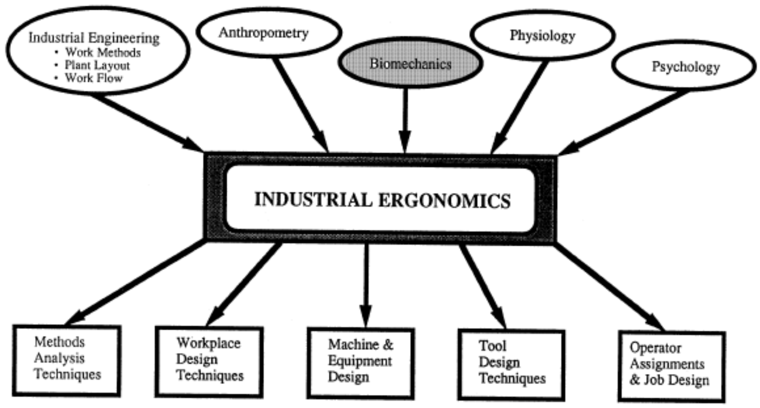
Tools & Techniques



Reference: The Practice and Management of Industrial Ergonomics, David C. Alexander, Prentice-Hall Inc., 1986.

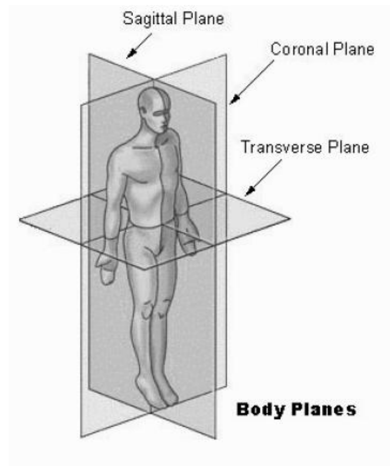
Anatomy

- "The build of the human body"
- 'Subassemblies' of interest in ergonomics
  - spine
    - structure – figures 2.1-2.5
    - potential injuries – figures 2.6-2.7
  - upper extremities
    - figures 2.8-2.15
  - lower extremities
    - figure 2.17
  - joints, cartilage & ligaments, and tendons
    - figures 2.18-2.19

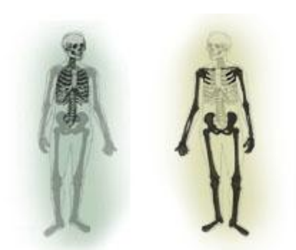
http://training.seer.cancer.gov/module_anatomy/unit3_5_skeleton_divisions.html

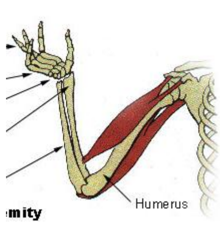
Reference planes & directions

- Planes
  - Coronal Plane (Frontal Plane)
  - Sagittal Plane (Lateral Plane)
    - Median plane
  - Axial Plane (Transverse Plane)
- Directions
  - Proximal
  - Distal
  - Anterior or ventral
  - Posterior or dorsal
  - Medial
  - Lateral
  - Superior or cranial
  - Inferior or caudal



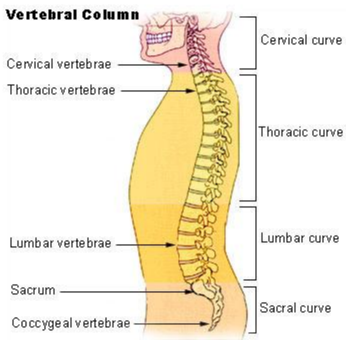
Musculoskeletal System





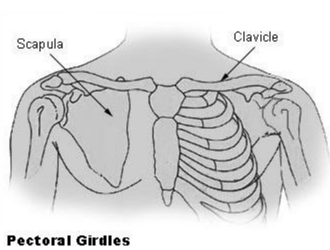
- Skeleton
  - Provides framework for the body
  - Protects the soft body parts
  - With muscles, work as simple mechanical lever systems to produce body movement
- Muscles
  - Provide motion, balance, stability
  - Also responsible for heat production

The Spine

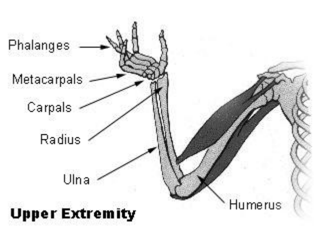


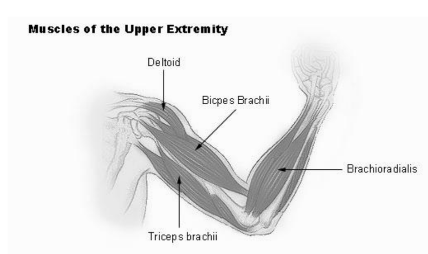
- Complex structure
  - structure – figures 2.1-2.5
  - potential injuries – figures 2.6-2.7
  - a variety of models, including 3-D models are used to predict potential sources of injury

Upper Extremity



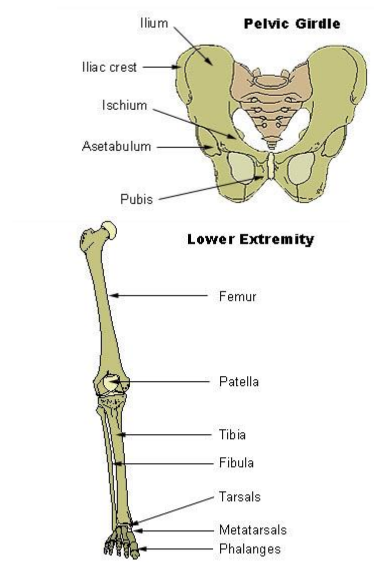
- Divided into shoulder, arm, and hand
  - figures 2.8-2.15





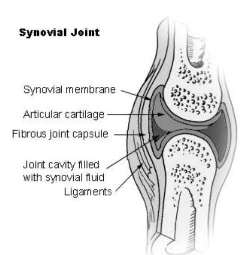
Lower extremity

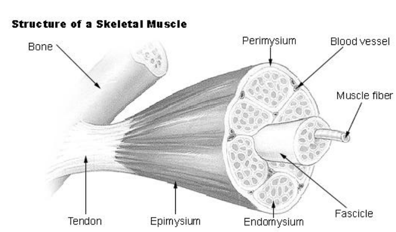
- Source of few occupational injuries
  - Foot and ankle, figure 2.17
- Importance is balance and support for the spine



Joints & Tendons

- Joints (articulations)
  - three types of joints: immovable, slightly movable and freely movable.
  - figure 2.18, pg 24
- Tendons
  - transmit force from muscle to bone
  - figure 2.19, pg. 25





In-Class Exercise 1

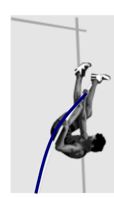
- Complete the following table:

Subassembly	potential cause(s) of injury
spine	
upper extremities	
lower extremities	
joints, cartilage & ligaments, and tendons	

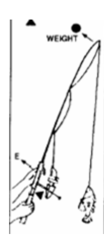
Biomechanics

- Lever systems
  - 1^{st} class levers

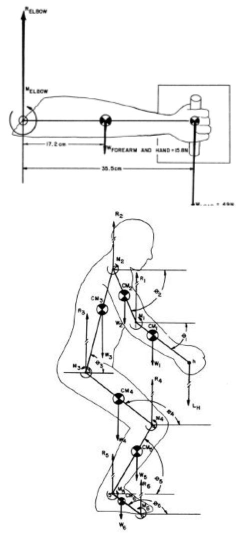
  - 2^{nd} class levers



  - 3^{rd} class levers



Biomechanical Models



- 2-D & 3-D models have been developed
- Simple statics & dynamics can be used to estimate the effect of tool and equipment design on forces exerted on the joints and skeletal system

Your turn …

- Hold your textbook straight out in front of you. On a scale of 1 – 10, where 1 is barely noticeable and 10 is too much to hold, rate the level of effort required.
- Draw the free body diagram of this exercise.
- Now bend your elbow so that you are holding your textbook up at a 90° angle to your upper arm. Rate the level of effort required for this.
- Draw the free body diagram of this exercise.
- Now hold out your note packet straight out and at a 90° angle. Rate the level of effort required for each of these.
- Use the free body diagrams to explain the differences among your ratings.

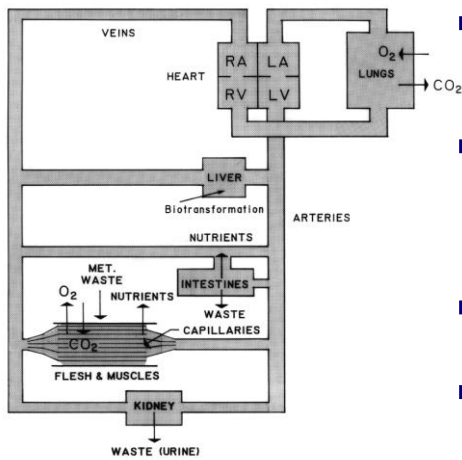
Biomechanics Exercise

Situation	Level of Effort	Free Body Diagram
Textbook held straight out		
Textbook held at 90° angle		
Notes held straight out		
Notes held at 90° angle		

Factors affecting force capabilities

- Posture
- Individual differences
- Gender
- Age
- Training

Cardiovascular Anatomy



- *Pulmonary circulation* passes blood through the heart and lungs.
- *Systemic circulation* passes blood through the arteries, capillaries, and veins.
- Blood transfers gases, compounds, and heat.
- If legs are immobile, blood pools in them (venous pooling)

Cardiac Output

- Output of left ventricle:

  $CO = HR \times SV$

- Basal cardiac output:

  $COBASL = CI \times DBSA$

- Activity cardiac output:

  $COACT = CLMW \times TOTMET$

Metabolism

- Basal metabolism: maintains body temperature, body functions, blood circulation.
  - 1.28 W/kg for males
  - 1.16 W/kg for females
- Activity metabolism: provides energy for activities
  - Very light work: $<100\ W/m^2$
  - Light work: $100 – 165\ W/m^2$
  - Moderate to heavy work: $\geq 165\ W/m^2$
- Digestion metabolism: accounts for transformation of food

Metabolism and Body Weight

- Calorie requirement (in kcal)

$$(BSLMET*T + DIGMET*T + \sum(ACTMET_i*t_i))*0.86\ kcal/W\text{-}hr$$

*note: DIGMET is the weighted average given by:

$$DIGMET = 0.1*(BSLMET + \sum(ACTMET_i*t_i)/T)$$

Where $T = \sum t_i$, in hrs.

- Eating more or less results in weight gain or loss.

Your turn …

- A 6 ft tall, 175 pound man works as a carpenter. He spends 1.5 hours per day driving to and from work. At work, he spends a total of about 4.5 hours doing "heavy carpentry", 1 hour sawing with a handsaw, and 0.5 hour cleaning up (i.e., sweeping.) What is the metabolic cost of this job?

Responses to Exercise

1. Heart rate
2. Stroke volume
3. Artery–vein differential
4. Blood distribution
5. Going into debt

Heart Rate

- Measuring Heart Rate
  - Shining light on artery in earlobe
  - Listening to sound through stethoscope
  - Detecting surge of blood with fingers (palpation)
  - Electronic recording and analysis
  - Estimated by “rating of perceived exertion” (RPE)
- Effect of metabolic activity

  INCHR = K + 0.12* INCMET

  K = 2.3 (arm work)

  -11.5 (arm and leg work)

An example …

- A 175 pound man is performing a job (arm and leg work) that increases his heart rate by 43 beats per minute. What is the metabolic cost (i.e., increase in metabolic rate) associated with this job? What is the man’s overall metabolic rate at work?

Stroke Volume

- Amount of blood pumped through left ventricle
- Adjusts oxygen supply to the body
- Depends on exertion, body posture, exercise, and physical fitness
- Peaks at about 40% of maximum oxygen consumption

Artery–Vein Differential

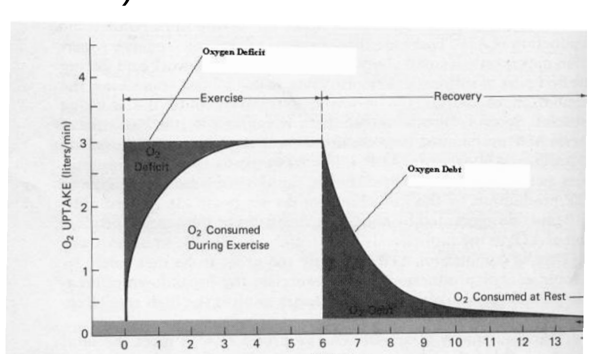
- Difference between oxygen content of blood in arteries and blood in veins
  - Resting a-v differential is ~ 4 mL O_2 / 100 mL of blood
  - Increases in emergencies to up to 13 mL / 100 mL
  - Normal coronary blood artery–vein differential is 17 mL / 100 mL

Blood Distribution

- During exercise, capillary density and muscle blood flow increase.
  - Blood flow to kidneys and intestines decreases
  - Cramps may result from reduced digestion.

Going into Debt

- Muscles draw on anaerobic oxygen stored in blood
- Anaerobic supply is limited and must be repaid (with interest)



Cardiovascular Limits

- Individual's work capacity is determined from maximum oxygen uptake (*VO_2max*).
- *VO_2max* is product of cardiac output and A–V differential.
- Determined from treadmill or ergonometer test, step test, or walk/run test.
- Testing for screening purposes is controversial.

Cardiovascular Limits

- What proportion of capacity is reasonable for work?
  - Avoid anaerobic metabolism:
    - 50% for trained workers
    - 33% for untrained workers
  - Reduce for longer shifts.
  - Mechanize high metabolic rate jobs.
  - Reduce cardiovascular stress:
    - Engineering solutions (motors, wheels, balancers)
    - Administrative solutions (job rotation, part-time work)

Gender, Age, and Training Effects

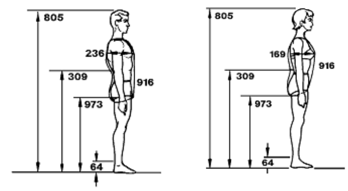
- Average female VO_2max 15–30% lower than males.
- VO_2max decreases approx. 1–2%/yr after age 25.
  - Most of decline due to low physical activity and increased body fat, not age itself.
- Fitness can improve cardiovascular endurance, muscle strength, and flexibility.
  - If work loads muscles dynamically, relax and stretch them.
  - If work loads muscles statically, exercise should move them.
- Industrial tasks should not require max output.

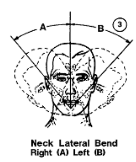
Responses to Mental Work

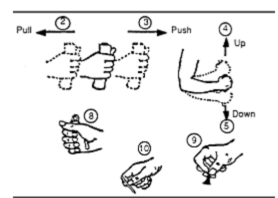
- Mental load can be measured by heart rate variability.
- Low variability corresponds to high mental load.

Anthropometry

- Literally, 'The measure of man'
  - quantifies human variability
- What?
  - physical measures
  - height, weight, reach, length, width, depth, circumference, surface area, etc.
  - strength, dexterity, range of motion





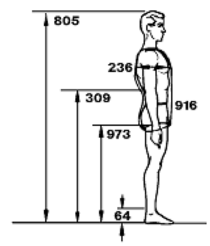


Why?

- We are not all the same size.
  - Exclude as few as possible:
    - "Let the small person reach, let the large person fit."
  - Poor design for mechanical abilities of the human body can lead to discomfort or injury, e.g., the height of keyboard for a computer.
- Sources of Anthropometry Data
  - Text
    - Ergo software
  - Tables in books in the HF/SQC lab (215)
  - Online sources, e.g.
    http://mreed.umtri.umich.edu/mreed/downloads.html#ansur

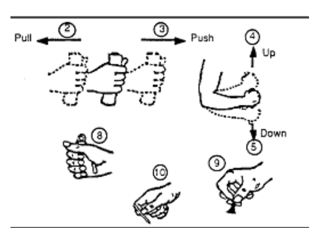
Example Anthropometric Data

- Static Measures
  - Passive measures of the dimensions of the human body.
  - These measures are used to determine size and spacing requirements of work space.
  - Example Measures
    - arm length (e.g., your lab …)
    - height
    - weight
    - wing span
    - seat to elbow height.



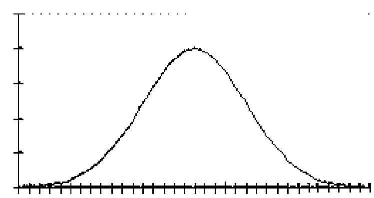
More Anthropometric Data

- Dynamic Measures
  - Measures of the dynamic properties of the human body, such as strength and endurance.
  - These measures are used to match the dynamic characteristics of controls to user.
  - Measures
    - range of motion for various joints
    - force of leg pushes
    - strength of fingers



How?

- Populations
- Tools & techniques
- Statistical calculations
  - based on central limit theorem
  - typical calculations
    - mean
    - standard deviation
    - percentiles
      - from ordered data
      - estimate for normal distribution



An Example …

A study was performed to determine key anthropometric measures of school-aged children to be used in the design of playground equipment. Based on a sample size of 1050, the vertical reach of 7-year old boys was found to have a mean of 57.1 inches and a standard deviation of 3.3 inches.

- 5th percentile = ______________________ (z = _______)
- 50th percentile = ______________________ (z = _______)
- 95th percentile = ______________________ (z = _______)

Using Anthropometric Data

- Know your population
  - If your measures are from a different group than your users are from problems could result.
    - Women are different from men.
    - Asians are different from Europeans.
- Use Recent Data
  - Changes in diet and habit lead to changes in size and fitness of population
  - Most size measures are done on nude or lightly clothed subjects.
    - clothes change our sizes
      - think of seat belts in summer vs. winter.

Using Anthropometric Data

- Understand the task
  - how will the system or device be used?
  - reach, fit, & strength requirements
- Cautions about adding segments:
  - every measure contains variability
    - $s_t^2 = s_1^2 + s_2^2 + s_3^2 + \ldots$
  - the n^{th} *percentile* person is not composed of n^{th} percentile segments

Using Anthropometric Data

- Refer to Table 2.10 on page 44 of your text.
  - (“Let the small person reach …”) If you were designing a console requiring a forward reach to activate a control, what reach distance would you use to define your maximum console depth?
  - (“Let the large person fit …”) What is the minimum height of the bottom of the console if the operator is seated?

Your turn …

- In-class design problem (if we have time):

  Design a student desk & chair for the engineering school. Assume the student population mirrors the general population. How do the tables and chairs used in the building compare to your design?