell this!



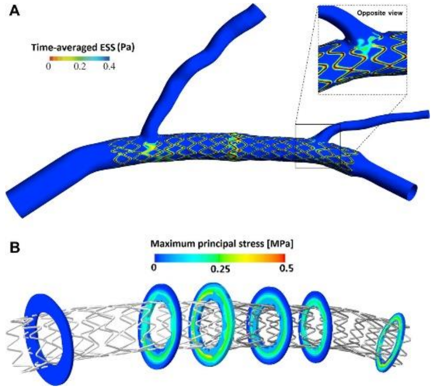
Gait Biomechanics



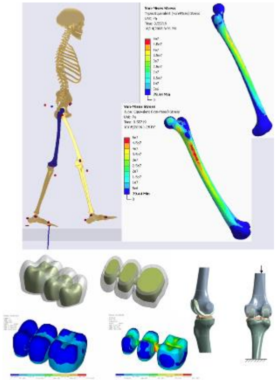
Sports Biomechanics



Injury Biomechanics



Cardiovascular Biomechanics

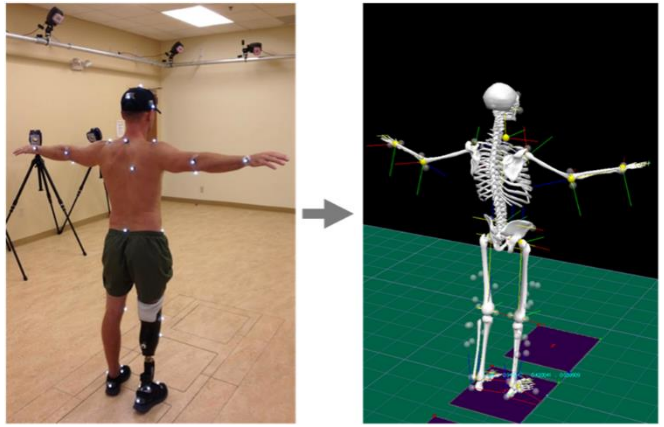


Orthopedic Biomechanics

Experimental Biomechanics

Limited by biosafety and ethics:

Cadaveric Tissue Experiments



Experimental Gait Analysis

Exercise Testing

Can we study these experimentally?

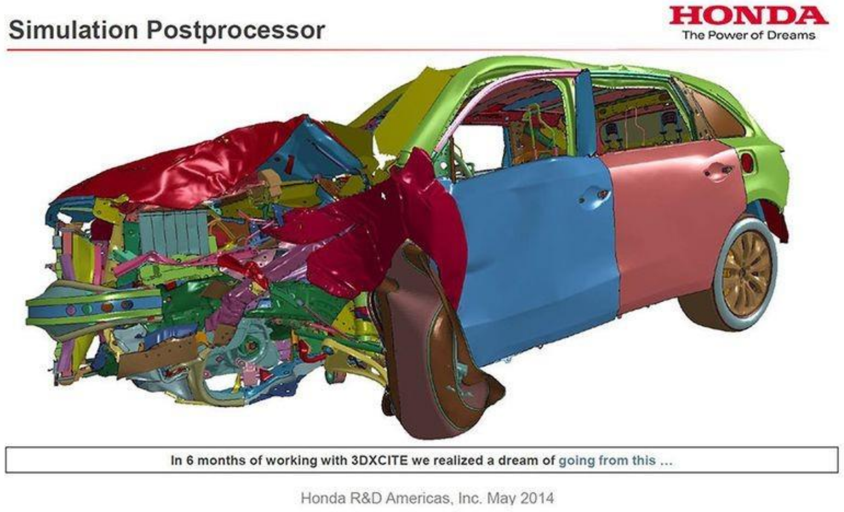
Blast Injury

Slips and Falls

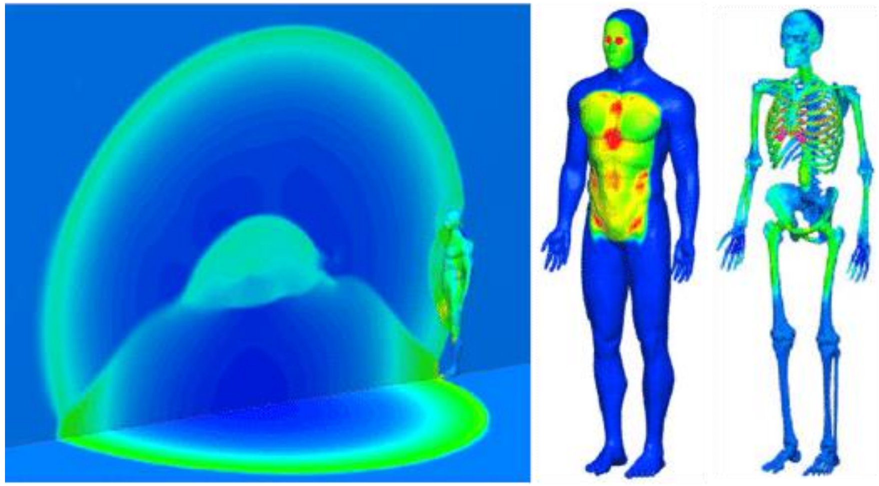
Armor Testing

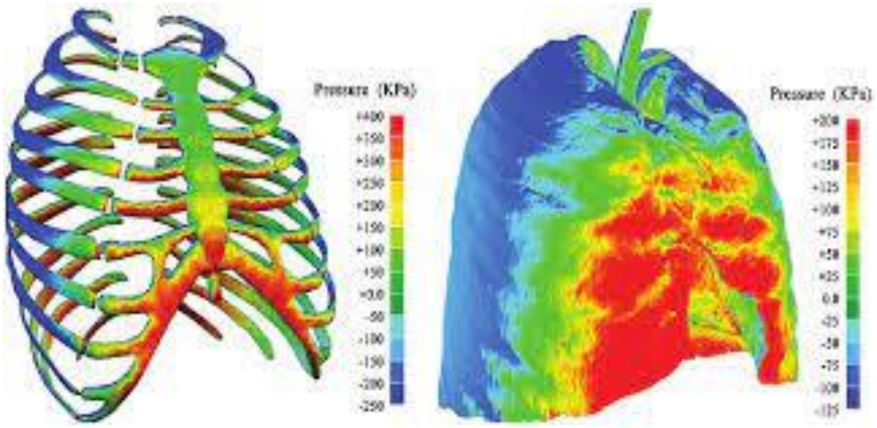
Finite Element Modeling (FEM)

Allows us to simulate complex scenarios



Vehicular Crash Testing

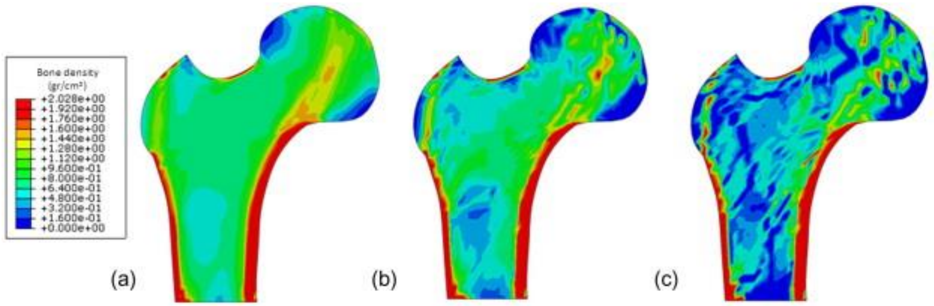




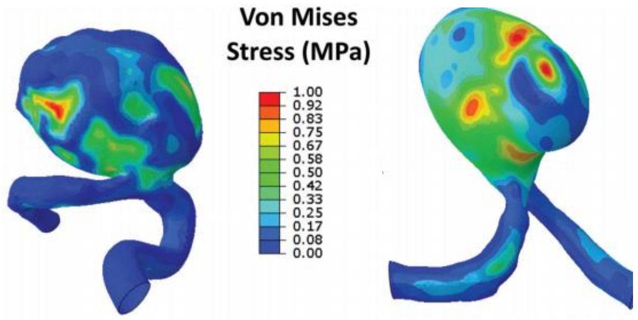
Organ Damage due to IED Blast

Disease Biomechanics

Allows us to study disease progressions and forms

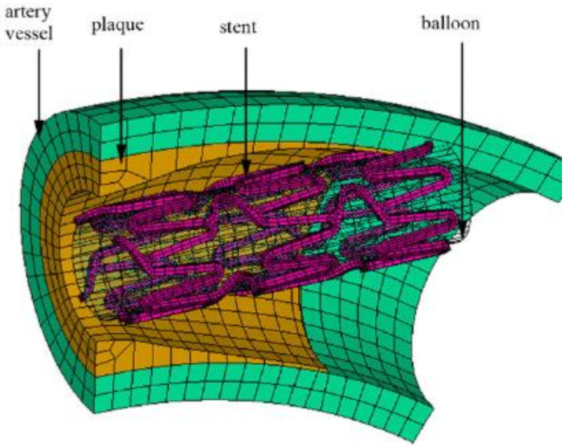


Stress Distribution-Varying degrees of Osteoporosis

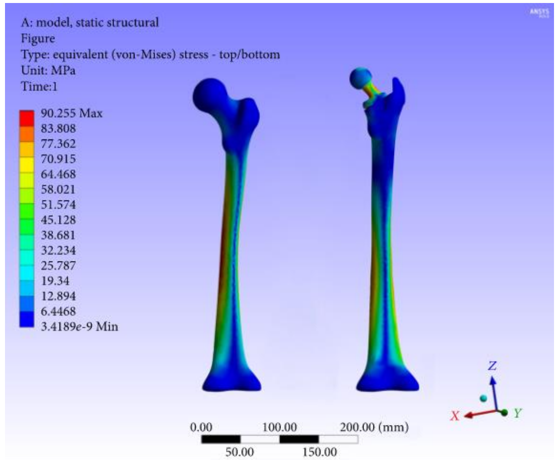


Stress Distribution-Varying Aneurysm Forms

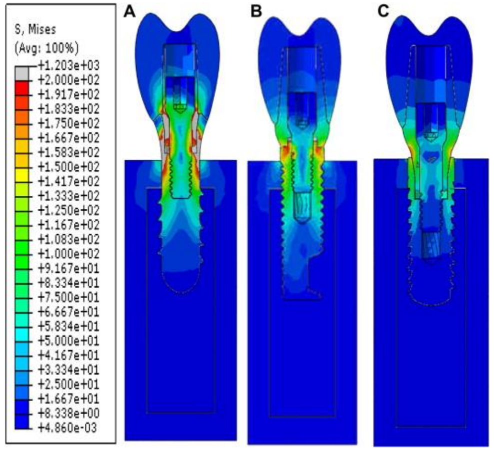
Also can test interventions and medical devices



Arterial Stent Implantation

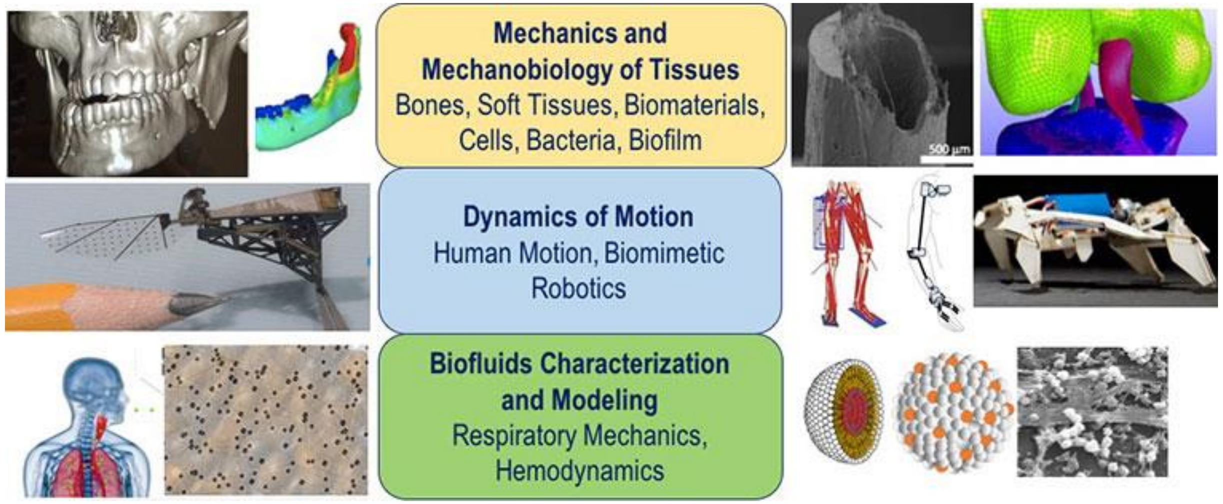


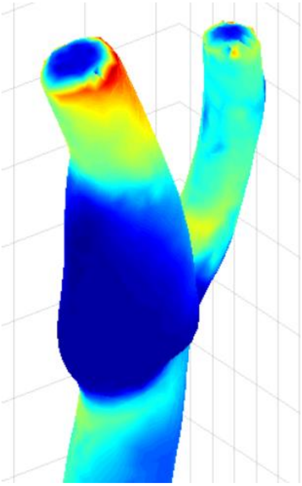
Hip Implant Testing

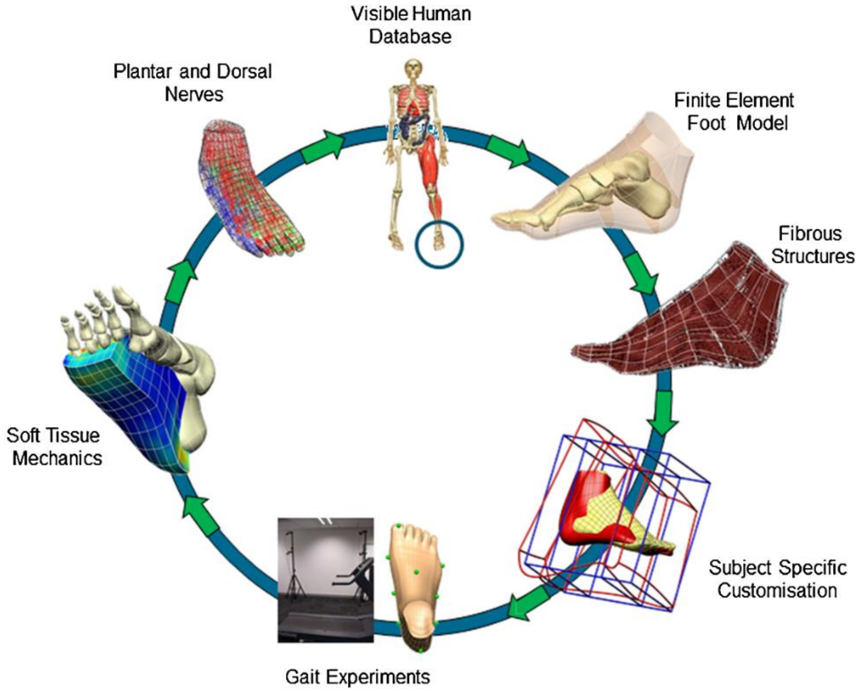


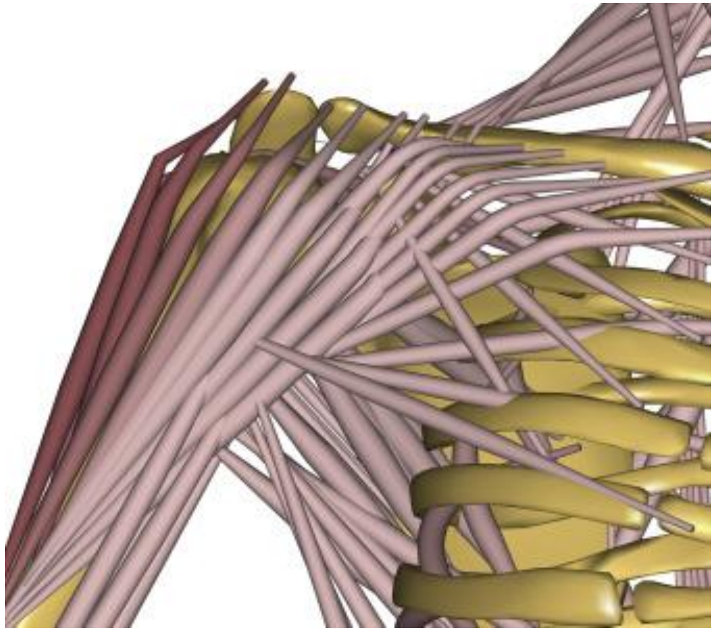
Stress-Commercial Dental Implants

INTRODUCTION: Why Biomechanics?

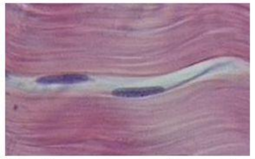






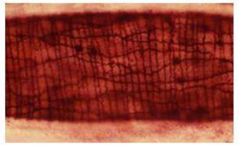


WHY STUDY SOFT TISSUE MECHANICS?

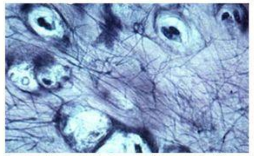


Tendon

http://www.gwc.maricopa.edu/class/bio201/histo



Blood Vessel

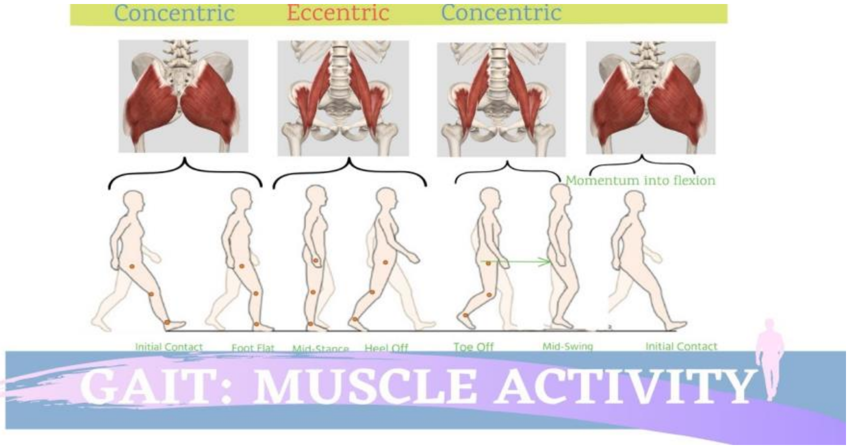


Elastic Cartilage

http://www.lumen.luc.edu/lumen

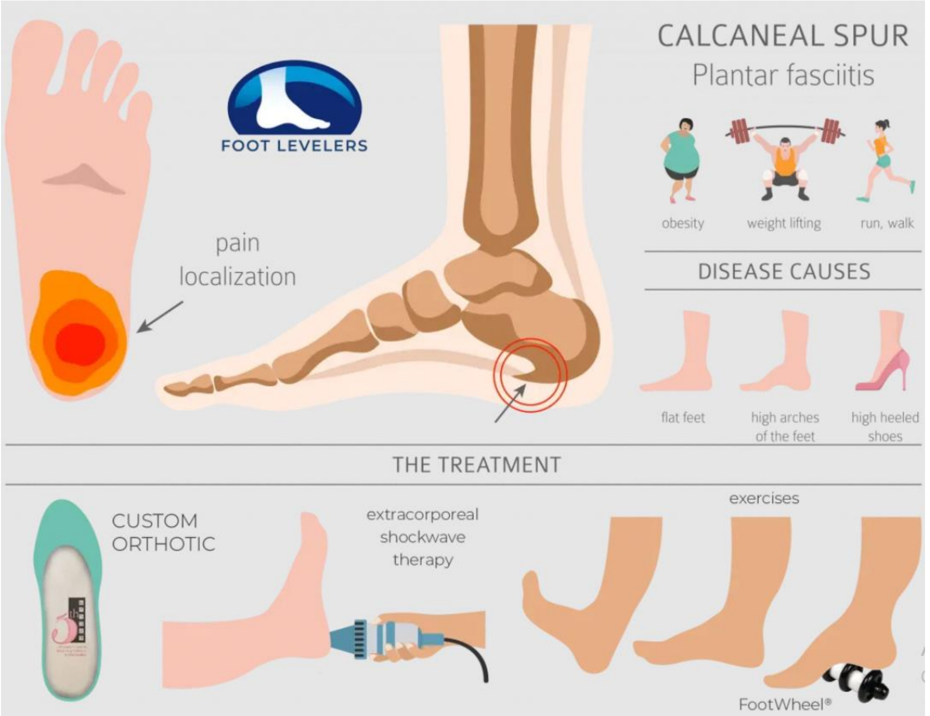
MANY BIOLOGICAL TISSUES HAVE EVOLVED TO PERFORM SPECIFIC MECHANICAL FUNCTIONS.

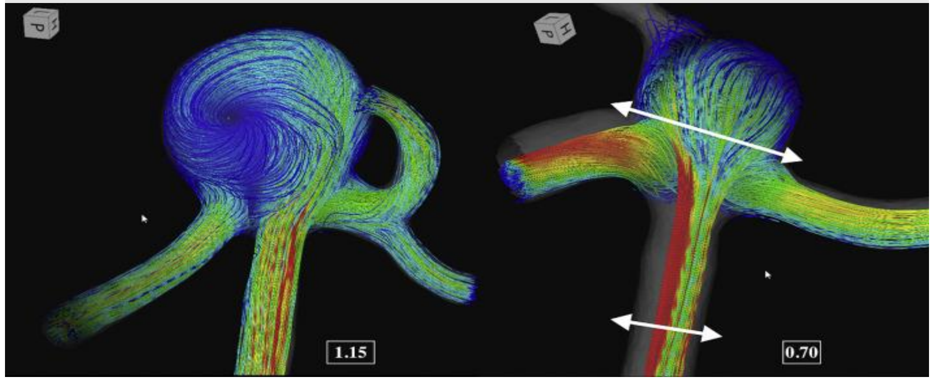
SOMETIMES, THESE TISSUES FAIL (PHYSICALLY AND/OR FUNCTIONALLY).

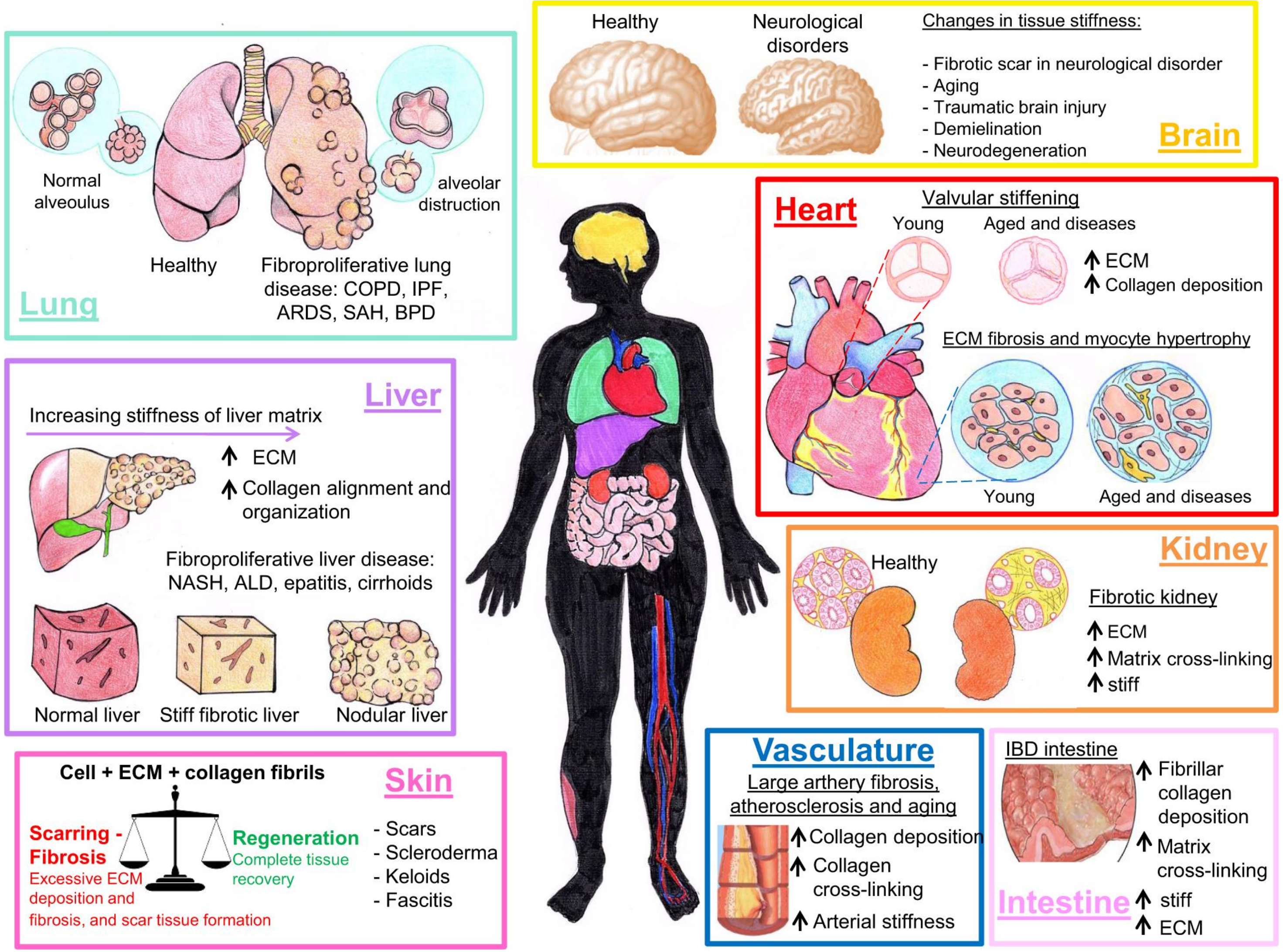


INTRODUCTION: Why Biomechanics?

STUDY OF DISEASES

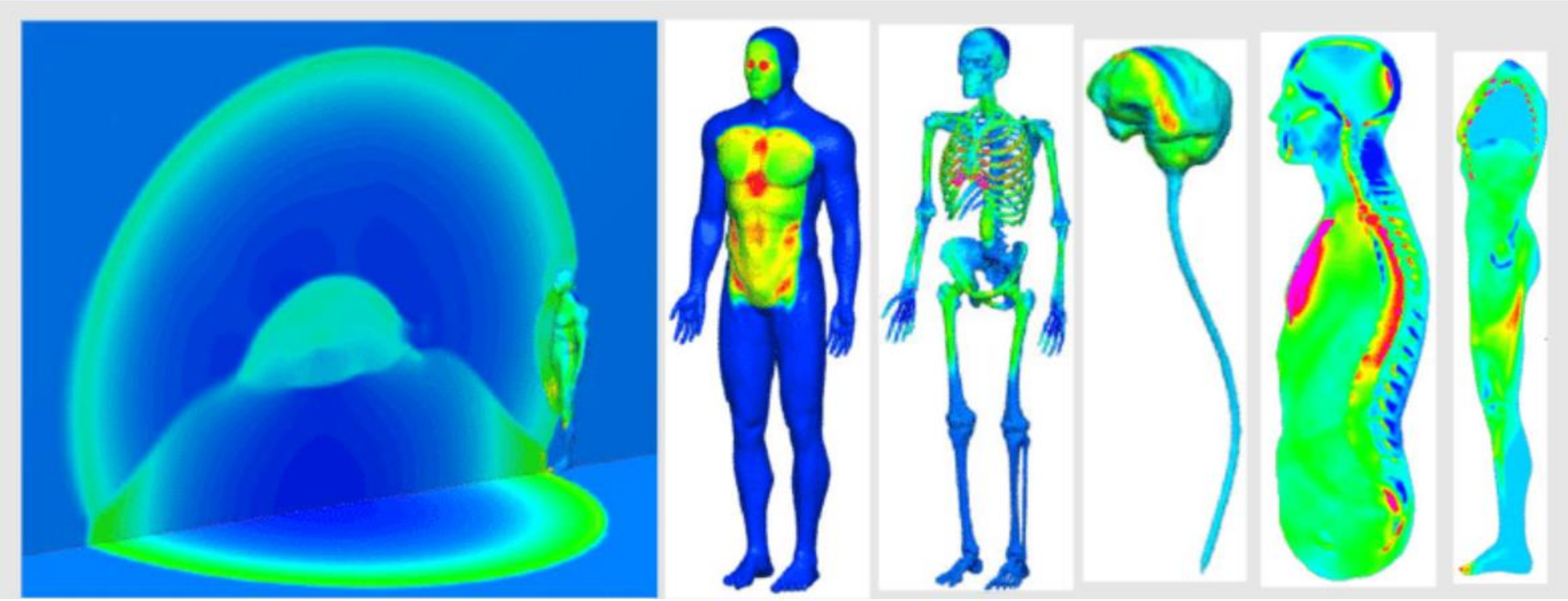






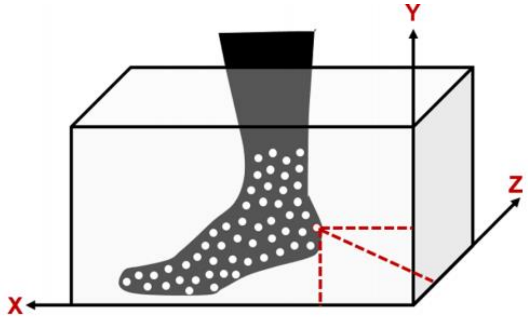
INTRODUCTION: Why Biomechanics?

STUDY OF INJURIES

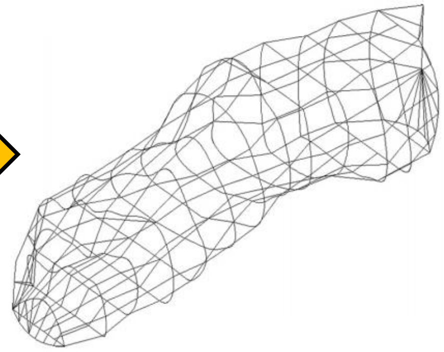


Finite Element Modeling (FEM)

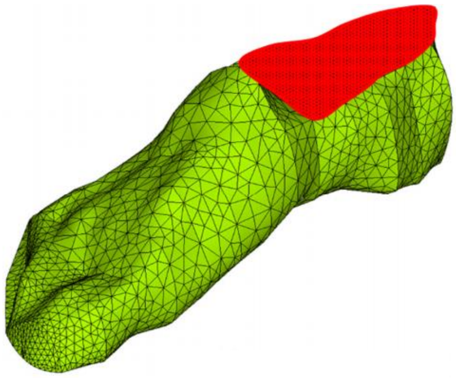
STEPS



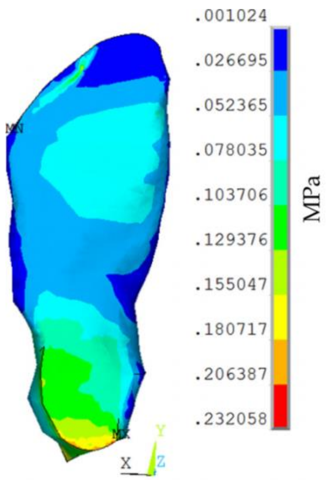
Imaging/Scanning



Geometry Modeling



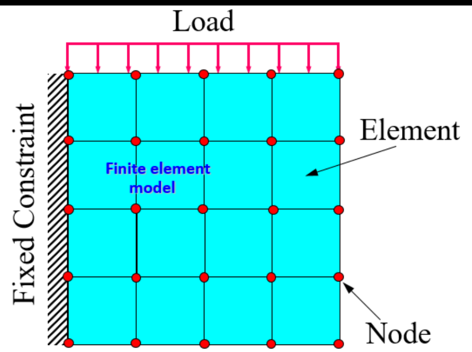
FE Modeling



Simulations

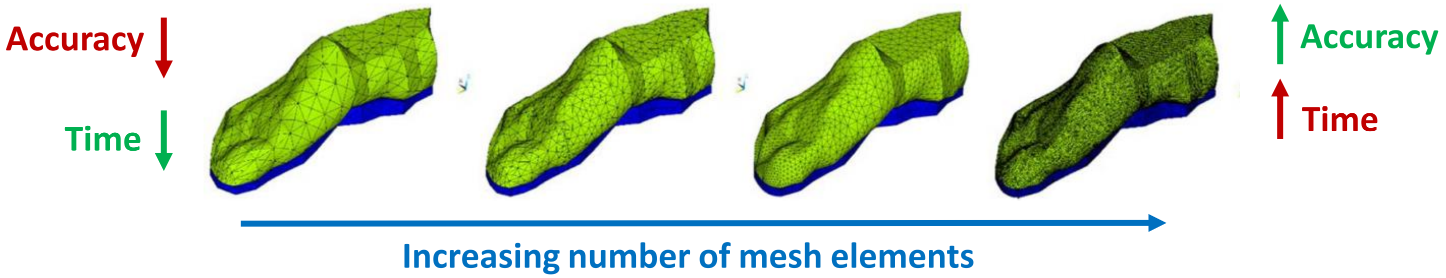
Finite Element (FE) Software

Finite Element Modeling (FEM)

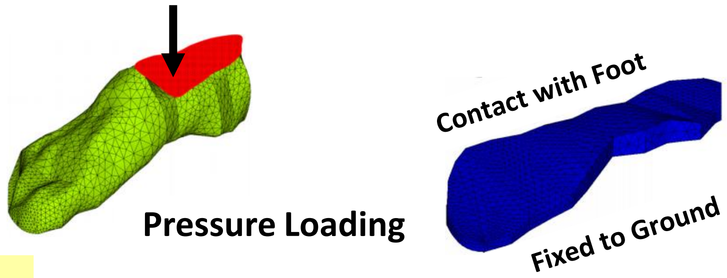


STEPS:

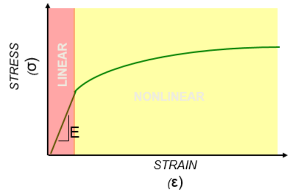
- FE Meshing



- Assignment of Loads, Constraints, and Contacts

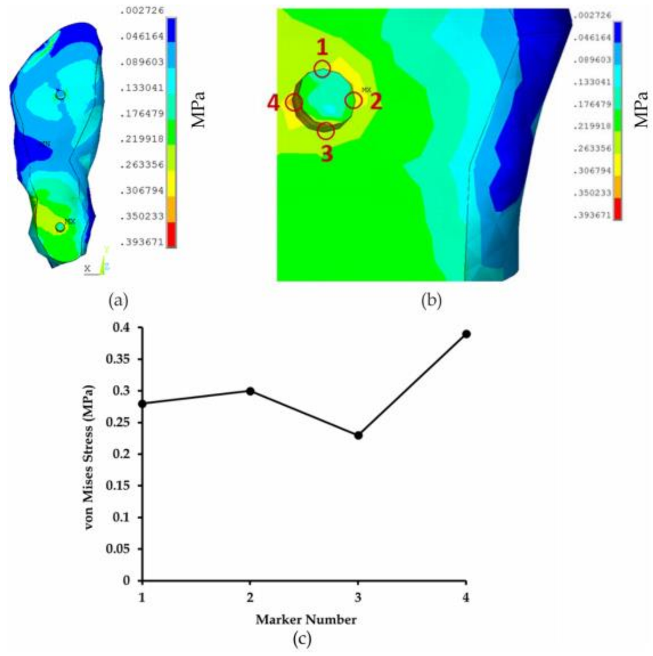


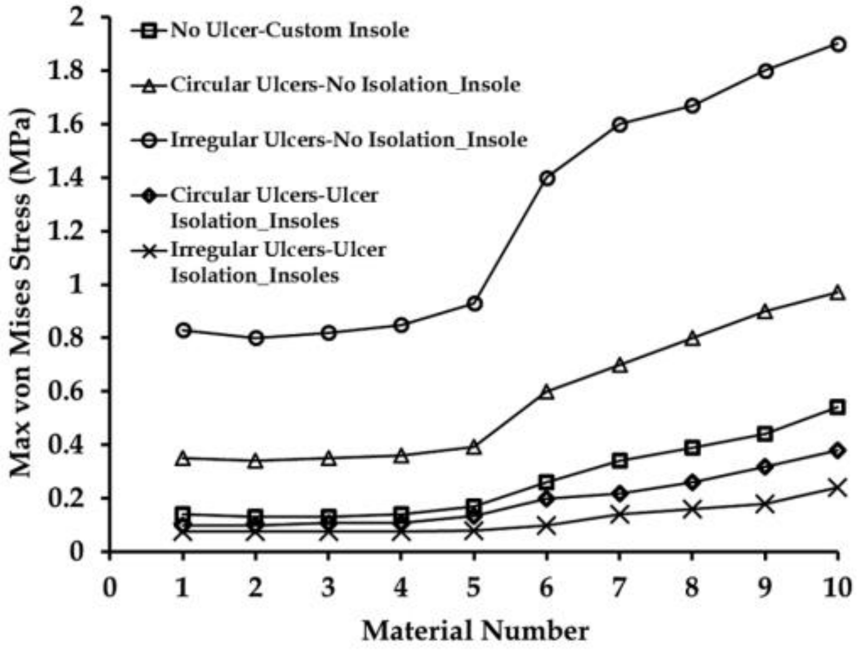
- Assignment of Material Properties



- Analysis

FEM Analysis



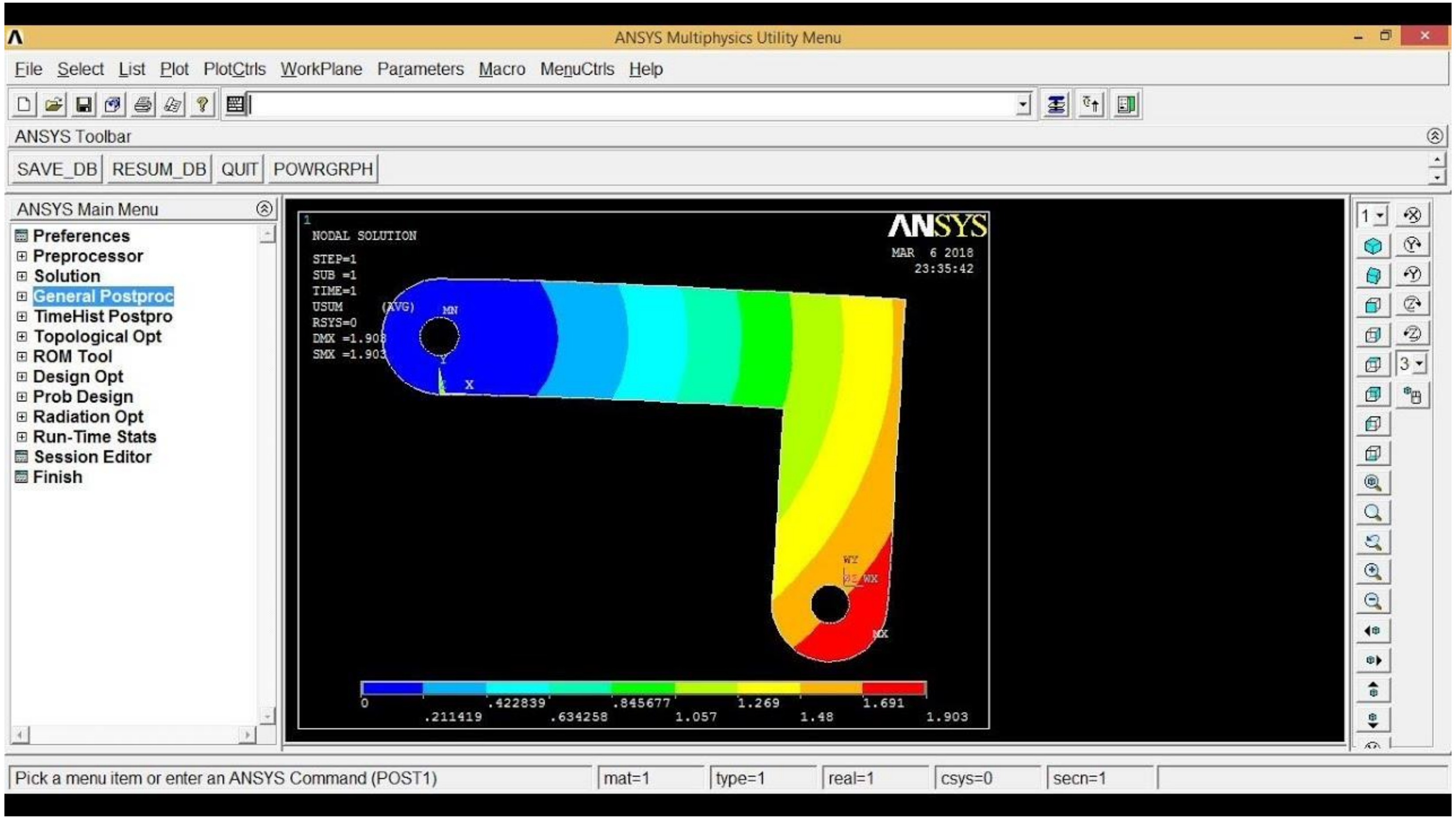


STEPS:

1. Stress and Strain Distributions
2. Effect of Material Properties on Results
3. Identifying Injury or Disease Specific Stresses or Strains
4. Effect of Interventions on Stresses/Strains

Orthotic Interventions

Software-ANSYS



Download ANSYS Student Version (Free)

Gait Analysis

- Study of human locomotion
- Walking and running
- Walking is a series of gait cycles
  - A single gait cycle is known as a STRIDE

The Main Tasks of the Gait Cycle

- **(1) Weight acceptance**
  - most demanding task in the gait cycle
  - involves the transfer of body weight onto a limb that has just finished swinging forward and has an unstable alignment.
  - Shock absorption and the maintenance of a forward body progression

- **(2) single limb support**
  - One limb must support the entire body weight
  - Same limb must provide truncal stability while bodily progression is continued.
- **(3) limb advancement**
  - Requires foot clearance from the floor
  - The limb swings through three positions as it travels to its destination in front of the body.

Why Study Normal Gait?

- Loss of the ability to walk can result is significant health problems

  (co-morbidities)

- Pain, injury, paralysis or tissue damage can alter normal gait and lead to:
  - further musculoskeletal problems (compensations)
  - Cardiovascular and pulmonary problems (inactivity due to pain)
  - Psychological problems (depression)

- Sports, Exercise/Fitness, and Rehabilitation Professionals must have a sound knowledge of normal gait so they can accurately detect, interpret, and ultimately correct deviations and/or gait pathologies to restore “normal,” pain-free function
- It is important to remember that each person displays “normal” variations from the normal pattern of walking
- **ULTIMATE GOAL: KEEP YOURSELF AND YOUR PATIENTS/CLIENTS MOVING PAIN-FREE THROUGHOUT YOUR/THEIR LIFESPANS!!!**

Normal Walking Requirements

- There are (4) major criteria essential to walking.
  - **Equilibrium**
    - the ability to assume an upright posture and maintain balance.
  - **Locomotion**
    - the ability to initiate and maintain rhythmic stepping

Walking Requirements Cont’d

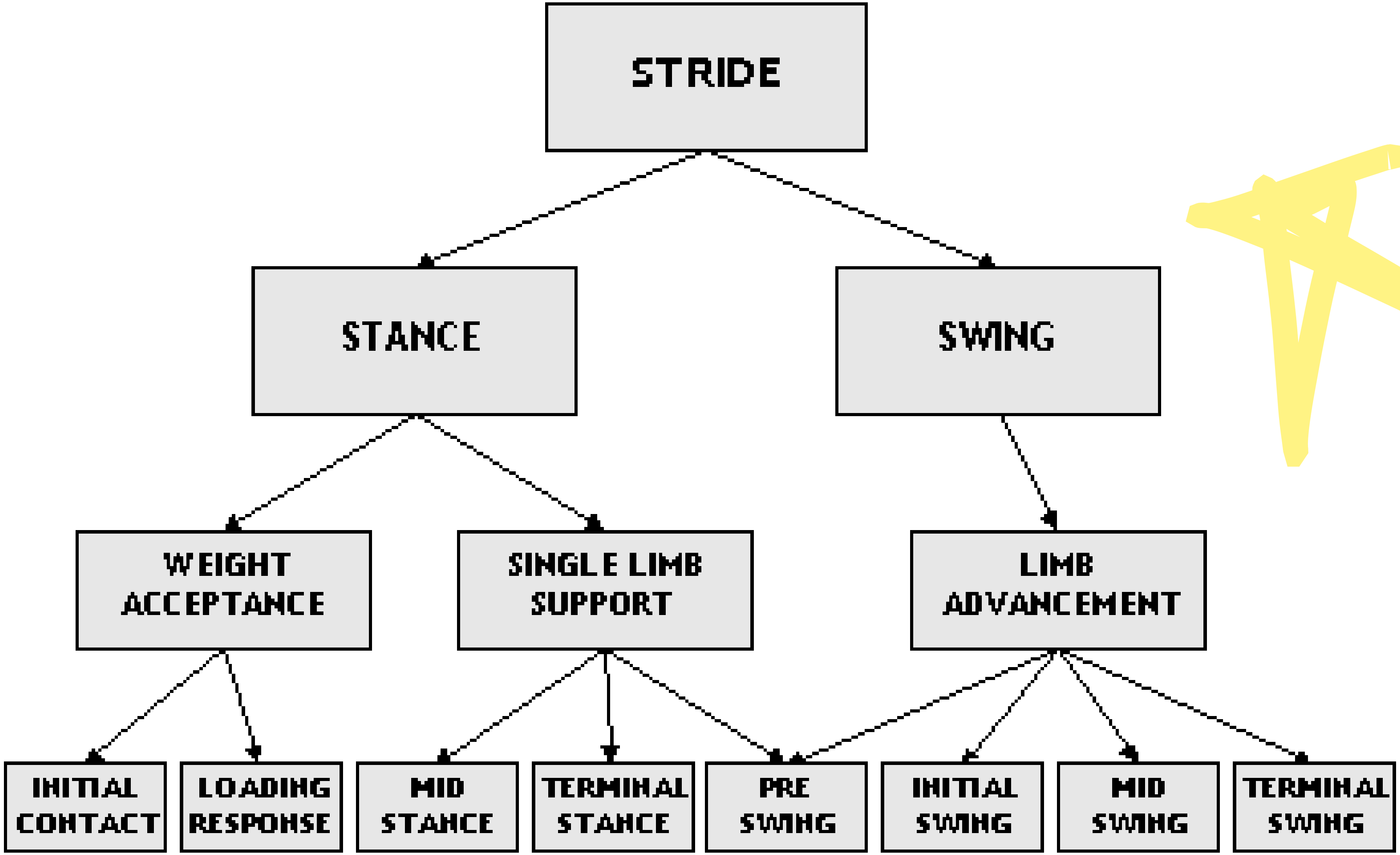
- **Musculoskeletal Integrity**
  - normal bone, joint, and muscle function
- **Neurological Control**,
  - must receive and send messages telling the body how and when to move. (visual, vestibular, auditory, sensorimotor input)

Gait Cycle or Stride

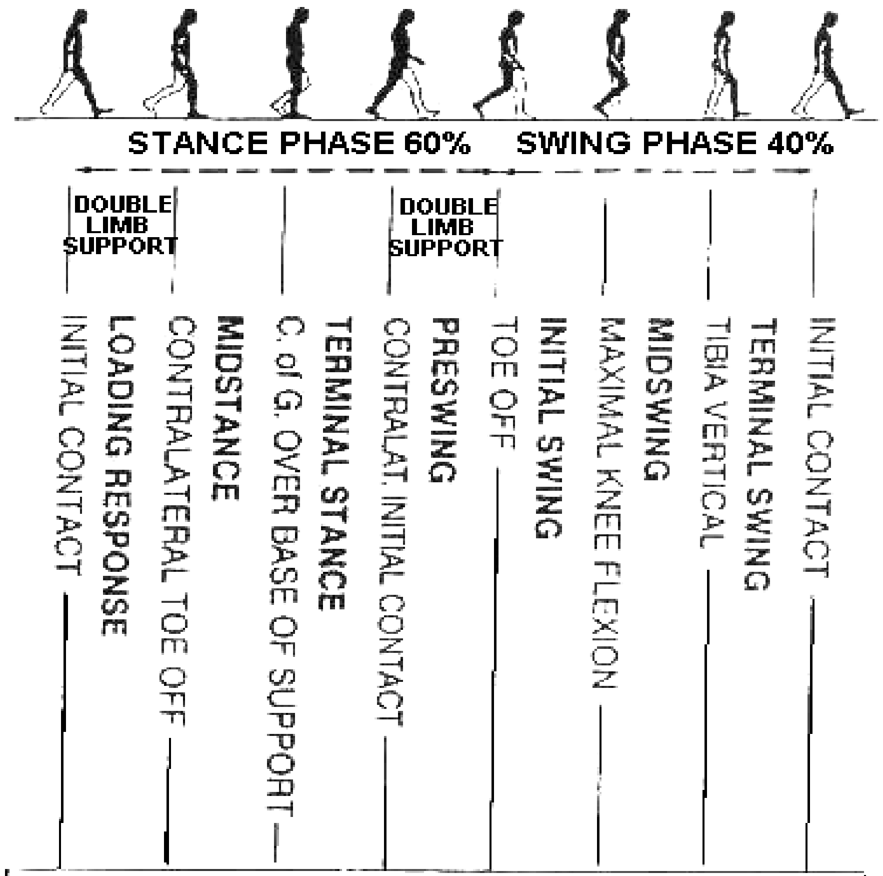
- A single gait cycle or stride is defined:
  - Period when 1 foot contacts the ground to when that same foot contacts the ground again
  - Each stride has 2 phases:
    - Stance Phase
      - Foot in contact with the ground
    - Swing Phase
      - Foot NOT in contact with the ground

A Single Gait Cycle or Stride

Gait Flow Chart



GAIT CYCLE
JOINT MOTION AND MUSCLE ACTIVITY



JOINT RANGE OF MOTION

	INITIAL CONTACT	CONTRALATERAL TOE OFF	C. of G. OVER BASE OF SUPPORT	CONTRALAT. INITIAL CONTACT	TOE OFF	MAXIMAL KNEE FLEXION	TIBIA VERTICAL	INITIAL CONTACT
PELVIC FWD ROTATION	5		0	-5			0	5
HIP FLEXION	30	30	5	-10	0	20	30	30
KNEE FLEXION	0	15	5	0	40	60	30	0
ANKLE PLANT. FLEX.	0	15	-5	-10	20	10	0	0
SUBTALAR SUPINATION	5	-10	-5	5	10			5

Stance Phase of Gait

- When the foot is contact with the ground only
- Propulsion phase
- Stance phase has 5 parts:
  - Initial Contact (Heel Strike) (1)
  - Loading Response (Foot Flat) (2)
  - Midstance (2)
  - Terminal Stance (3)
  - Toe Off (Pre-Swing) (4)

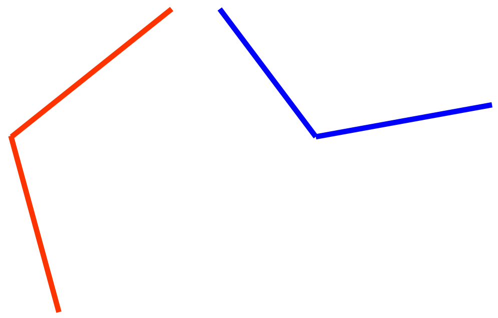
(Missing Loading Response in picture)

Motions during Stance Phase

- Shoulder flexes
- Pelvis rotates right (transverse plane)
- Spine rotates left
- Hip extends, IRs
- Knee flexes, extends
- Ankle plantarflexes, dorsiflexes, plantarflexes
- Foot pronates, supinates
- Toes flex, extend, flex

Initial Contact

- **Phase 1**
- The moment when the red foot just touches the floor.
- The heel (calcaneous) is the first bone of the foot to touch the ground.
- Meanwhile, the blue leg is at the end of terminal stance.

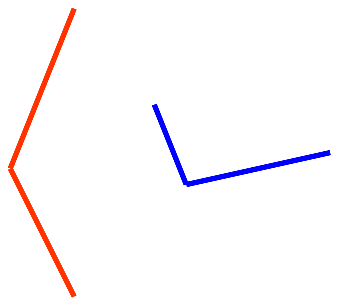


Static Positions at Initial Contact

- FREEZE FRAME POSITIONS
- Shoulder is extended
- Pelvis is rotated left
- Hip is flexed and externally rotated
- Knee is fully extended
- Ankle is dorsiflexed
- Foot is supinated
- Toes are slightly extended

Loading Response

- **Phase 2**
- The double stance period beginning
- Body weight is transferred onto the red leg.
- Phase 2 is important for shock absorption, weight-bearing, and forward progression.
- The blue leg is in the pre-swing phase.

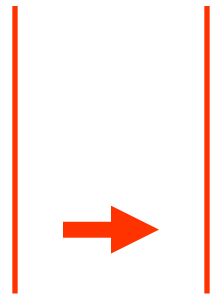


Static Positions at Loading Response

- Shoulder is slightly extended
- Pelvis is rotated left
- hip is flexed and slightly externally rotated
- knee is slightly flexed
- ankle is plantarflexing to neutral
- foot is neutral
- Toes are neutral

Midstance

- **Phase 3**
- **single limb support** interval.
- Begins with the lifting of the blue foot and continues until body weight is aligned over the red (supporting) foot.
- The red leg advances over the red foot The blue leg is in its mid-swing phase.

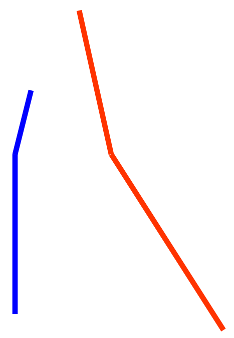


Static Positions at Midstance

- Shoulder is in neutral
- Pelvis is in neutral rotation
- Hip is in neutral
- Knee is fully extended
- Ankle is relatively neutral
- Foot is pronated
- Toes are neutral

Terminal Stance

- **Phase 4**
- Begins when the red heel rises and continues until the heel of the blue foot hits the ground.
- Body weight progresses beyond the red foot

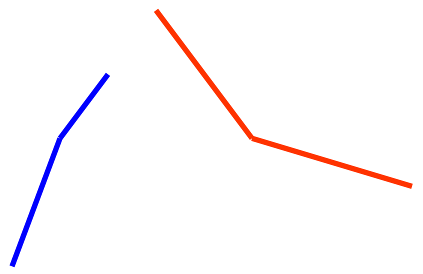


Static Positions at Terminal Stance

- Shoulder is slightly flexed
- Pelvis is rotated left
- Hip is extended and internally rotated
- Knee is fully extended
- Ankle is dorsiflexed
- Foot is slightly supinated
- Toes are neutral

Toe-Off

- **Phase 5**
- The second double stance interval in the gait cycle.
- Begins with the initial contact of the blue foot and ends with red toe-off.
- Transfer of body weight from ipsilateral to opposite limb takes place.



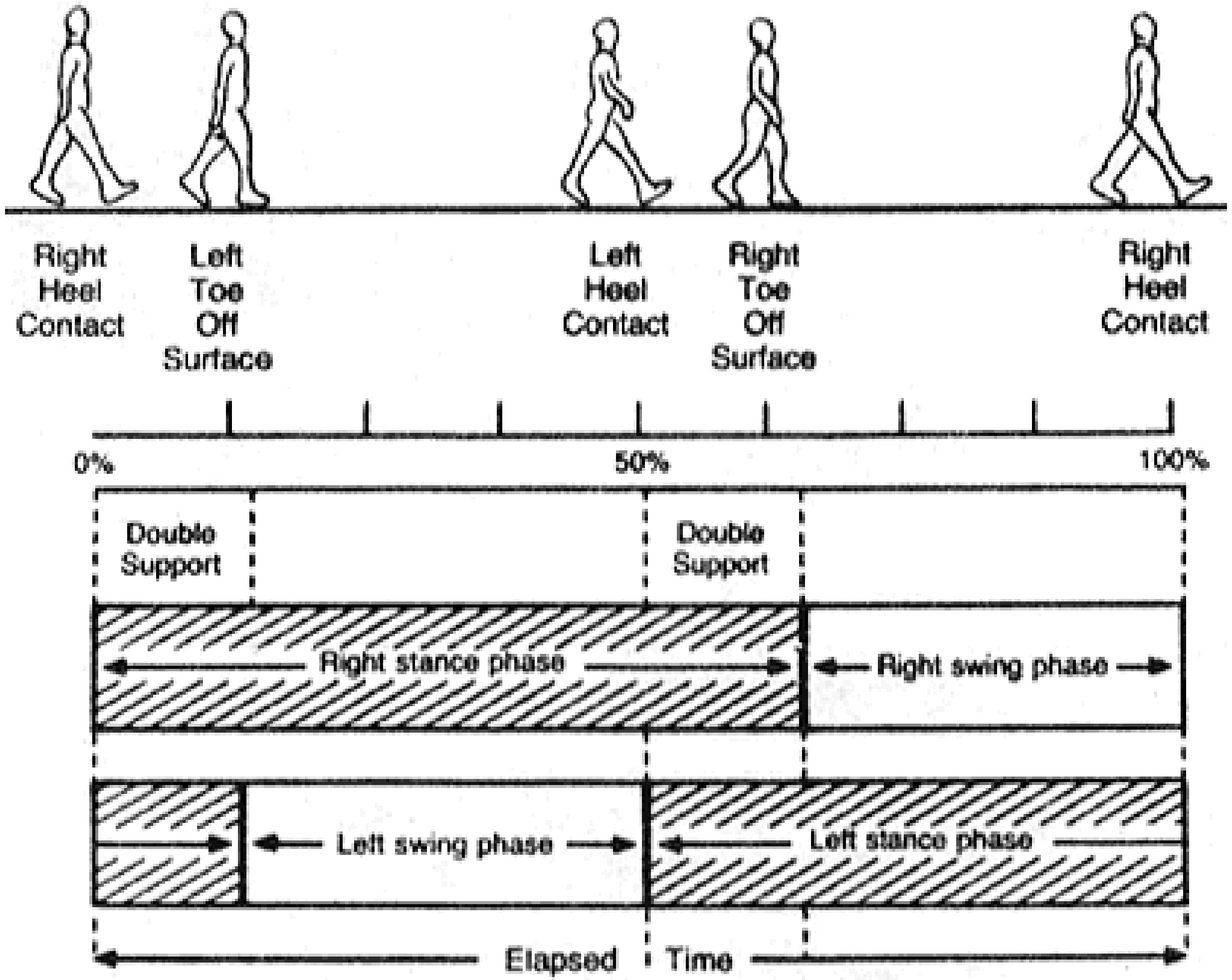
Static Positions at Toe-Off

- Shoulder is flexed
- Pelvis is rotated right
- Hip is fully extended and internally rotated
- Knee is fully extended
- Ankle is plantarflexed
- Foot is fully supinated
- Toes are fully extended

Stance Phase Characteristics

- During a single stride, there are 2 periods of double limb support (both feet on ground):
  - Loading response (right) & Toe Off (left)
  - Loading response (left) & Toe Off (right)

Gait Progression



Swing Phase

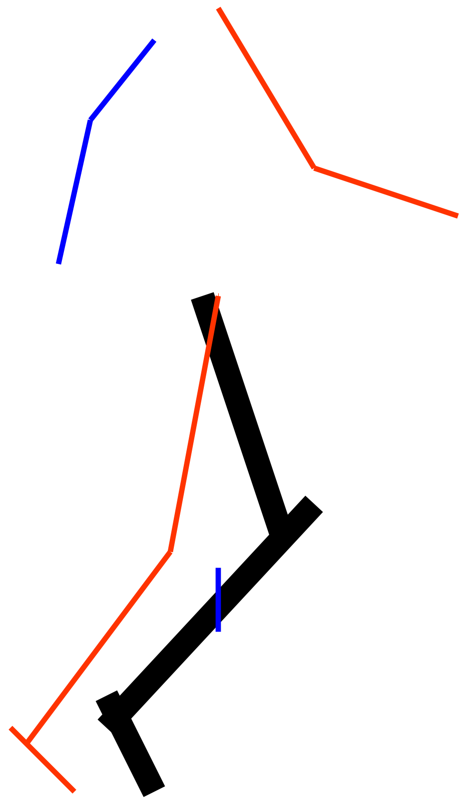
- When foot is NOT contacting the ground, it is swinging!
- Limb advancement phase
- 3 parts of swing phase:
- Initial swing
- Midswing
- Terminal swing

Motions during Swing Phase

- Shoulder extends
- Spine rotates right
- Pelvis rotates left (passive)
- Hip flexes, ERs
- Knee flexes, then extends
- Ankle dorsiflexes
- Foot supination (inversion)
- Toes extend

Initial Swing

- **Phase 6**
- Begins when the red foot is lifted from the floor and ends when the red swinging foot is opposite the blue stance foot.
- It is during this phase that a footdrop gait is most apparent.
- The blue leg is in mid-stance.



Static Positions at Initial Swing

- Shoulder is flexed
- Spine is rotated left
- Pelvis is rotated right
- hip is slightly extended and internally rotated
- Knee is slightly flexed
- Ankle is fully plantarflexed
- Foot is supinated
- Toes are slightly flexed

Midswing

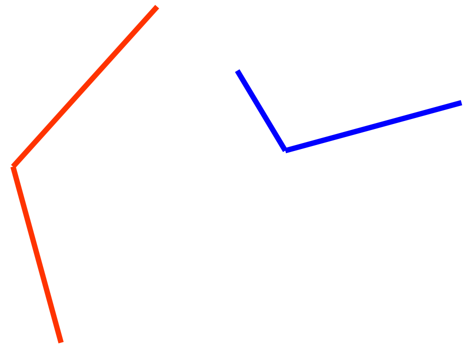
- **Phase 7**
- Starts at the end of the initial swing and continues until the red swinging limb is in front of the body
- Advancement of the red leg
- The blue leg is in late mid-stance.

Static Positions at Midswing

- Shoulder is neutral
- Spine is neutral
- Pelvis is neutral
- Hip is neutral
- Knee is flexed 60-90°
- Ankle is plantarflexed to neutral
- Foot is neutral
- Toes are slightly extended

Terminal Swing

- **Phase 8**
- Begins at the end of midswing and ends when the foot touches the floor.
- Limb advancement is completed at the end of this phase.



Static Positions at Terminal Swing

- Shoulder is extended
- Spine is rotated right
- Pelvis is rotated left
- Hip is flexed and externally rotated
- Knee is fully extended
- Ankle is fully dorsiflexed
- Foot is neutral
- Toes are slightly extended

Gait Pathologies

- Deviations from “normal” gait pattern
- Result from
  - Pain
  - Injury (ROM restrictions)
  - Surgery (ROM restrictions)
  - Weakness
  - Balance deficits
- Consider all “normal” components of stance and swing phase of a gait cycle or stride
- Compare right and left sides when observing a person’s gait pattern

Antalgic Gait

- Painful leg gait
- Decreased stance time on painful leg
- Increased swing time on painful leg
- Decreased swing time on non-painful leg
- Increased stance time on non-painful leg

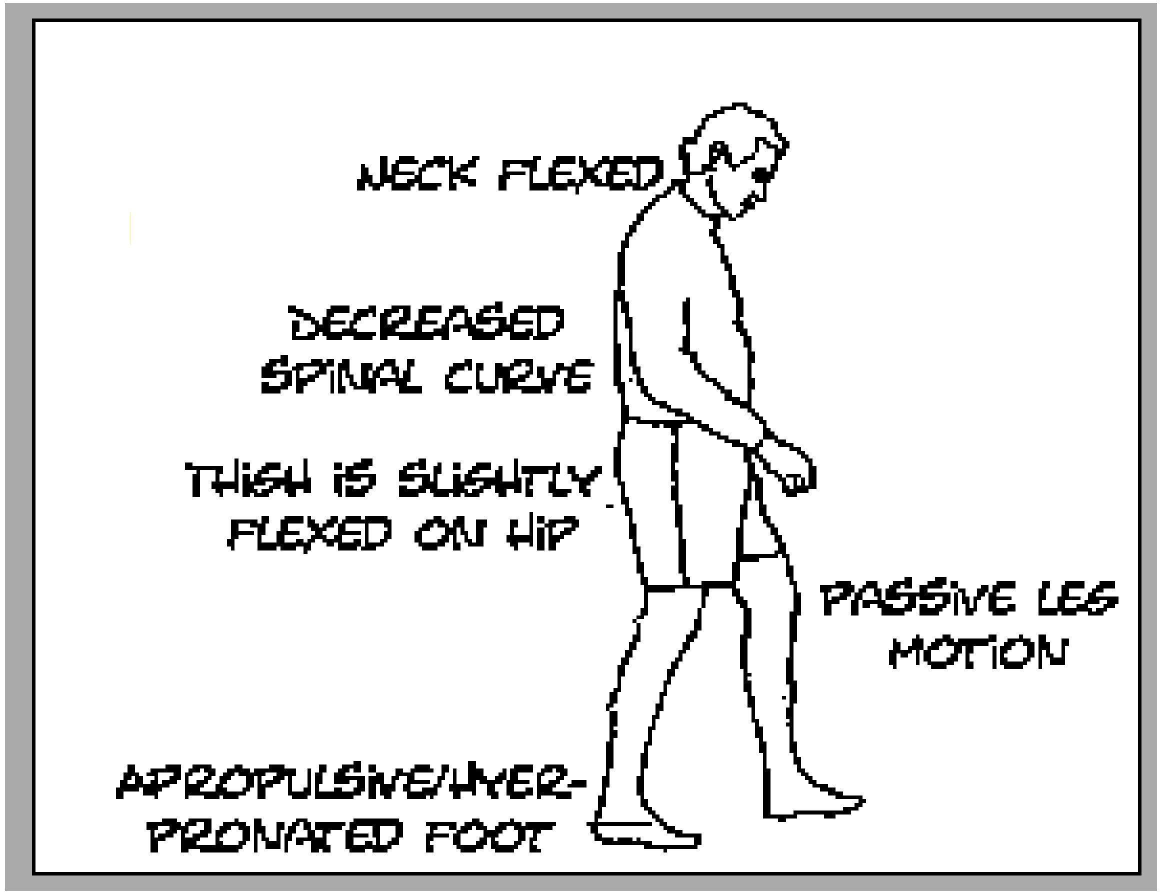
Trendelenburg Gait

- Gluteus medius weakness gait
- Lateral trunk lean towards side of weakness
- Maintain body's COG over weak side during stance phase

Flexed Knee Gait

- Flexed knees
- Flexed trunk posture
- No arm swing
- No initial contact
- No Toe-off
- No hip extension
- Short step
- Shortened stride
- COG stays within BOS
- Common in elderly with fear of falling

Flexed Gait Posture



Common Gait Posture in Elderly People