BML 300: INTRODUCTION TO HEALTHCARE ENGINEERING

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Date: Aug 12, 2024

What is Biomechanics?

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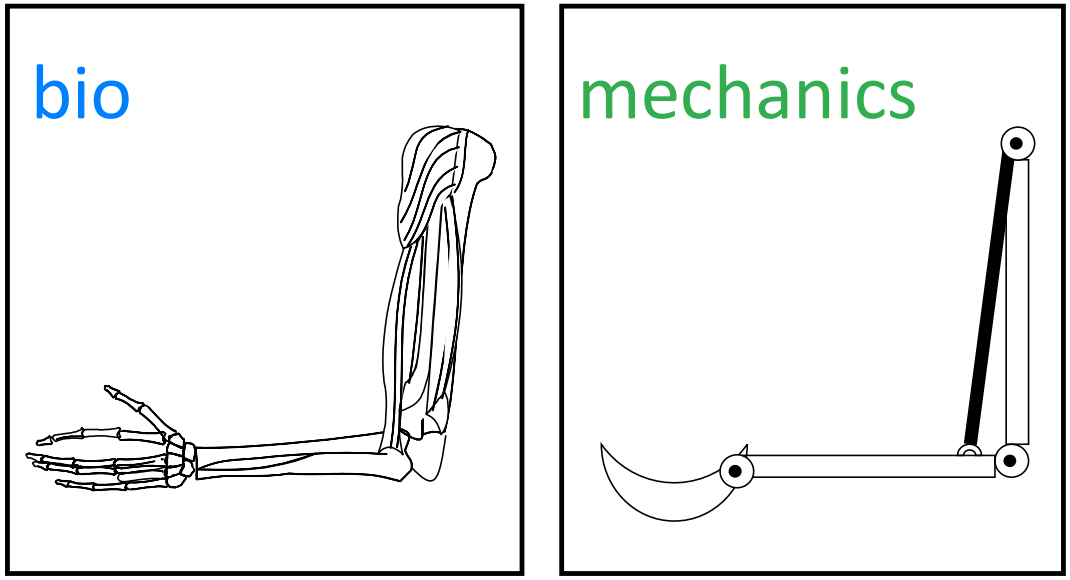


The term *biomechanics* combines the prefix *bio*, meaning "life," with the field of *mechanics*, which is the study of the actions of forces, (both internal muscle forces and external forces.) In biomechanics we analyze the mechanical aspects of living organisms.

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.)

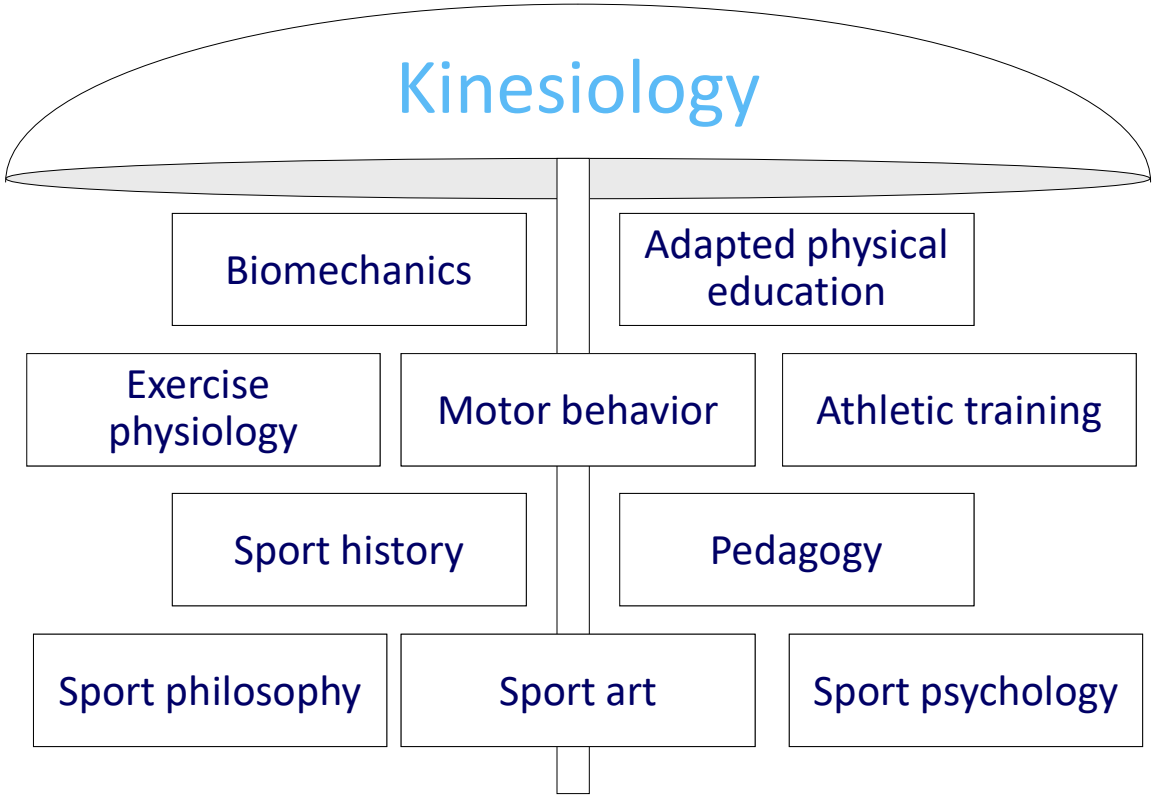
What is kinematics?

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?

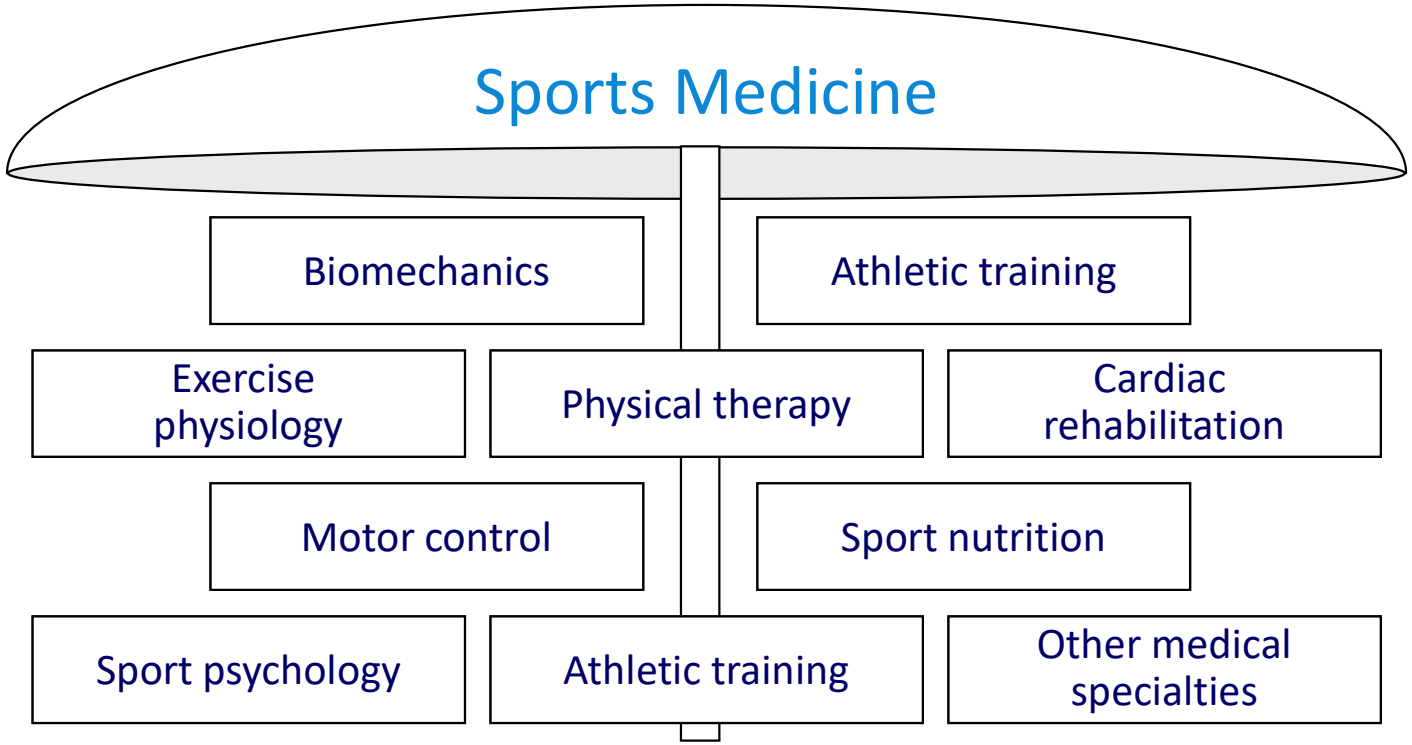
Kinetics is the study of forces, including internal forces (muscle forces) and external forces (the forces of gravity and the forces exchanged by bat and ball).

What is kinesiology?



Kinesiology is the study of human movement.

What is sports medicine?



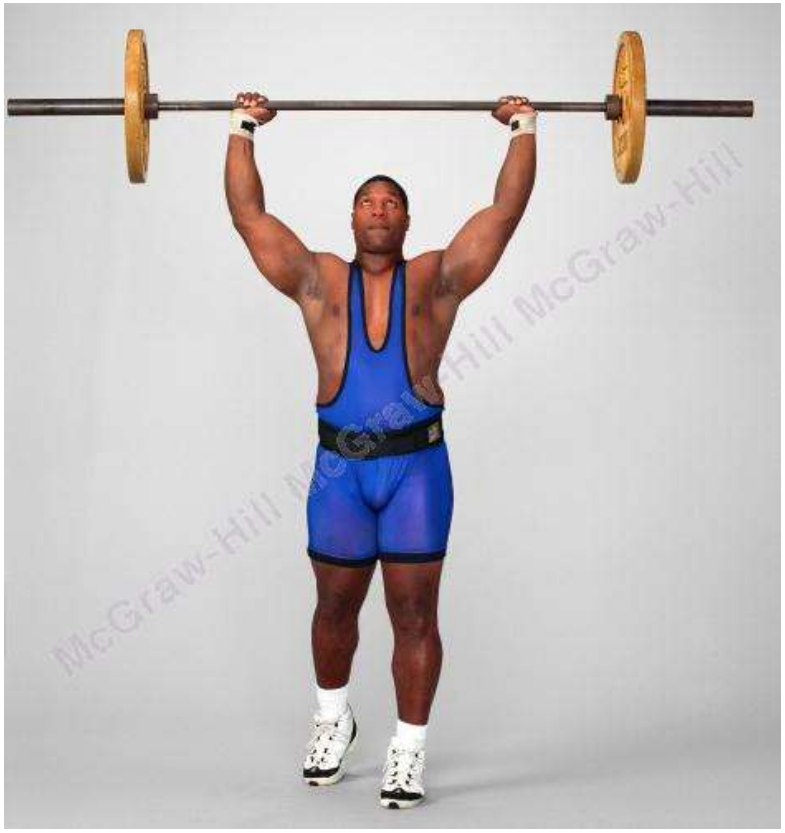
Sports medicine is an umbrella term that encompasses both clinical and scientific aspects of exercise and sport.

What questions or problems are studied by biomechanists?

What questions are studied by biomechanists?

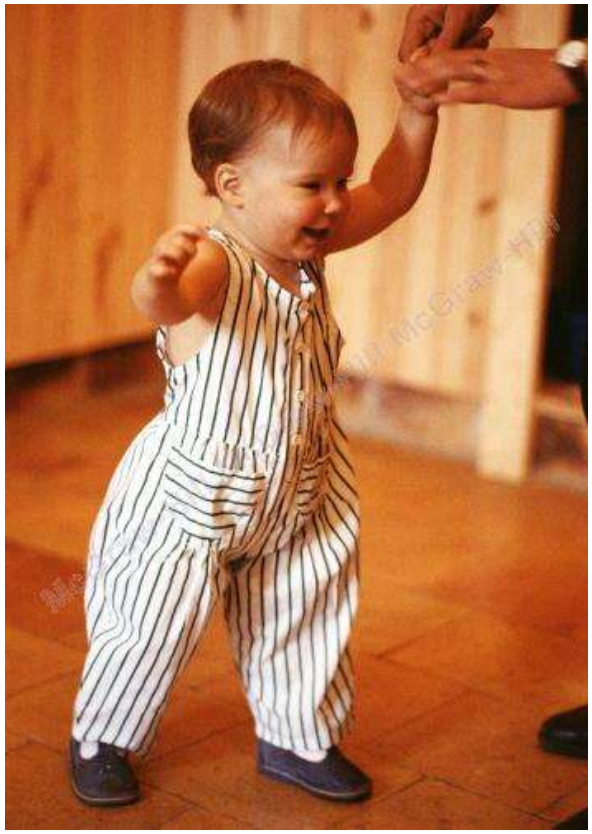
When not subject to gravitational force, astronauts lose significant amounts of bone mass. (Bone atrophies when not subjected to forces.) Exercise, however, is known to increase bone mass. So what kinds of exercise should astronauts do while in space in order to preserve as much bone as possible?

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

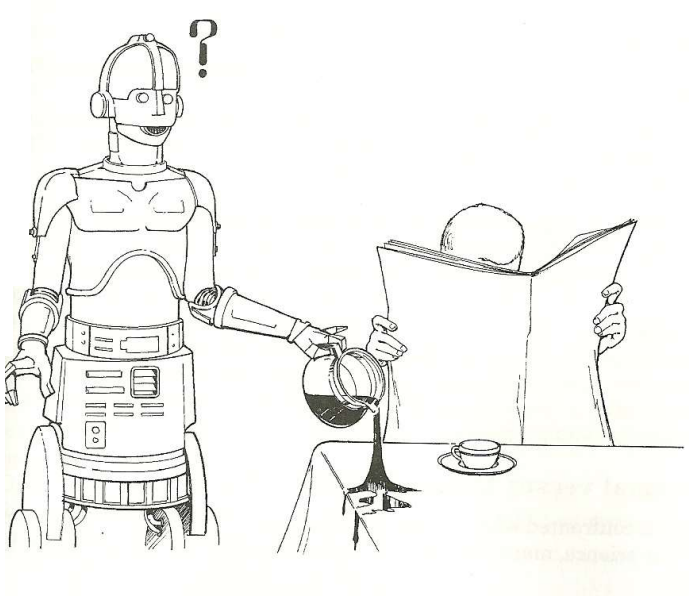
- **quantitative:** involving numbers

  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.

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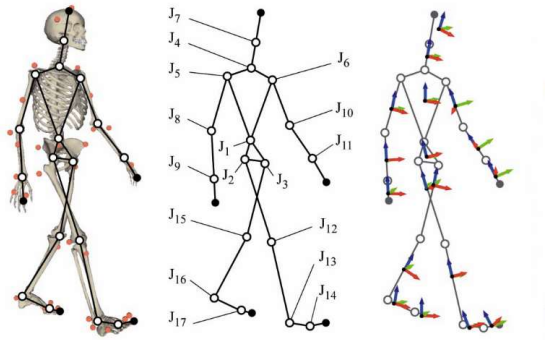
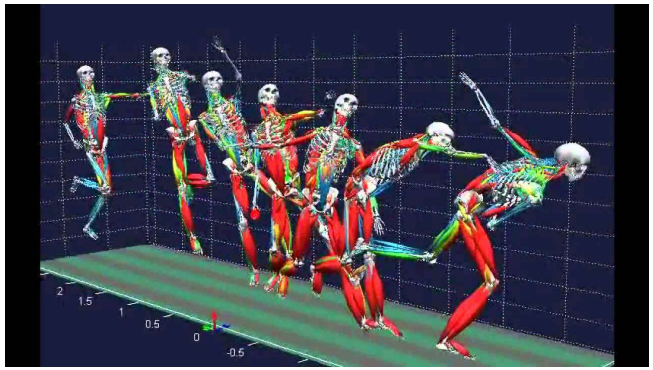
Introduction to Biomechanics

Biomechanics:

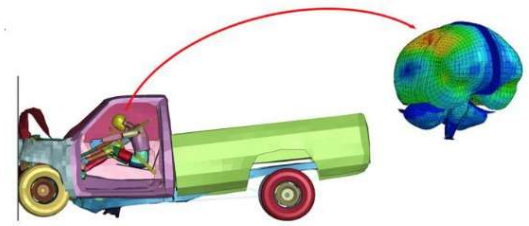
- Study of movement of living body (including bones, tissues, and organs)
- The **math** behind injury and tissue related disease-Doctors cannot tell this!



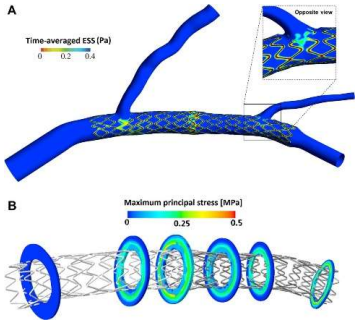
Gait Biomechanics



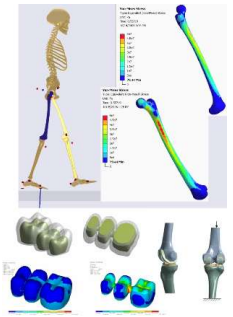
Sports Biomechanics



Injury Biomechanics



Cardiovascular Biomechanics

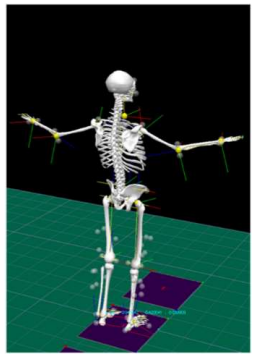


Orthopedic Biomechanics

Experimental Biomechanics

Limited by biosafety and ethics:

Cadaveric Tissue Experiments

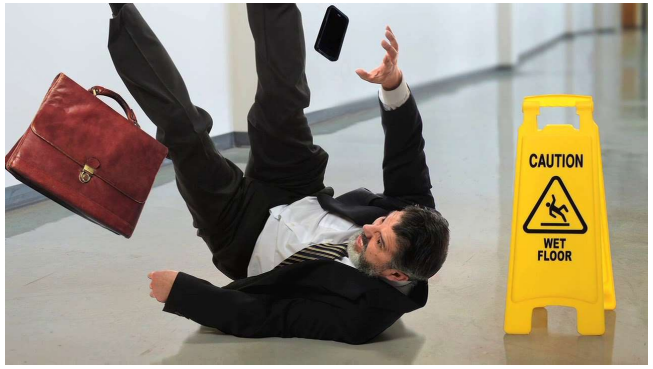


Experimental Gait Analysis

Exercise Testing

Can we study these experimentally?

Blast Injury

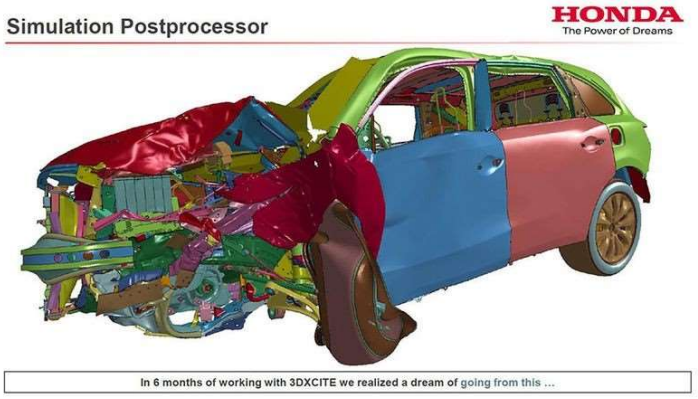


Slips and Falls

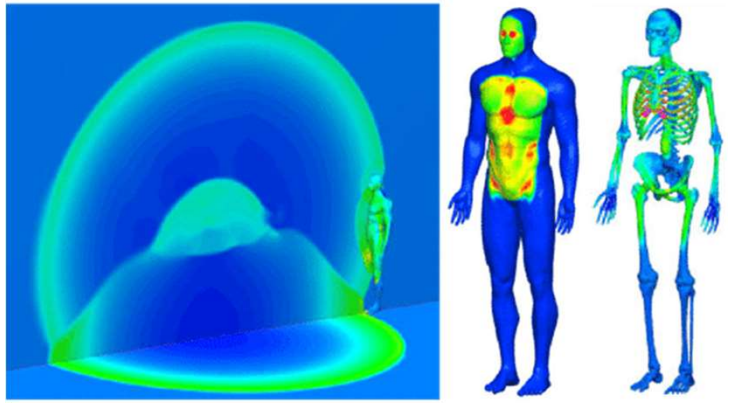
Armor Testing

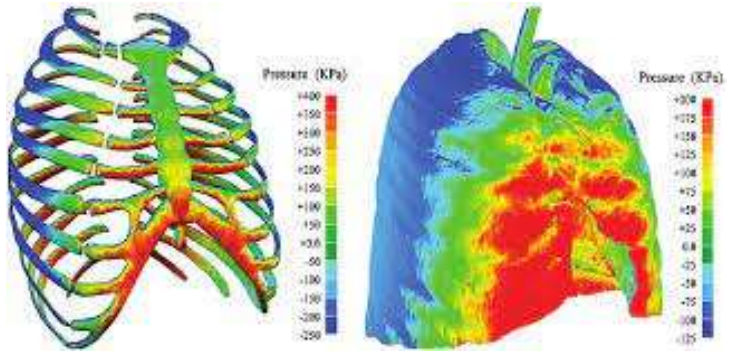
Finite Element Modeling (FEM)

Allows us to simulate complex scenarios



Vehicular Crash Testing





Organ Damage due to IED Blast

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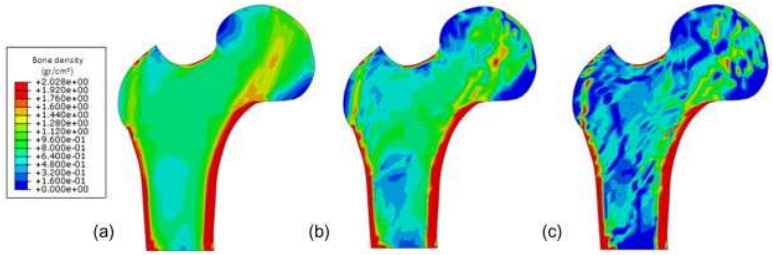
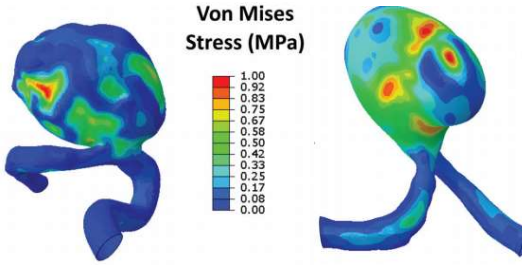
Disease Biomechanics

Allows us to study disease progressions and forms

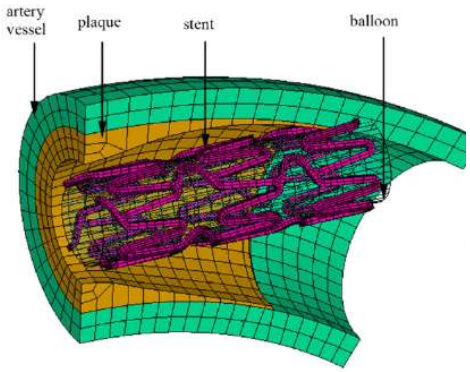


Stress Distribution-Varying degrees of Osteoporosis

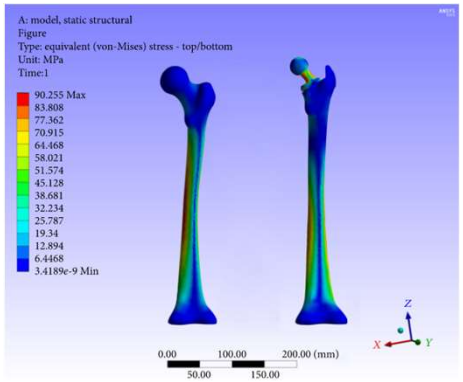


Stress Distribution-Varying Aneurysm Forms

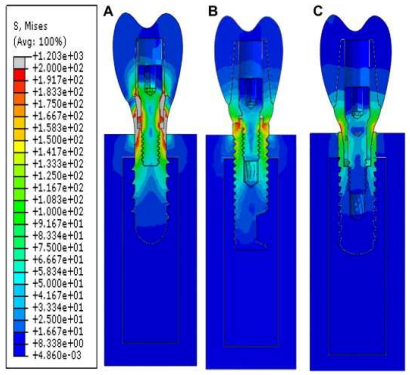
Also can test interventions and medical devices



Arterial Stent Implantation

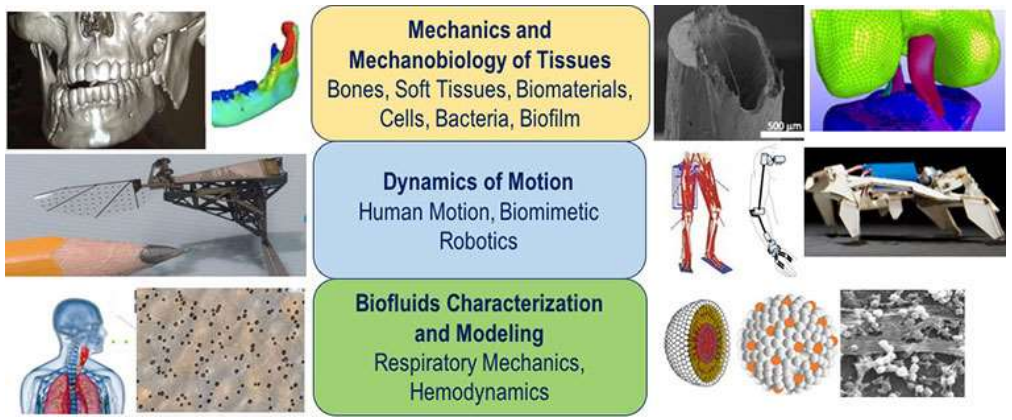


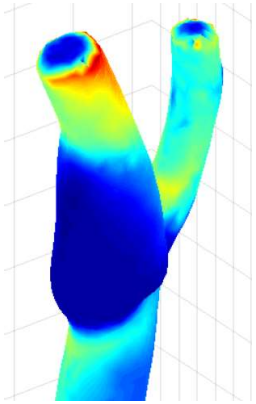
Hip Implant Testing

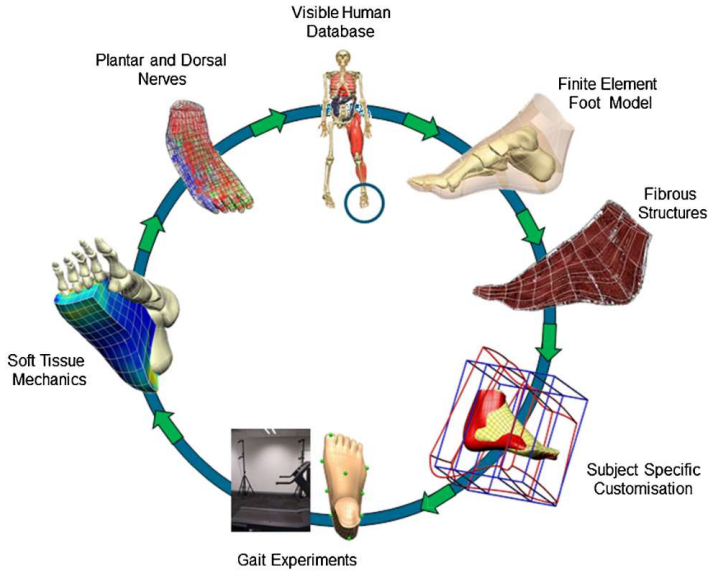


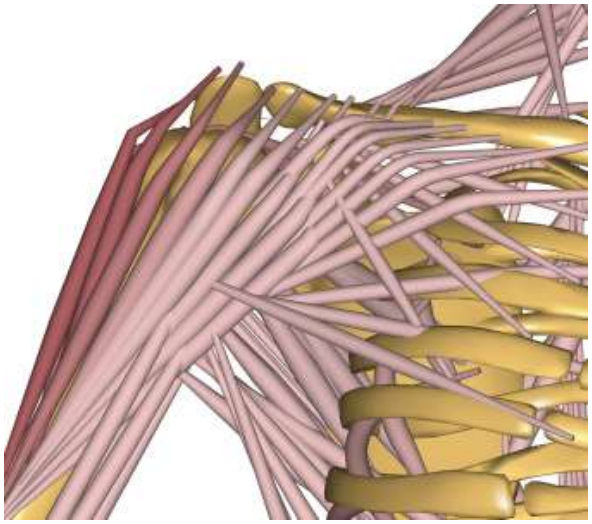
Stress-Commercial Dental Implants

INTRODUCTION: Why Biomechanics?





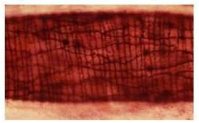




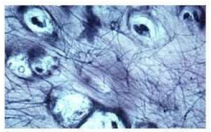
WHY STUDY SOFT TISSUE MECHANICS?

Tendon

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



Blood Vessel

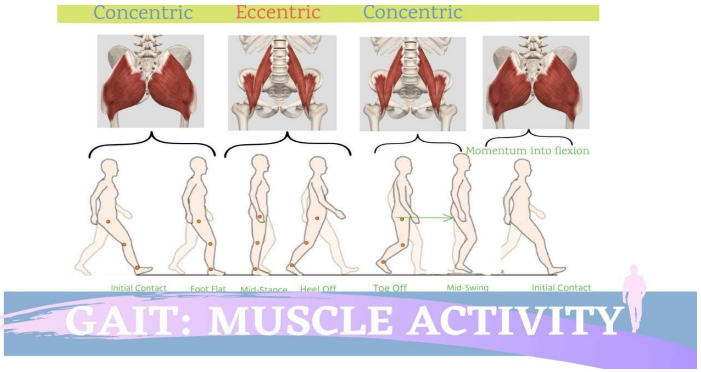


Elastic Cartilage

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

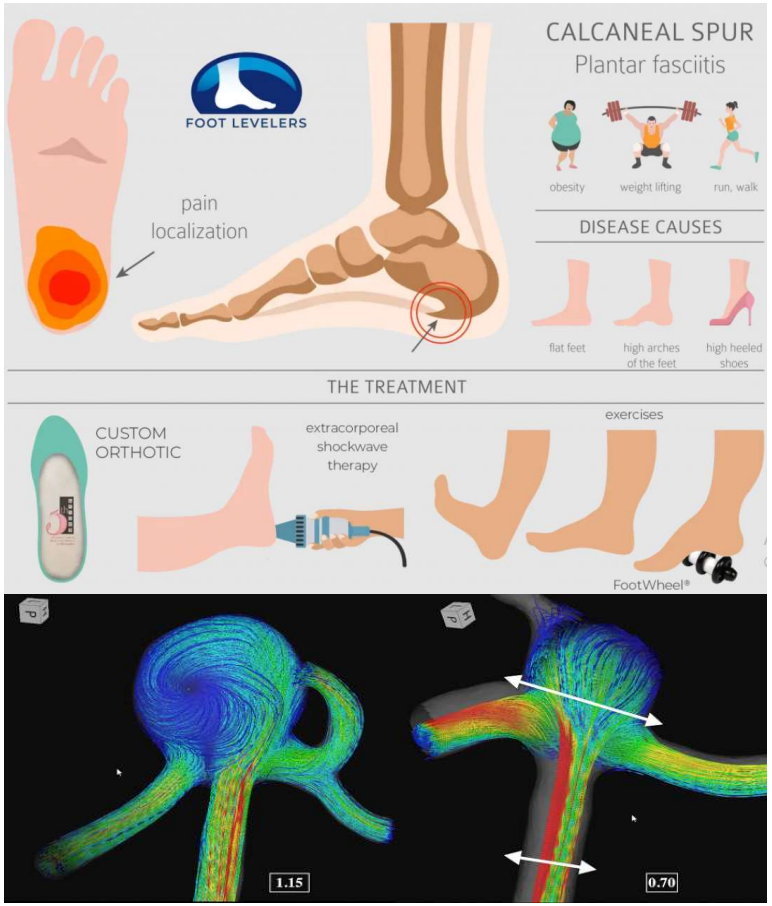
MANY BIOLOGICAL TISSUES HAVE EVOLVED TO PERFORM SPECIFIC MECHANICAL FUNCTIONS.

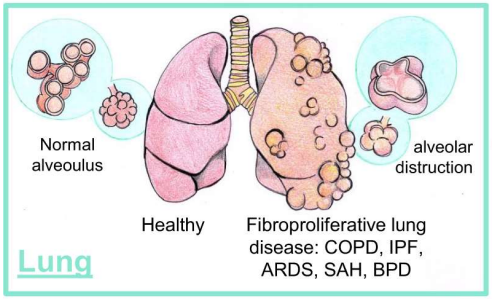
SOMETIMES, THESE TISSUES FAIL (PHYSICALLY AND/OR FUNCTIONALLY).

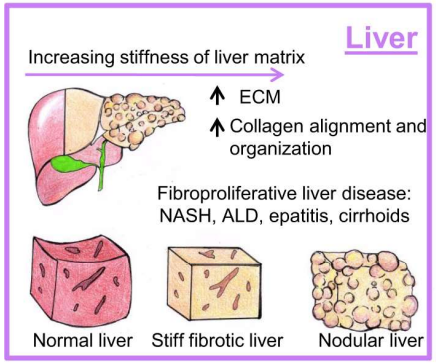


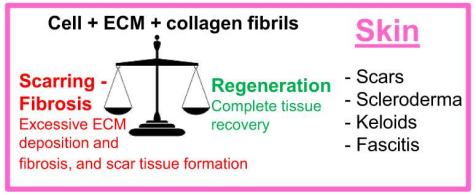
INTRODUCTION: Why Biomechanics?

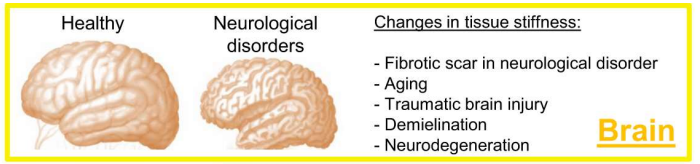
STUDY OF DISEASES

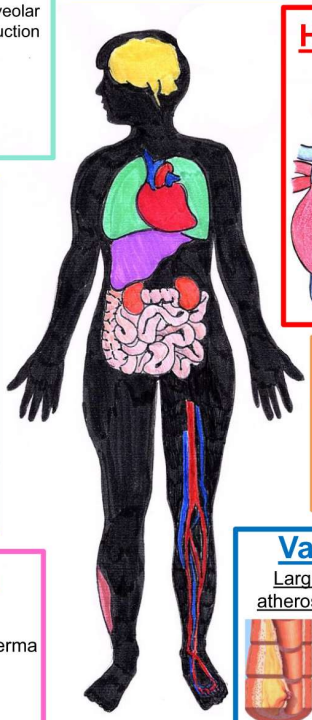


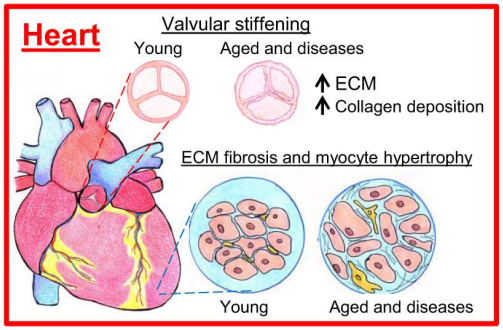


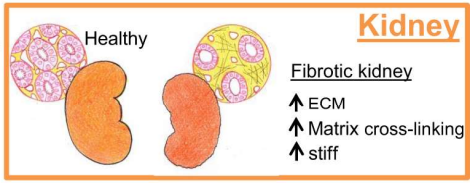


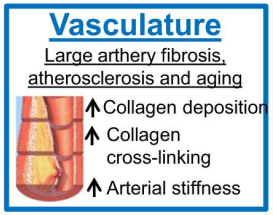


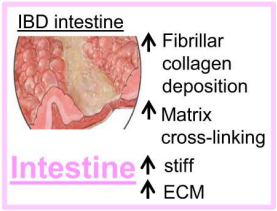






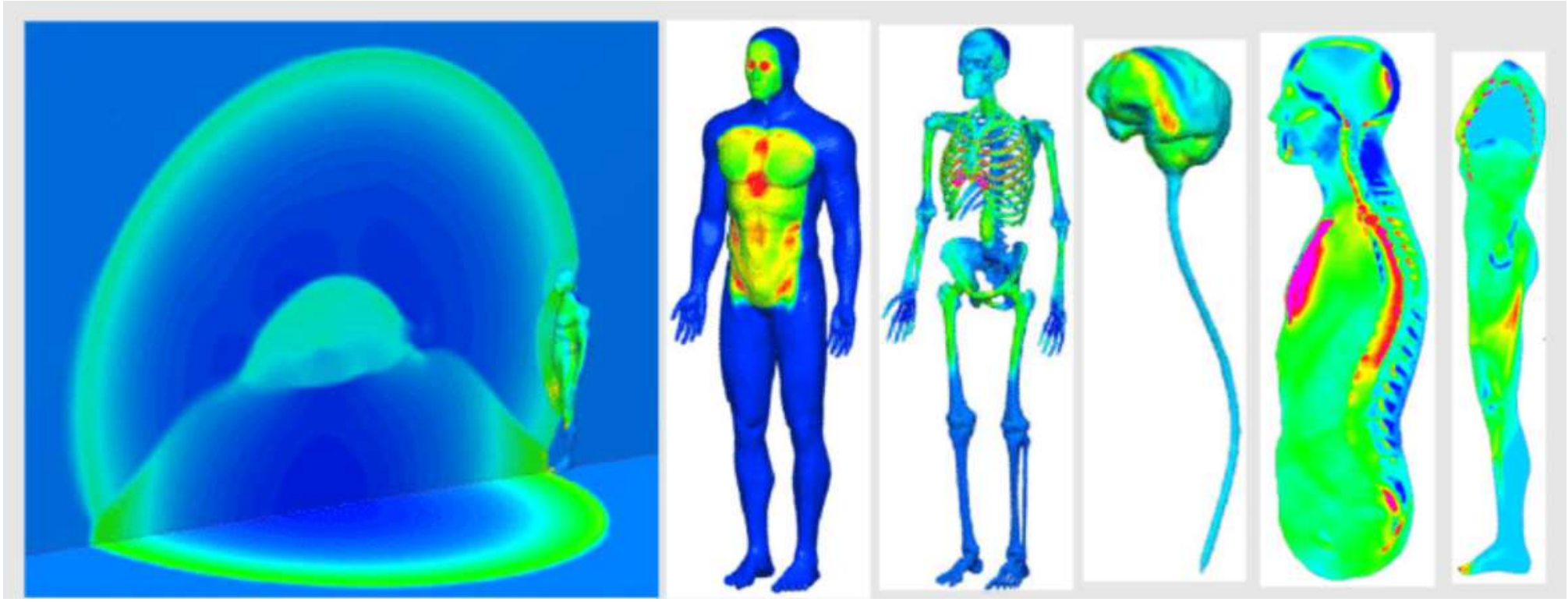






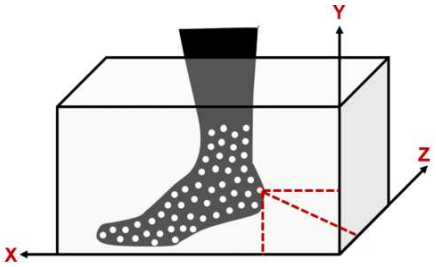
INTRODUCTION: Why Biomechanics?

STUDY OF INJURIES

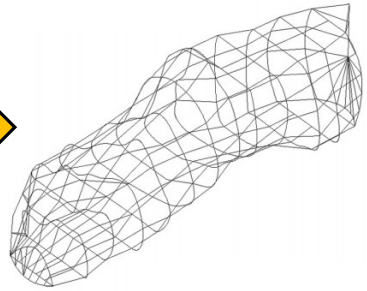


Finite Element Modeling (FEM)

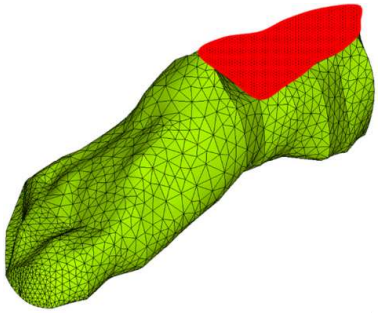
STEPS



Imaging/Scanning

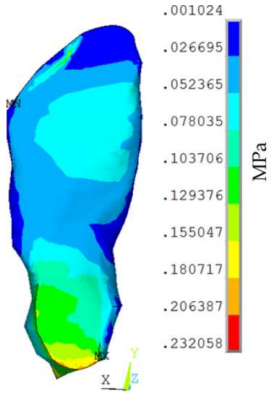


Geometry Modeling



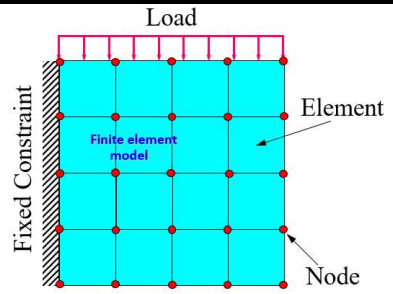
FE Modeling

Finite Element (FE) Software



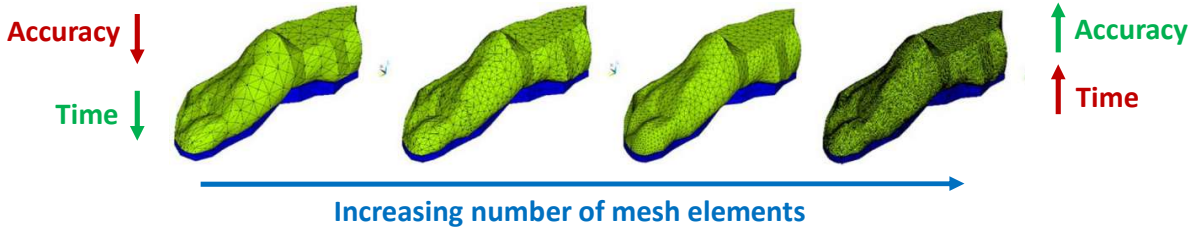
Simulations

Finite Element Modeling (FEM)

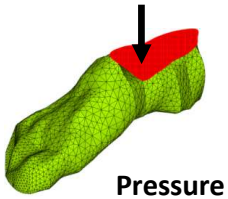


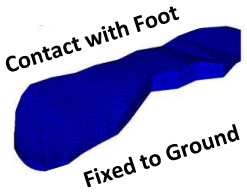
STEPS:

- **FE Meshing**

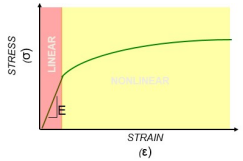


- **Assignment of Loads, Constraints, and Contacts**



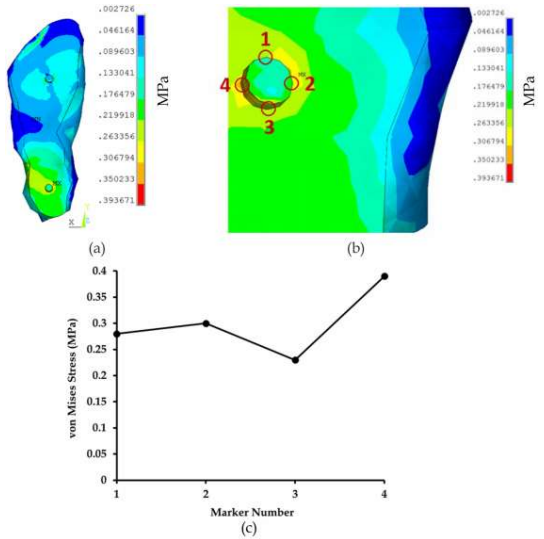


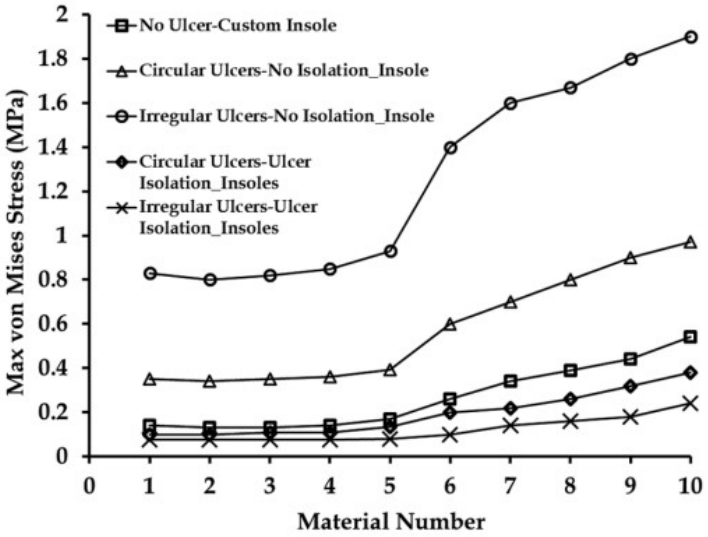
- **Assignment of Material Properties**



- **Analysis**

FEM Analysis



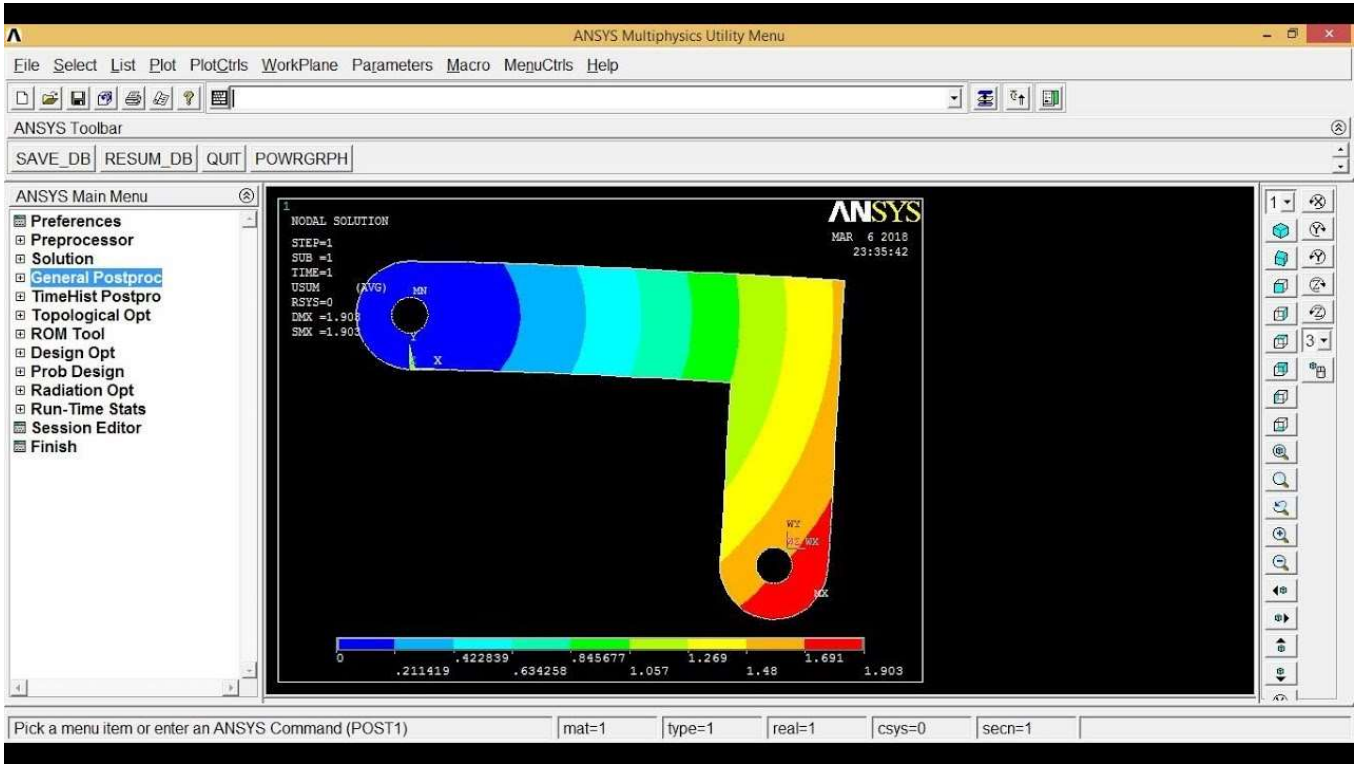


STEPS:

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



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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)