HUMAN FACTORS IN ENGINEERING

UNIT 1

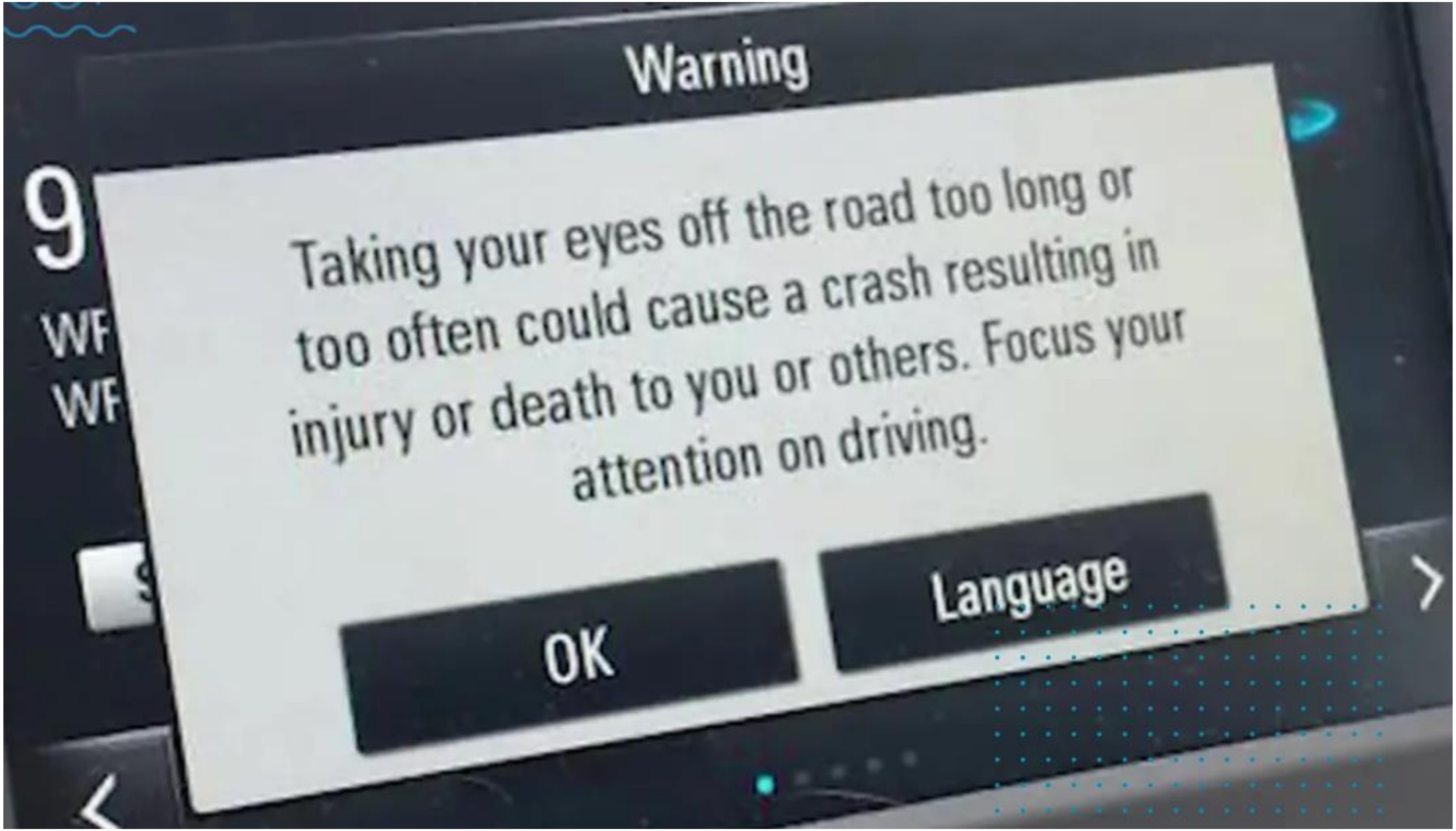
- **Fundamentals of Human Factors Engineering**: Human Biological, Ergonomic and psychological capabilities and limitations, Concepts of human factors engineering and Ergonomics, Man-Machine system and Design philosophy.
- **Physical work and energy expenditure**: Manual lifting, Work posture, Repetitive motion, Provision of energy for muscular work, Heat stress, Role of oxygen physical exertion, Measurement of energy expenditure, Respiration, Pulse rate and blood pressure during physical work, Physical work capacity and its evaluation.

Fundamentals of Human Factors in Engineering

- Have you ever used a tool, device, appliance, or machine and said to yourself, "**What a dumb way to design this; it is so hard to use!**

- If you have had such experiences, you have already begun to think in terms of human factors considerations in the design of things people use.

What a dumb designs these are !!!!!!!


Warning
Taking your eyes off the road too long or too often could cause a crash resulting in injury or death to you or others. Focus your attention on driving.
OK
Language


GIVE
CYCLISTS
SPACE

HUMAN FACTORS AND ERGONOMICS

- **Human factors and ergonomics** (commonly referred to as **human factors**) focuses on human beings and their interaction with products, equipment, facilities, procedures, and environments used in work and everyday living.

- The emphasis is on human beings and how the design of things influences people

- Human factors seeks to change the design of things to better match the capabilities, limitations, and needs of people.

OBJECTIVES OF HUMAN FACTORS

- The first objective is to enhance the effectiveness and efficiency with which work and other activities are carried out.

- Included here would be such things as increased convenience of use, reduced errors, and increased productivity.

- The second objective is to enhance certain desirable human values, including improved safety, reduced fatigue and stress, increased comfort, greater user acceptance, increased job satisfaction, and improved quality of life

APPROACH OF HUMAN FACTORS

- Commitment to the idea that things, machines, etc. are built to serve humans and must be designed always with the user in mind

- Recognition of individual differences in human capabilities and limitations and an appreciation for their design implications

- Conviction that the design of things, procedures, etc. influences human behaviour and well-being.

APPROACH OF HUMAN FACTORS

- Emphasis on empirical data and evaluation in the design process

- Reliance on the scientific method and the use of objective data to test hypotheses and generate basic data about human behavior

- Commitment to a systems orientation and a recognition that things, procedures, environments, and people do not exist in isolation

INTRODUCTION TO HUMAN FACTORS

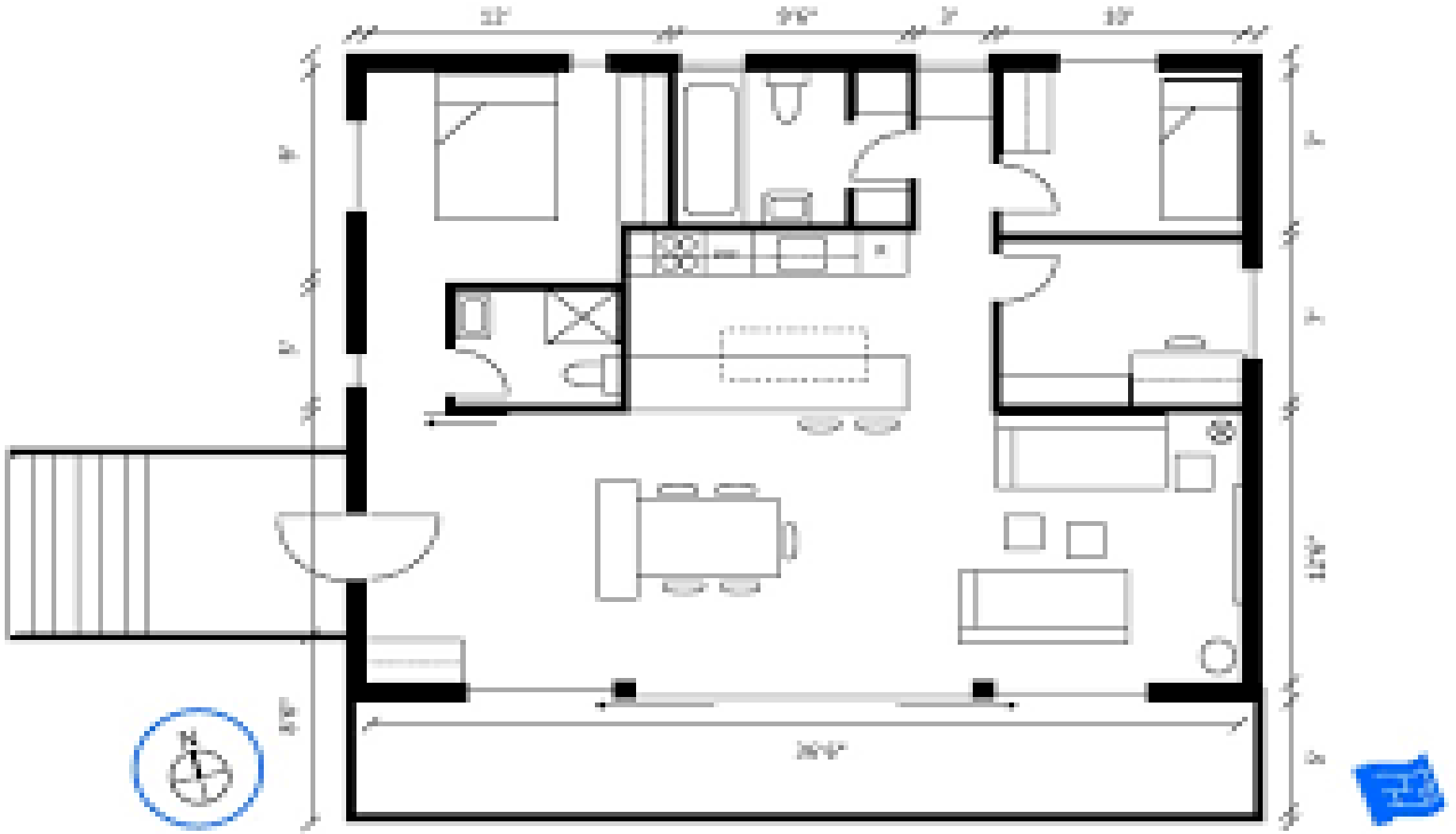
- Human factors is not just applying checklists and guidelines.
- Human factors is not using oneself as the model for designing things.
- Just because a set of instructions makes sense to an engineer, there is no guarantee others will understand them.

INTRODUCTION TO HUMAN FACTORS

- Just because a designer can reach all the controls on a machine, that is **no guarantee** **that everyone else** will be able to do so.

- Human factors recognizes **individual differences** and the **need to consider** the **unique characteristics** of user populations in designing things for their use

Civil Engineer trying to explain the building model



This is much better to understand !!!

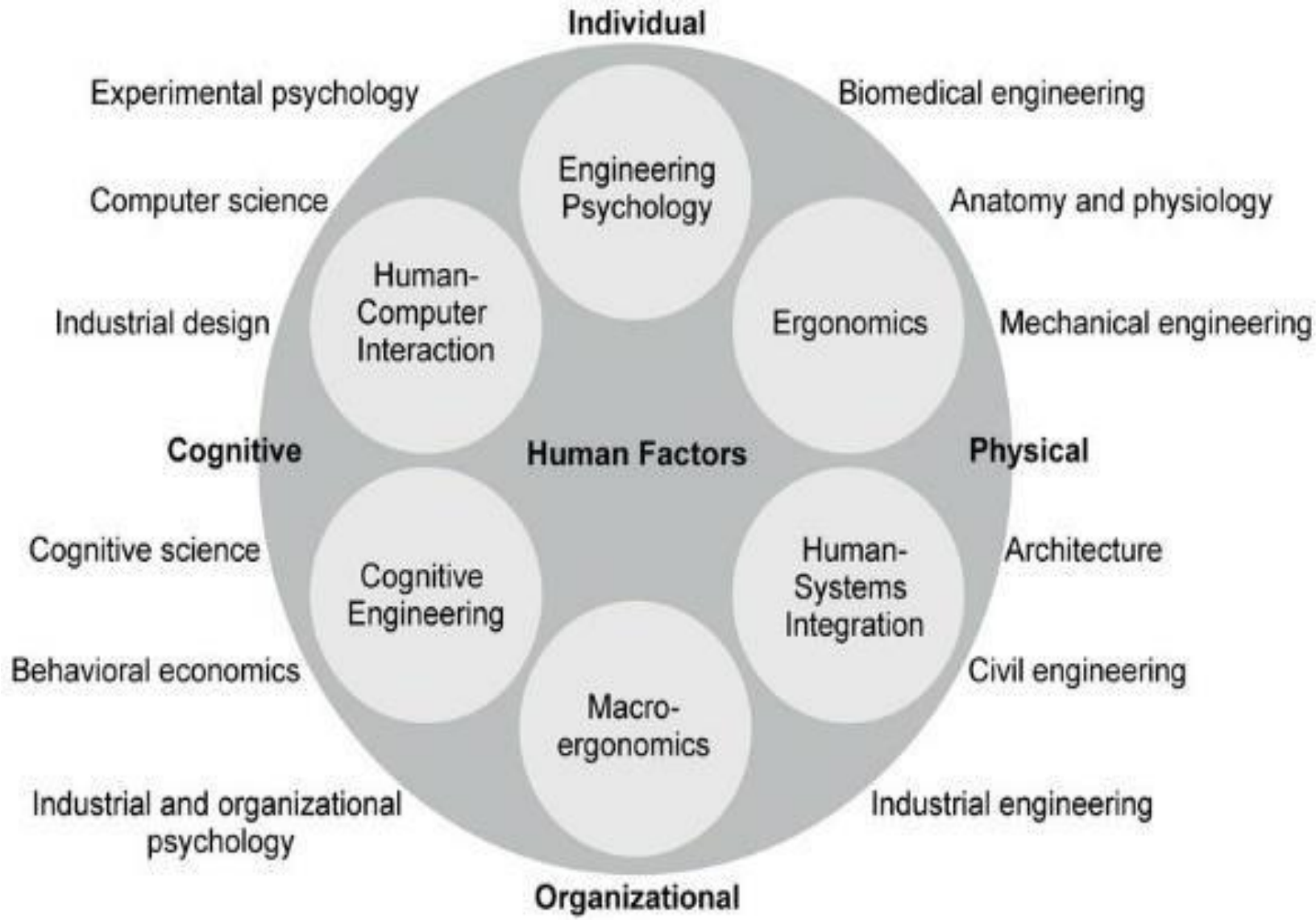
Comfortable post box height

Is it comfortable Height !!!!!

A comfortable design of scissors

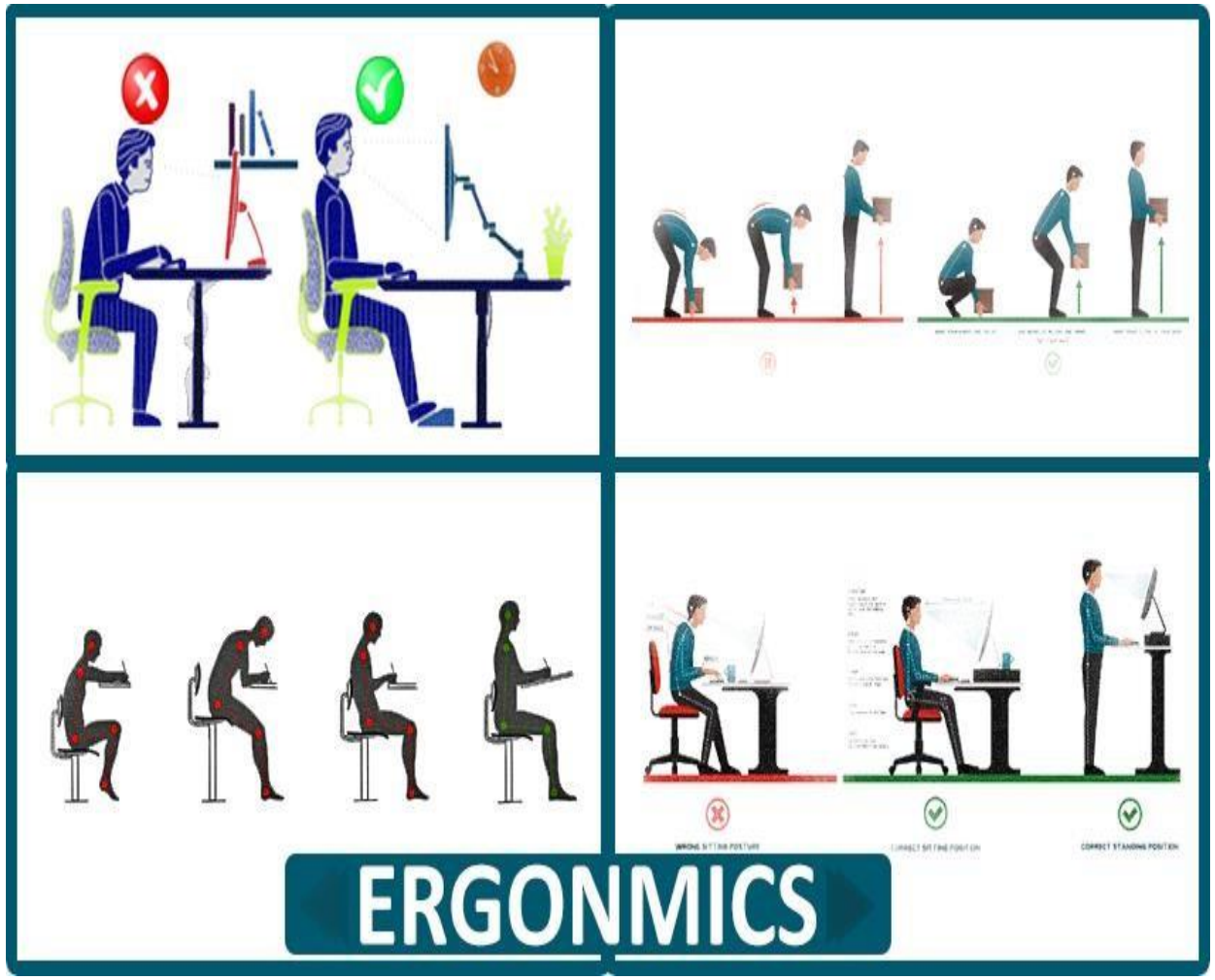
Not for me as I am a lefty

Design for human comfort


Individual
Experimental psychology
Biomedical engineering
Computer science
Anatomy and physiology
Industrial design
Mechanical engineering
Cognitive
Physical
Cognitive science
Architecture
Behavioral economics
Civil engineering
Industrial and organizational psychology
Industrial engineering
Organizational
Engineering Psychology
Human-Computer Interaction
Ergonomics
Human Factors
Cognitive Engineering
Human-Systems Integration
Macro-ergonomics

ERGONOMICS

- Ergonomics is the **science and art of** fitting the **job** and the **workplace** to **workers needs**.
- It is a way to make jobs/tasks fit the **employees better**
- It is a way to make **work easier**



HUMAN BIOLOGICAL CAPABILITIES AND LIMITATIONS

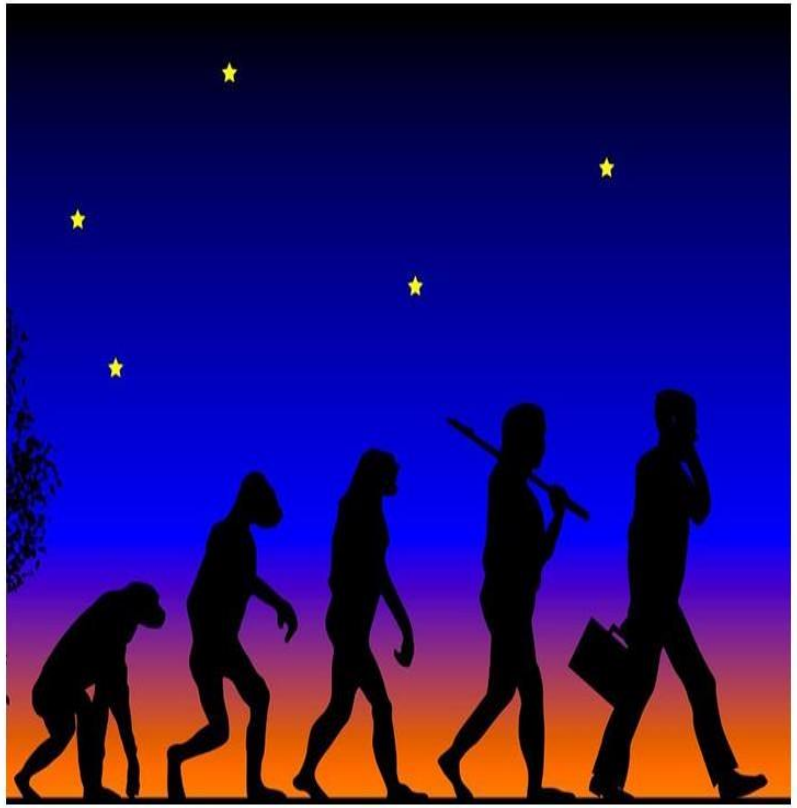
- The key aspects of **human biology** are those ways in which humans are substantially different from other mammals.

- Humans have a very large brain in a head that is very large for the size of the animal.

- This large brain has enabled a range of unique attributes including the development of complex languages and the ability to make and use a complex range of tools.

- The upright stance and bipedal locomotion is not unique to humans but humans are the only species to rely almost exclusively on this mode of locomotion.

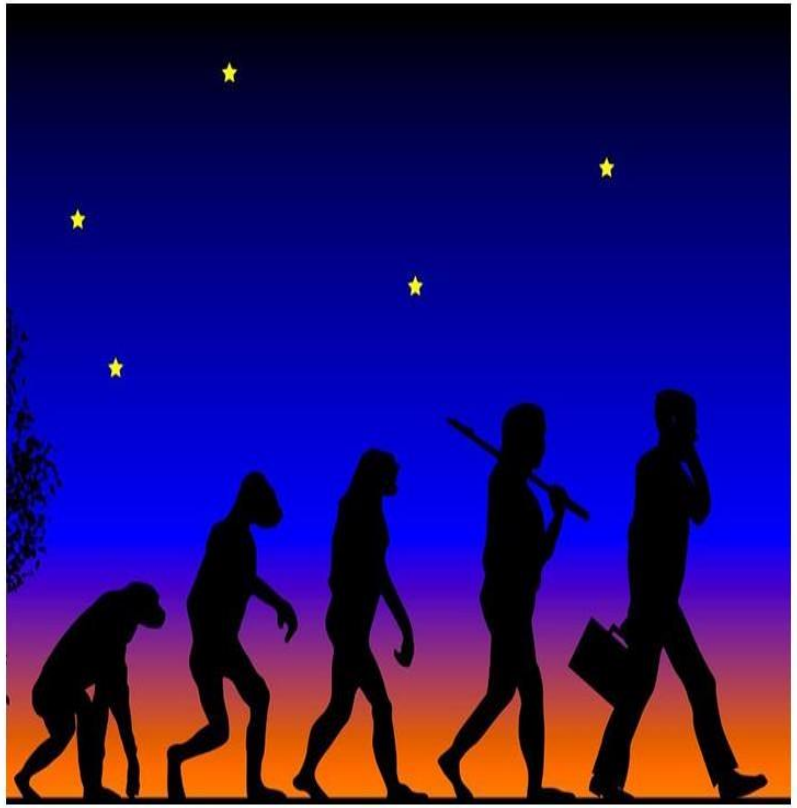
- In comparison with most other mammals, **humans** are very long lived.



- The human eye can see objects in colour but **is not well adapted to low light conditions**.

- The sense of smell and of taste are present but are relatively **inferior to a wide range of** other mammals.

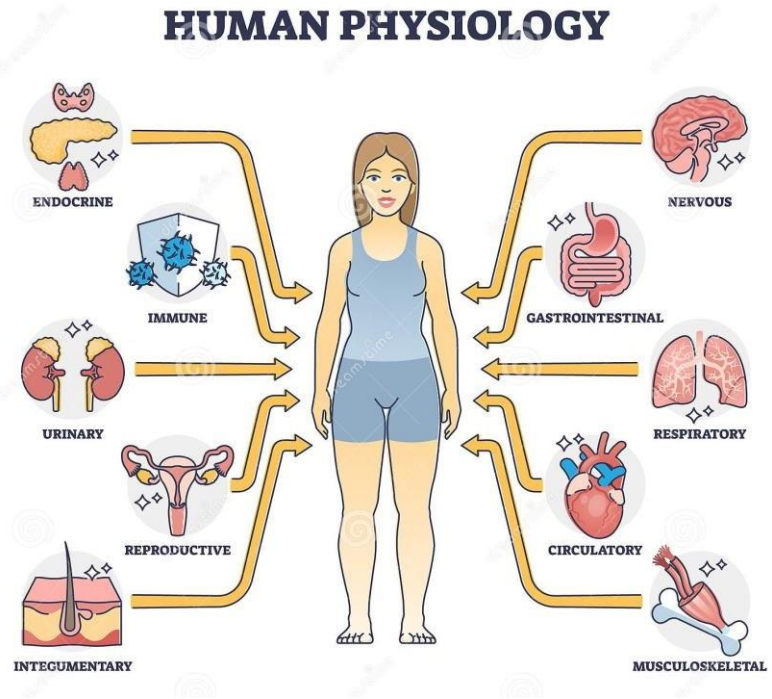
- Human **hearing is efficient** but lacks the acuity of some other mammals.



- Similarly human **sense of touch** is well developed especially in the **hands where dexterous tasks** are performed but the sensitivity is still significantly less than in other animals, particularly those equipped with sensory bristles such as cats.

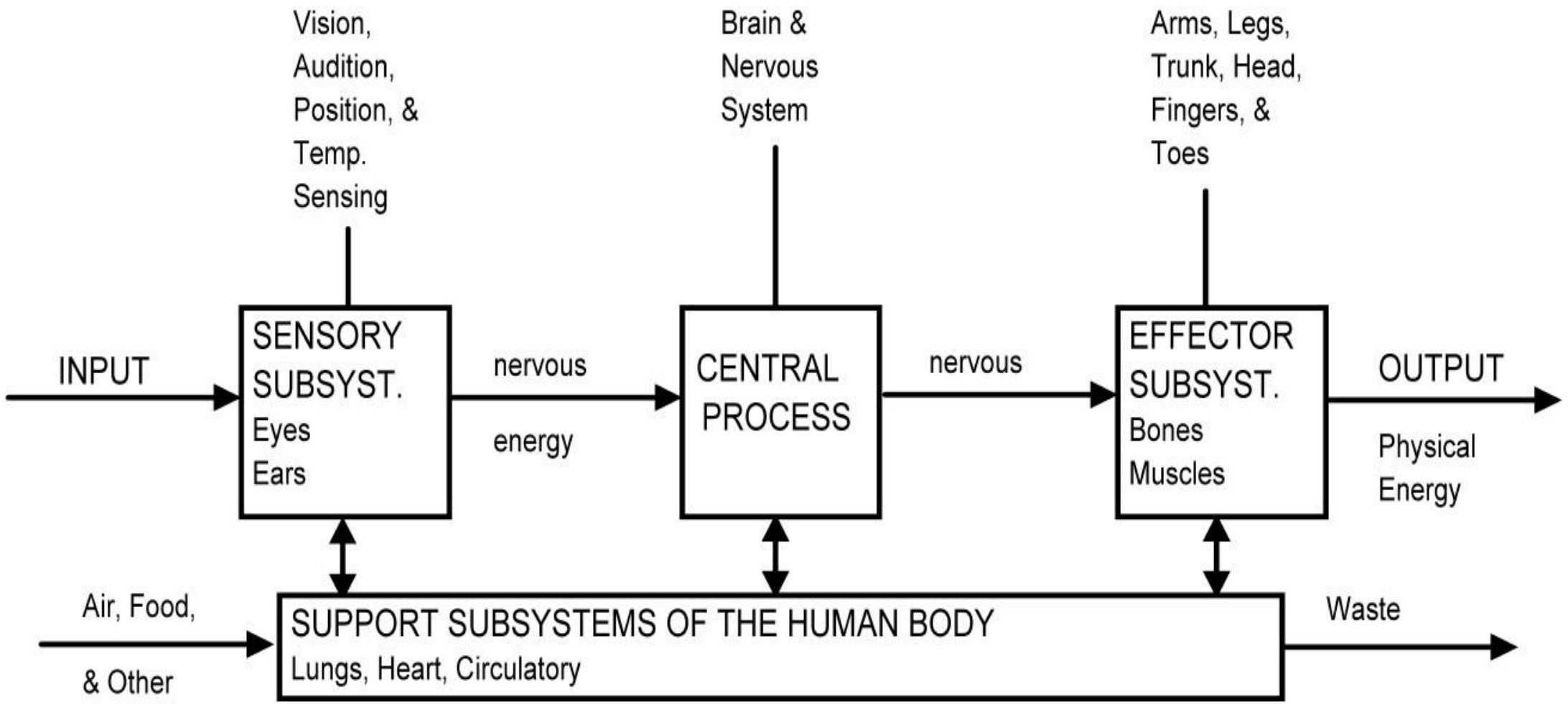
PHYSIOLOGY

- Physiology is the **study of** the functions of living things at **various levels of organization** (such as molecular level, cellular, tissue level etc).



- Physiology tests **how organs and systems within the body work**, how they communicate, and how they combine their efforts to make conditions **favorable for survival**.

Subsystems of the human body.



1. The ***sensory* systems** (vision, hearing, position, touch, taste, and smell) are stimulated by energy sources (e.g., light, sound, or heat) or materials (e.g., airborne chemicals, acid on skin, salt on tongue) in the outside environment.

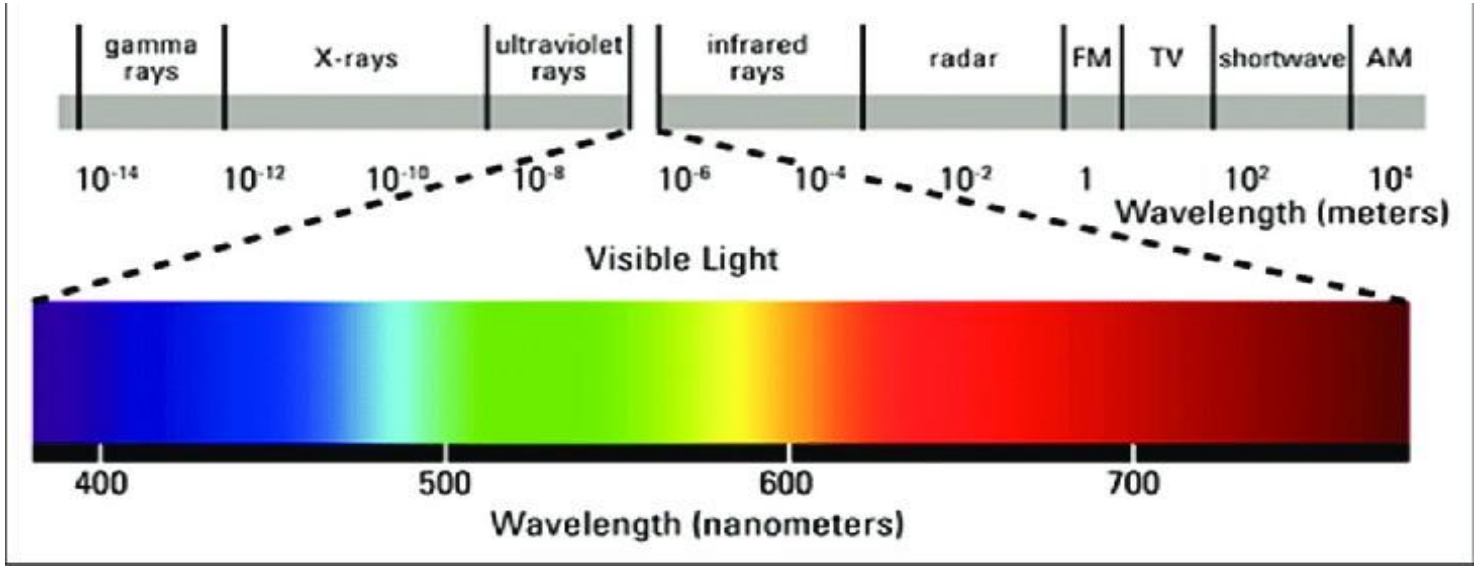
2. The **central *information processor*** (brain and nervous system) processes information acquired from the sensory systems.

3. The ***effector* systems** (arms, hands, eyes, legs, etc.) are consciously controlled to modify the environment and acquire information.

4. The ***support* sy**stems (circulatory, digestive, metabolic, heat-regulatory, etc.) act in various ways to keep the other systems functioning.

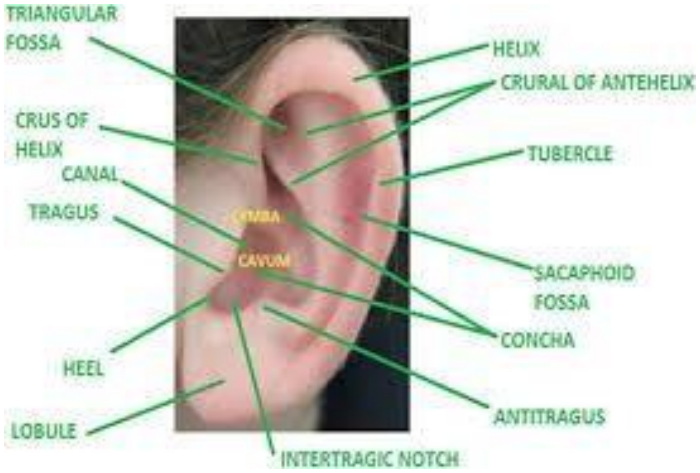
Human eye

- Almost 180 degree horizontal filed of view
- Stereoscopic view allows for depth perception
- High resolution image reception in direct field
- Peripheral vision – low resolution but excellent motion detection
- Visible spectrum only



Human ear

- The commonly stated range of human hearing is 20 to 20,000 Hz
- Under ideal laboratory conditions, humans can hear sound as low as 12 Hz, and as high as 28 kHz
- The human auditory system is most sensitive to frequencies between 2,000 and 5,000 Hz
- The range shrinks during life, usually beginning at around the age of eight with the upper frequency limit being reduced

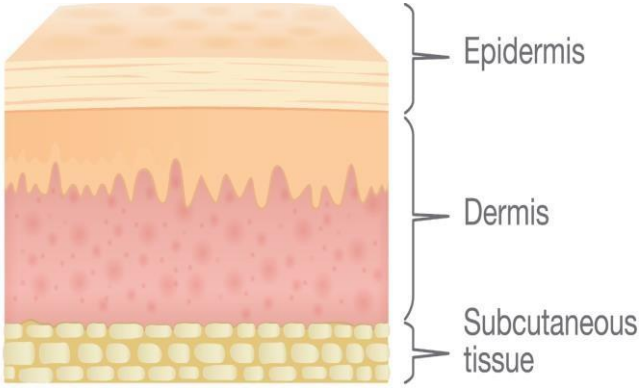


Human nose

- The human nose can distinguish at least 1 trillion different odours
- A human nose has around 400 scent receptors

Human skin

- Our sense of touch is controlled by a huge **network of nerve endings and touch** receptors in the skin known as the somatosensory system.
- Skin is capable of **sensing various levels of contact force, temperature etc**



Human tongue

- The tongue is a true all-rounder. It is not only very movable, which **allows us to speak, suck or swallow in a coordinated way.**

- **It helps us to recognize the taste of the food that is essential for us to remember the taste**

- we know that different regions of the tongue can detect **sweet, sour, bitter and salty**.

A Summary of Human Sensory Processes.

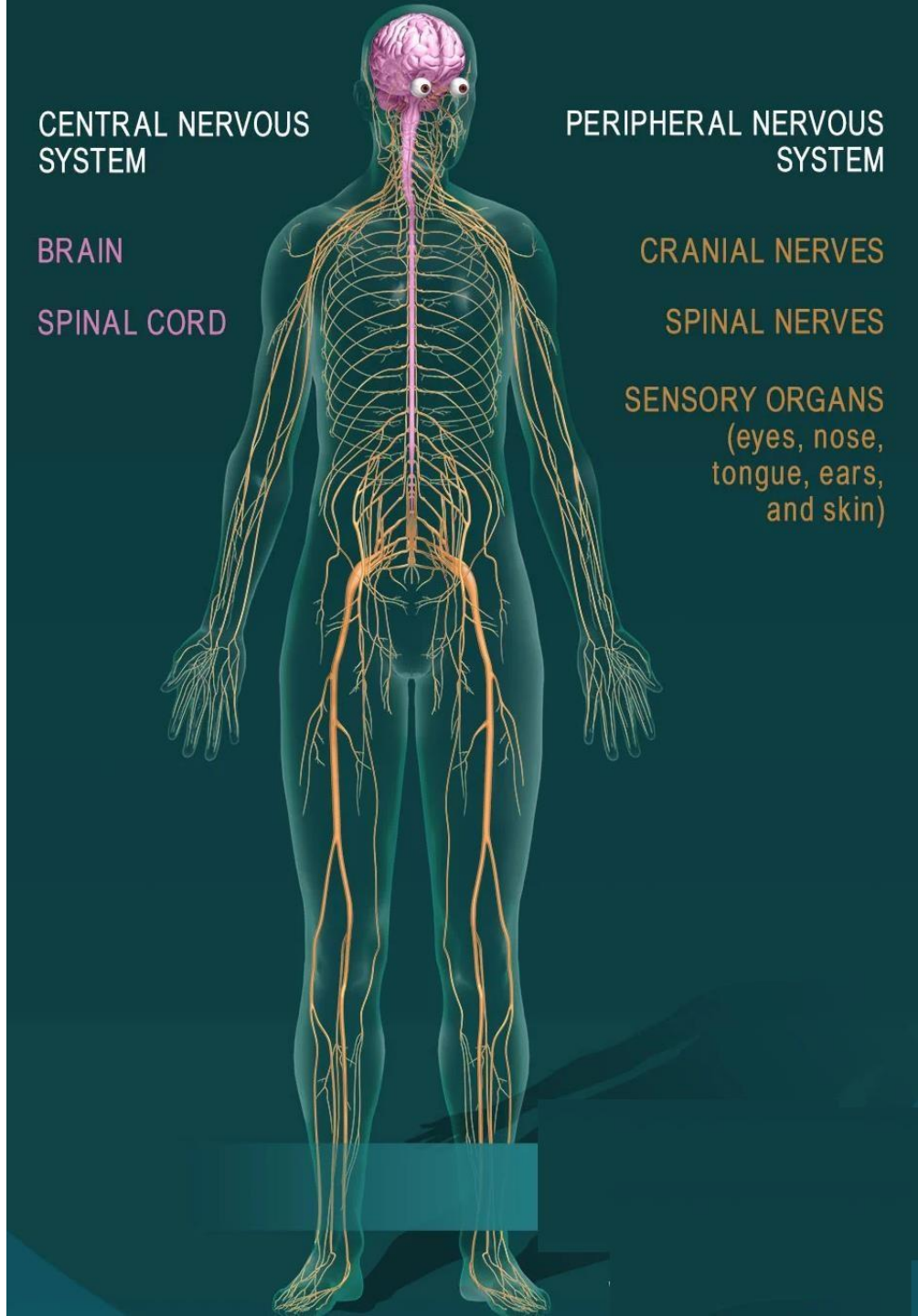
Sensation	Organ	Source of stimulation
Sight	Eye	Electromagnetic energy
Hearing	Ear	Air pressure intensity and frequency change
Rotation	Semicircular Canals of Inner Ear	Fluid pressure change in the inner ear
Taste	Tongue and Mouth	Chemical substances in saliva
Smell	Top of the Nasal Cavity	Vaporized chemical substances
Touch	Skin (mostly)	Surface deformations up to 4,000 pulses/second
Tactile (Vibration)	Skin (mostly)	Vibration amplitude and frequency of mechanical pressure
Pressure	Skin and Tissue below	Deformation
Temperature	Skin & elsewhere	Change in temperature–radiation, convection, and contact
Pain	Skin Partially	Pressure
Position & Movement	Muscle & Tendon ends	Muscle contraction or stretching

BRAIN AND NERVOUS SYSTEM

- Our nervous system is your body's command center. Originating from your brain, **it controls your movements, thoughts and automatic responses**.

- The brain is a complex organ that **controls thought, memory, emotion, touch, motor skills, vision, breathing, temperature, hunger and every process that regulates our body**.

- Peripheral nervous system (PNS) is that part of your nervous system that lies outside your brain and spinal cord. It plays key role in both **sending information from different areas of your body back to your brain, as well as carrying out commands from your brain to various parts of your body**



Musculoskeletal system

- Musculoskeletal system **includes your bones, cartilage, ligaments, tendons and connective tissues**.

- Skeleton provides a framework for your muscles and other soft tissues.

- Together, they support your body's weight, maintain your posture and help you move.

Support Sub systems

Circulatory System

- The blood **circulatory system** is a system of organs that includes the heart, blood vessels, and blood which is circulated throughout the entire body of a human or other vertebrate.

Respiratory System

- The respiratory system is **the network of organs and tissues that help you breathe**.
- It includes your airways, lungs and blood vessels. The muscles that power your lungs are also part of the respiratory system.

PHYSIOLOGICAL LIMITATIONS

Human physical and physiological limitations can alter throughout working life, and refer to, for example:

- Poorer eyesight and / or hearing.
- Reduction in memory capacity.
- Reduced strength.
- Increased fatigue.

These factors should be monitored to ensure staff remains fit for work.

HUMAN PSYCHOLOGICAL CAPABILITIES AND LIMITATIONS:

Human psychological capabilities and limitations refer to the range of mental abilities and constraints that are inherent to the human mind.

CAPABILITIES:

Perception: Humans have the ability to perceive their environment through their senses, including vision, hearing, taste, smell, and touch.
Attention: Humans can focus their attention on specific things or tasks, allowing them to filter out distractions and concentrate on what is important.
Memory: Humans can store and retrieve information in their memory, allowing them to learn from past experiences and make better decisions in the future.
Language: Humans have the ability to use language to communicate with others, expressing their thoughts and ideas, and understanding others.
Creativity: Humans have the ability to think creatively, coming up with new ideas and solutions to problems.

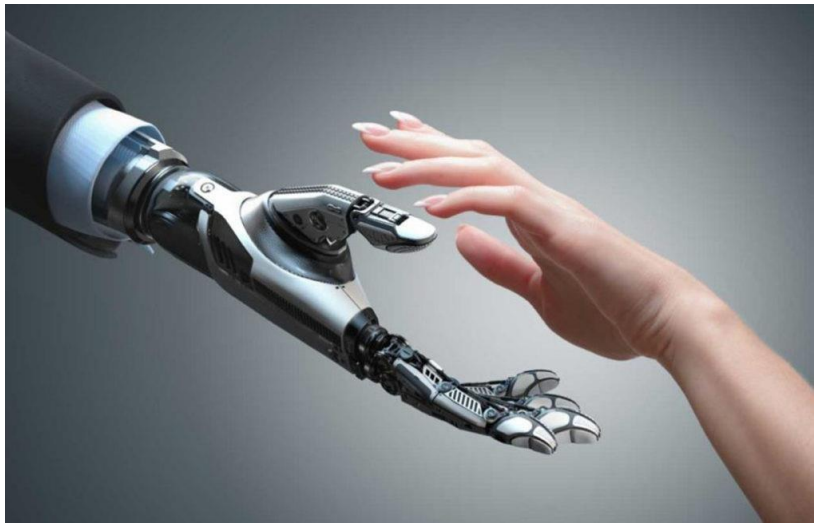
LIMITATIONS:

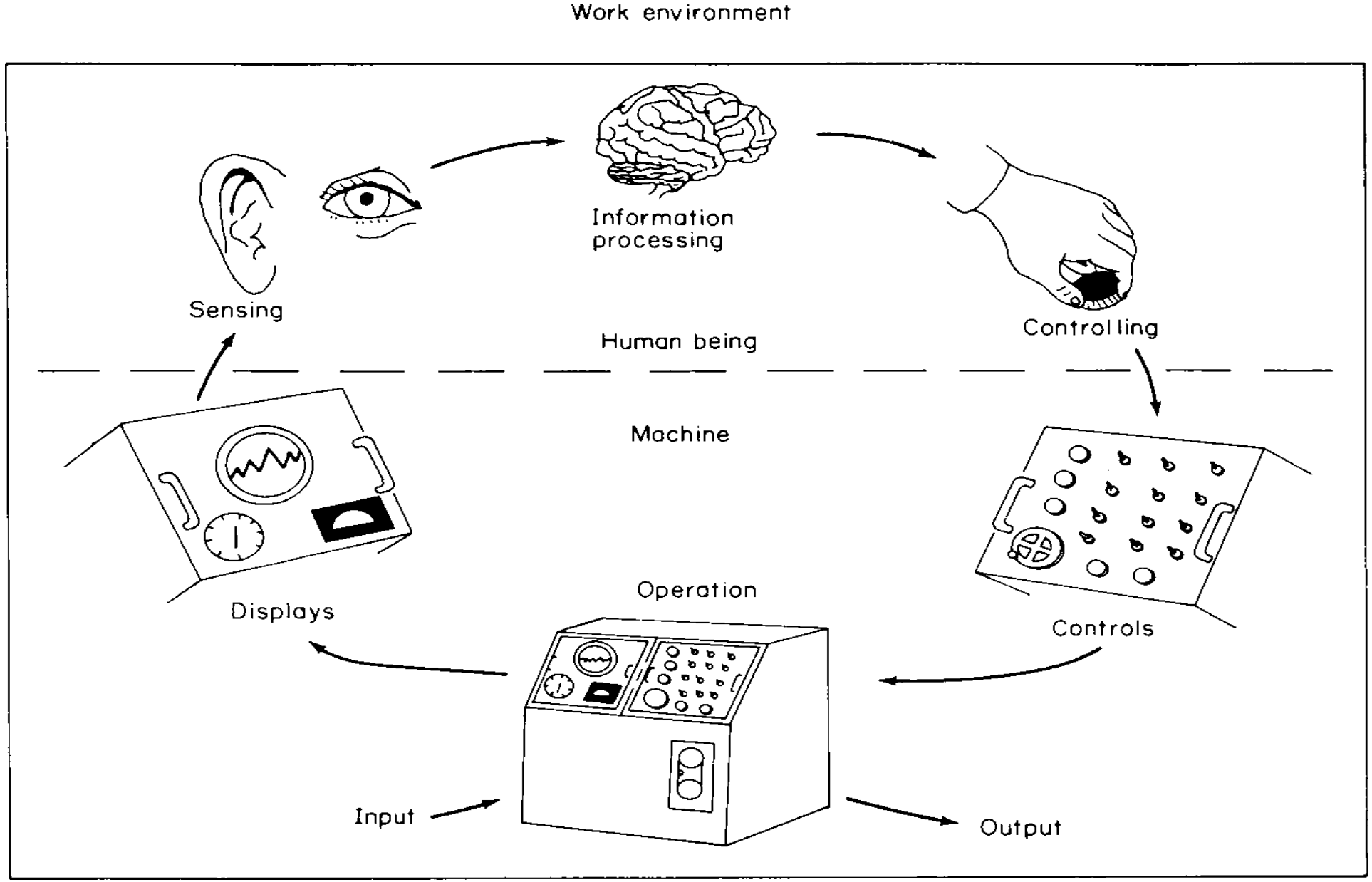
Cognitive biases: Humans are prone to cognitive biases, which can lead to errors in thinking and decision-making.
Limited attention span: Humans have a limited capacity for sustained attention, making it difficult to focus on complex or lengthy tasks for extended periods.
Limited memory capacity: Humans have a limited capacity for storing and retrieving information, which can make it difficult to recall details from the past or remember important information.
Emotional biases: Humans are influenced by their emotions, which can lead to biased thinking and decision-making.
Limited processing speed: Humans have a finite processing speed, which can make it difficult to process large amounts of information quickly.

Understanding these capabilities and limitations can help us better understand how the human mind works and develop strategies to overcome its limitations and maximize its potential.

THE MAN-MACHINE SYSTEM

- **The man-machine system consists of the man, the machine and system environment**
- A man machine system can be as simple as a person working with a small tool like hammer and it can go up to any level of complexity.




Work environment
Information processing
Sensing
Controlling
Human being
Machine
Displays
Controls
Operation
Input
Output

Types of man machine systems

- Manual System
- Mechanical System
- Automated system

Manual System

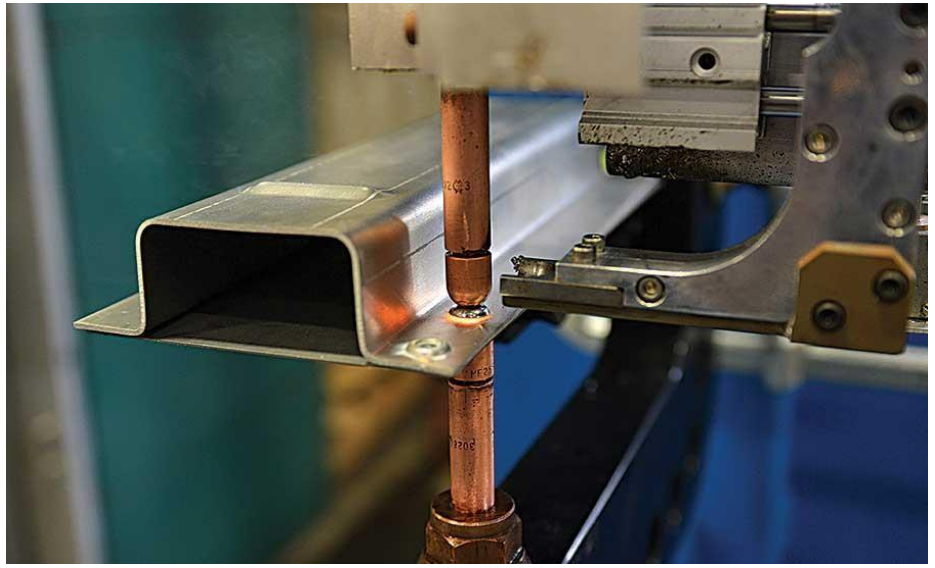
- A *manual system* consists of hand tools and other aids which are coupled by a human operator who controls the operation.

- Operators of such systems use their own physical energy as the power source.

MECHANICAL SYSTEMS

- These systems (also referred to as *semiautomatic* systems) consist of well-integrated physical parts, such as various types of powered machine tools.

- The power typically is provided by the machine, and are generally designed to perform their functions with little variation.

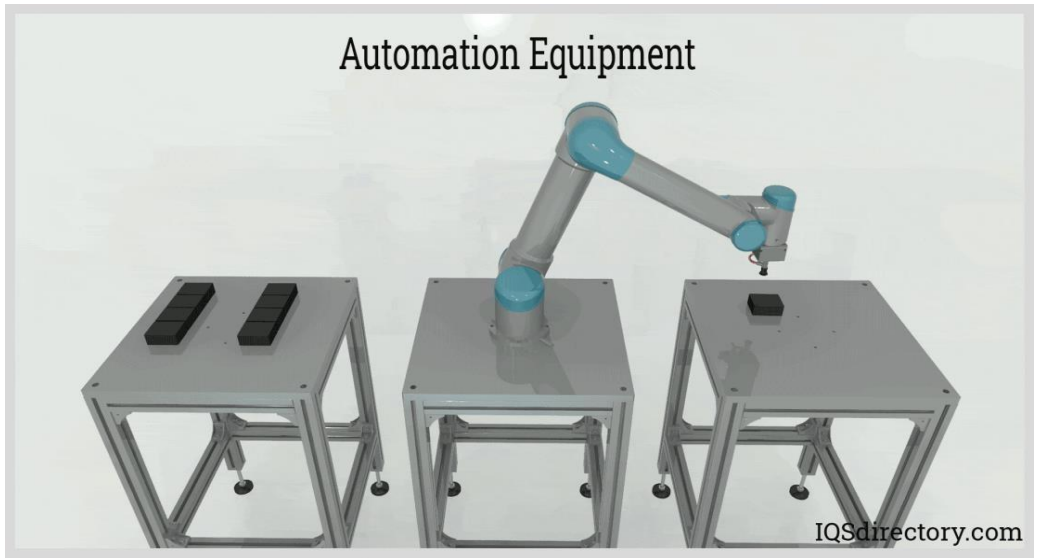


AUTOMATED SYSTEMS

- When a system is fully automated, it performs all operational functions with **little or no human intervention**.

- **Robots** are a good example of an automated system.

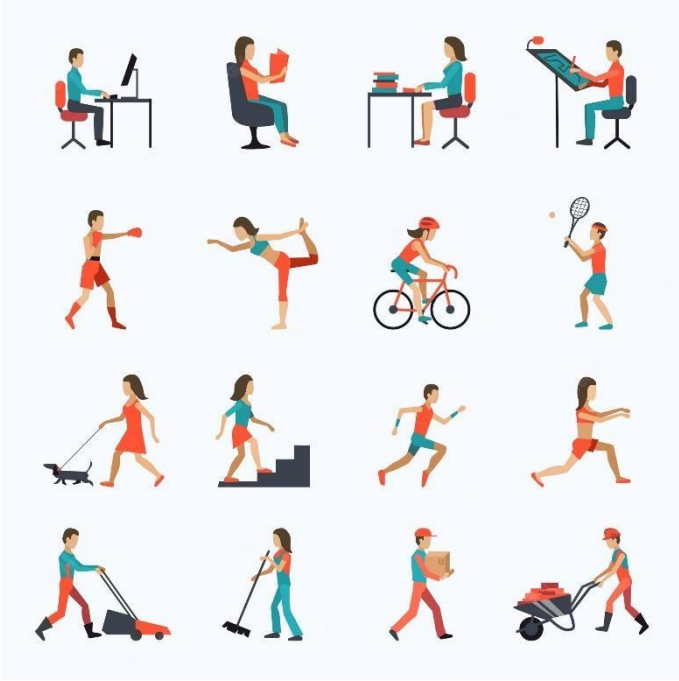
- All automated systems require **humans** to install, program, reprogram, and maintain them.



PHYSICAL WORK AND ENERGY EXPENDITURE

PHYSICAL WORK AND ENERGY EXPENDITURE

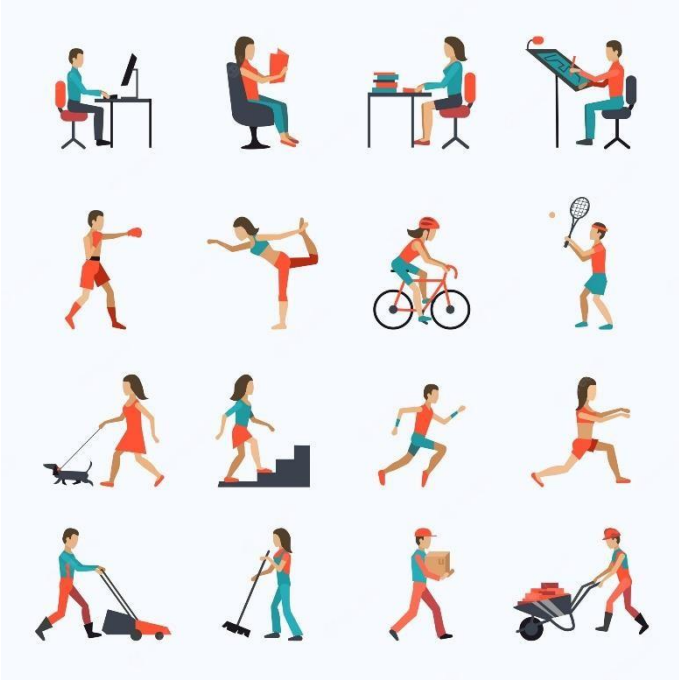
- Physical work or activity is defined as **any bodily movement produced** by skeletal muscles that results in **energy expenditure**.



- **Total daily energy expenditure** (TDEE) is the number of calories you burn throughout a 24-hour period.

PHYSICAL WORK AND ENERGY EXPENDITURE

- TDEE is determined by **body movement and body size**.



- It requires more energy to move a large body than a small body, one of the reasons why obese people generally move less than lean people

Table 72–1

Energy Expenditure During Different Types of Activity for a 70-Kilogram Man

Form of Activity	Calories per Hour
Sleeping	65
Awake lying still	77
Sitting at rest	100
Standing relaxed	105
Dressing and undressing	118
Typewriting rapidly	140
Walking slowly (2.6 miles per hour)	200
Carpentry, metalworking, industrial painting	240
Sawing wood	480
Swimming	500
Running (5.3 miles per hour)	570
Walking up stairs rapidly	1100

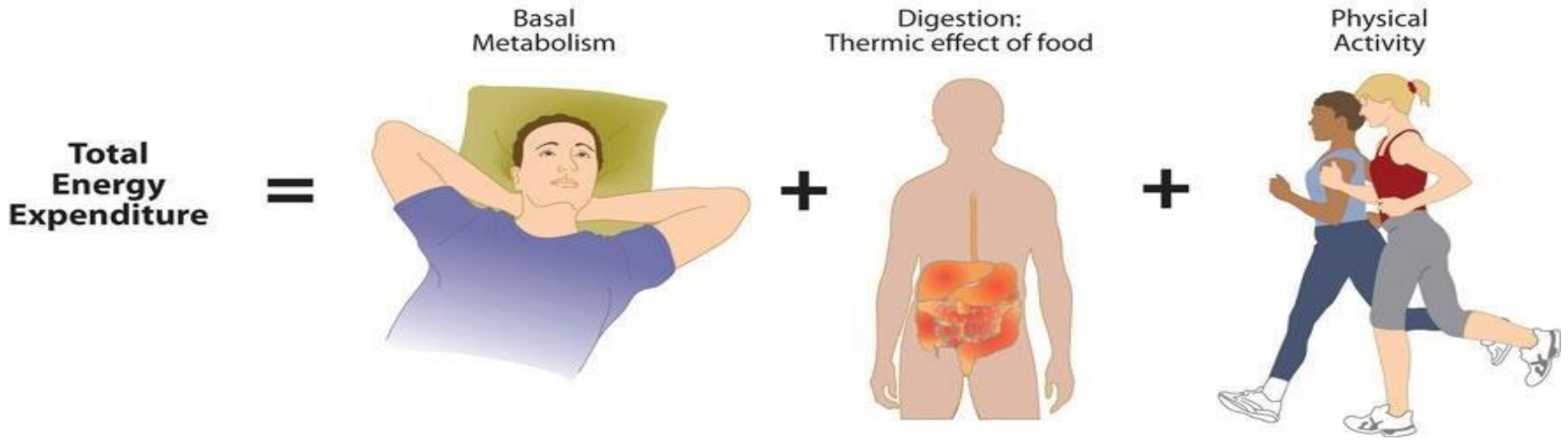
Extracted from data compiled by Professor M. S. Rose.

ENERGY EXPENDITURE

Energy expenditure is simply the **number of calories the body uses.**

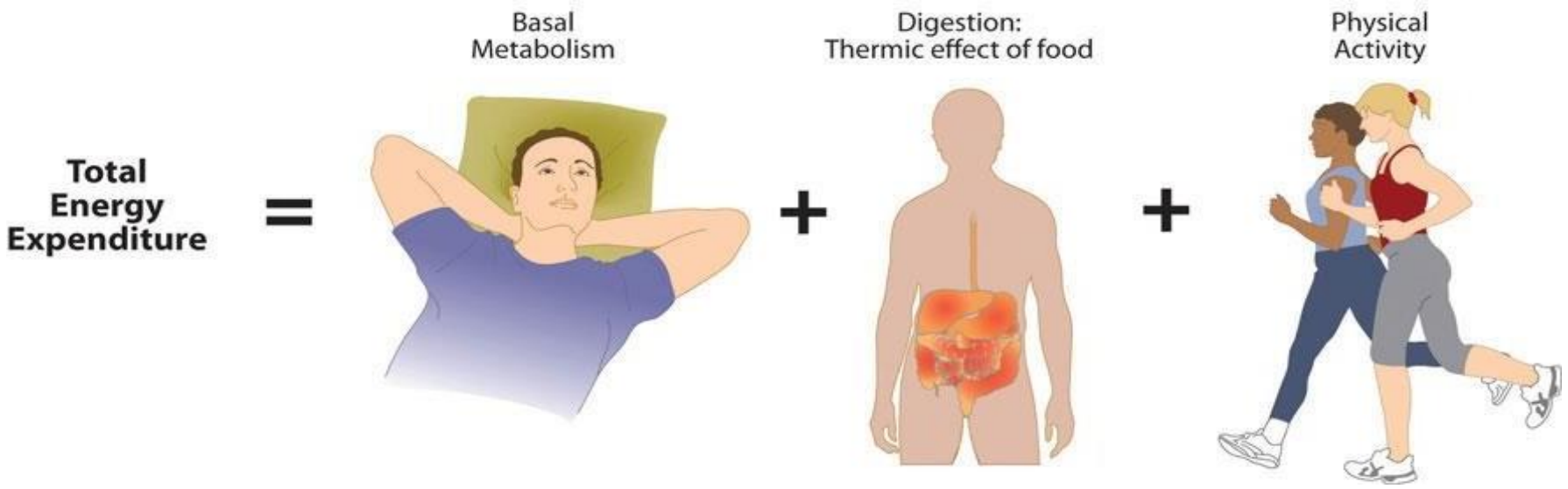
There are 3 main components that make up your energy expenditure.

1. **Basal Metabolic Rate (BMR):** Energy needed to maintain essential physiological functions including **growth, pregnancy, lactation** etc.

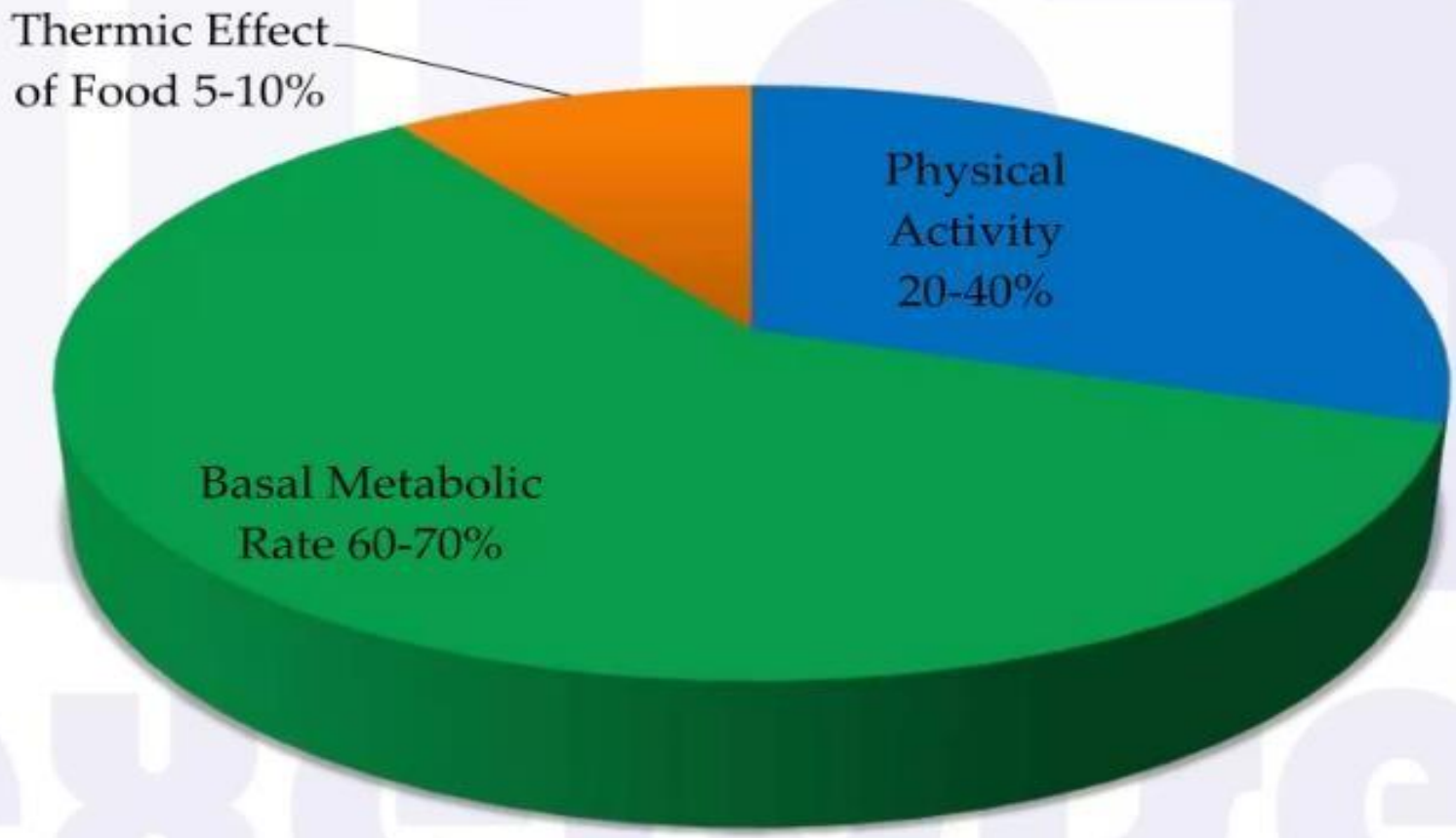


ENERGY EXPENDITURE

2. **The thermic effect of food (TEF)** : Thermogenesis necessary for digestive and metabolic utilization of **nutrients**
3. **Physical activity**: Energy for muscle contraction and movement



% of total energy expenditure



How you calculate your physical activity expenditure?

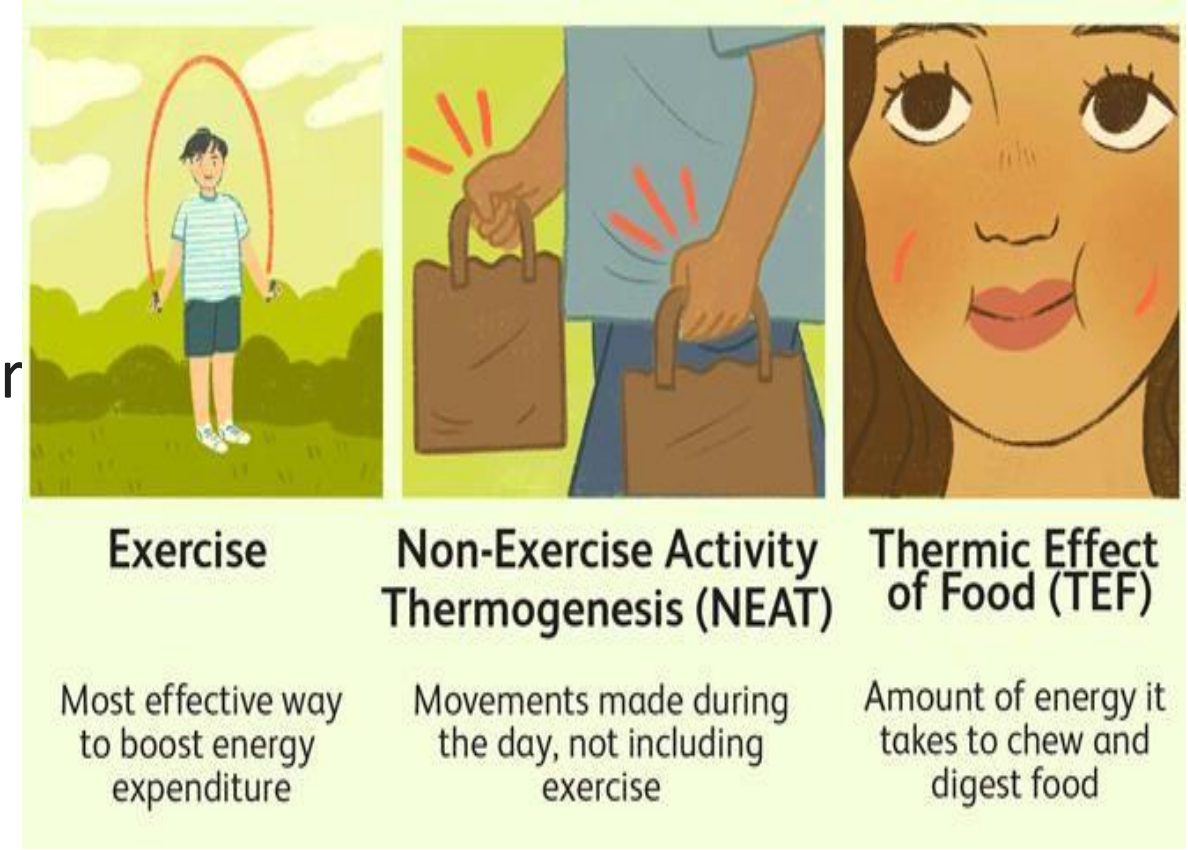
Type of activity	Kcla/kg of weight and minutes
Sleep	0,012
Lying awake	0,023
Shave	0,042
Shower	0,046
Tidy up	0,050
Eat	0,030
Cook	0,045
Sit	0,018
Stand	0,029
Study	0,020
Write	0,027
Sweep	0,050
Make the bed	0,057
Hoover	0,068
Play basketball	0,140

Climb stairs	0,254
Run 8-10 km/h	0,151
Walk 7 km/h	0,097
Walk 5 km/h	0,063
Walk 3,6 km/h	0,051
Go for a walk	0,038
Drive a car	0,043
Drive a motorbike	0,052
Ride a horse	0,107
Play the piano	0,038
Ride a bike 8 km/h	0,064
Ride a bike 14 km/h	0,100
Ride a bike 20 km/h	0,160
Take care of garden	0,086
Cut firewood	0,110
Dance	0,070
Dance hard	0,101

Example : Climb Stairs = 0.254 X 70 Kg X 60mins = 1066.8 kcals per hour

WAYS TO INCREASE DAILY ENERGY EXPENDITURE

- Cleaning your home or a particular room
- Taking a walk around the block, or walking a pet
- Setting a timer (or watch) for movement breaks throughout the day
- Taking the stairs (instead of an elevator or escalator)
- Choosing a parking spot further away from your destination
- Scheduling a walking meeting
- Using a standing desk



What is Manual Handling?

Manual handling is any activity requiring the use of force, exerted by a person to lift, lower, push, pull or carry or otherwise move, hold or restrain an object, person or animal.

CARRYING

LIFTING

PUSHING

Understanding Manual Handling Hazards

What are the risks?

Work related musculoskeletal disorders can occur as a result of:

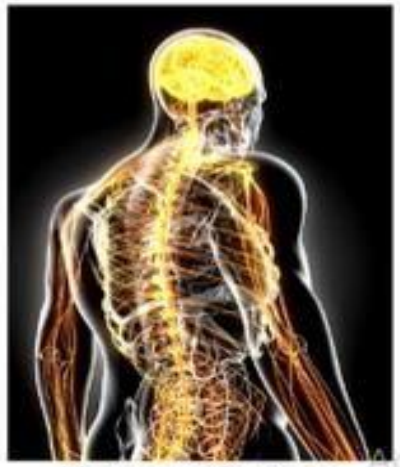
- repeated damage or strain
- a single case of overburdening

WMSD may include injuries to:

- Muscles
- Ligaments
- Intervertebral disc
- Nerves
- Tendons in the wrist, arms, shoulders, neck or legs

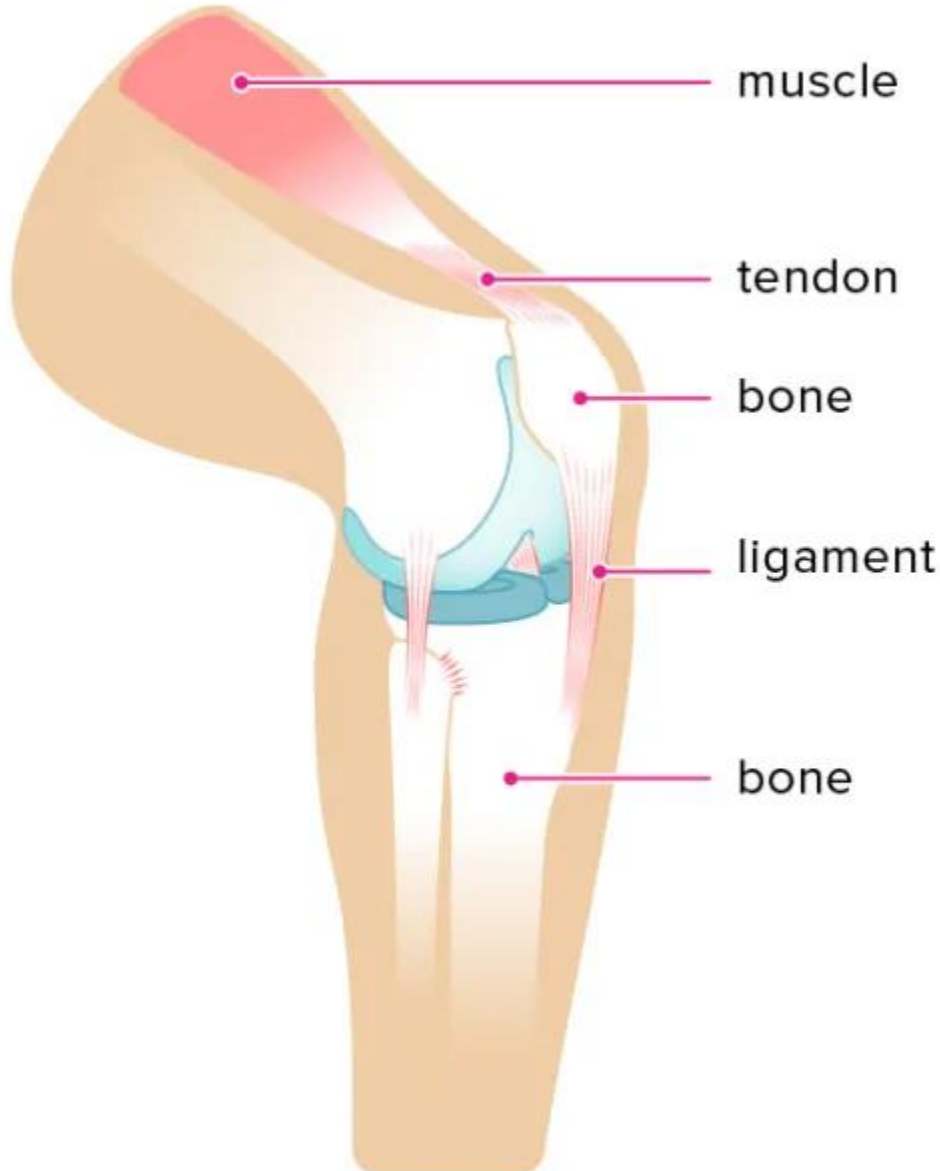
Torn Anterior Cruciate Ligament

Bones and muscle while flexing



Nervous System

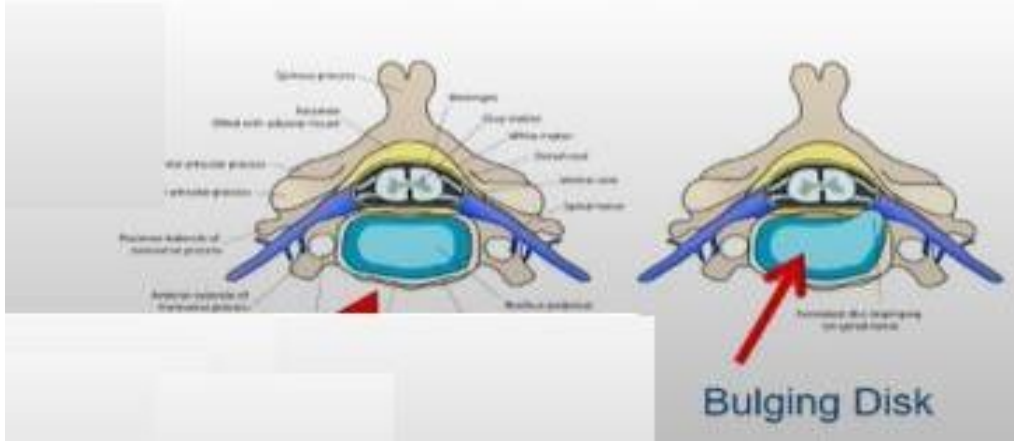
Activate W
Go to Setting

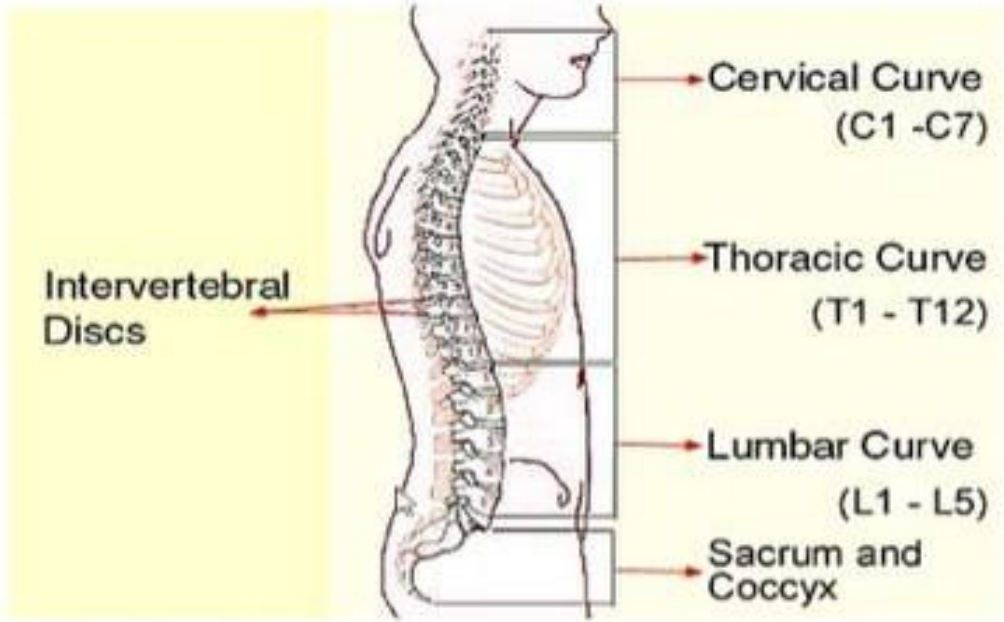

muscle
tendon
bone
ligament
bone

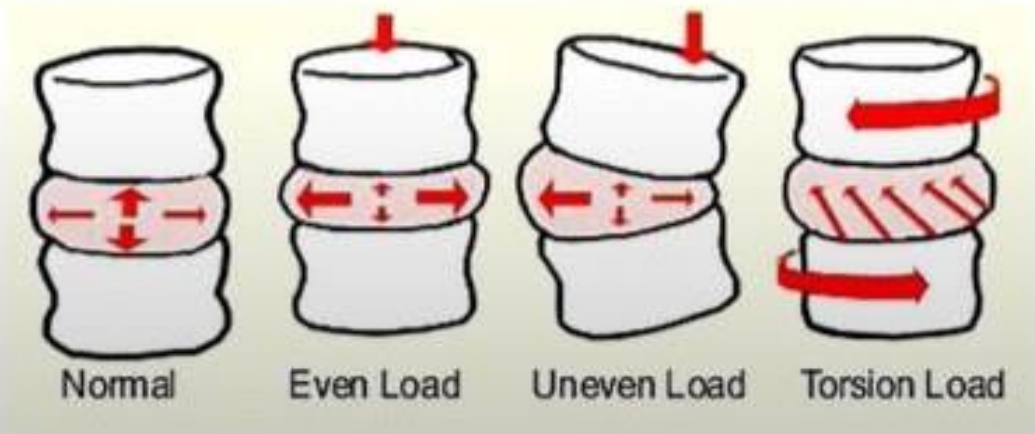
What are the risks?

The spine in its normal S-curve shape is very flexible, but is easily affected by movements which are: forceful, awkward, asymmetrical and or jerky, especially if the back is bent or twisted while moving.

Carrying a large or heavy load while the back is not in its normal S-curve shape puts much more strain on the discs between the vertebrae.



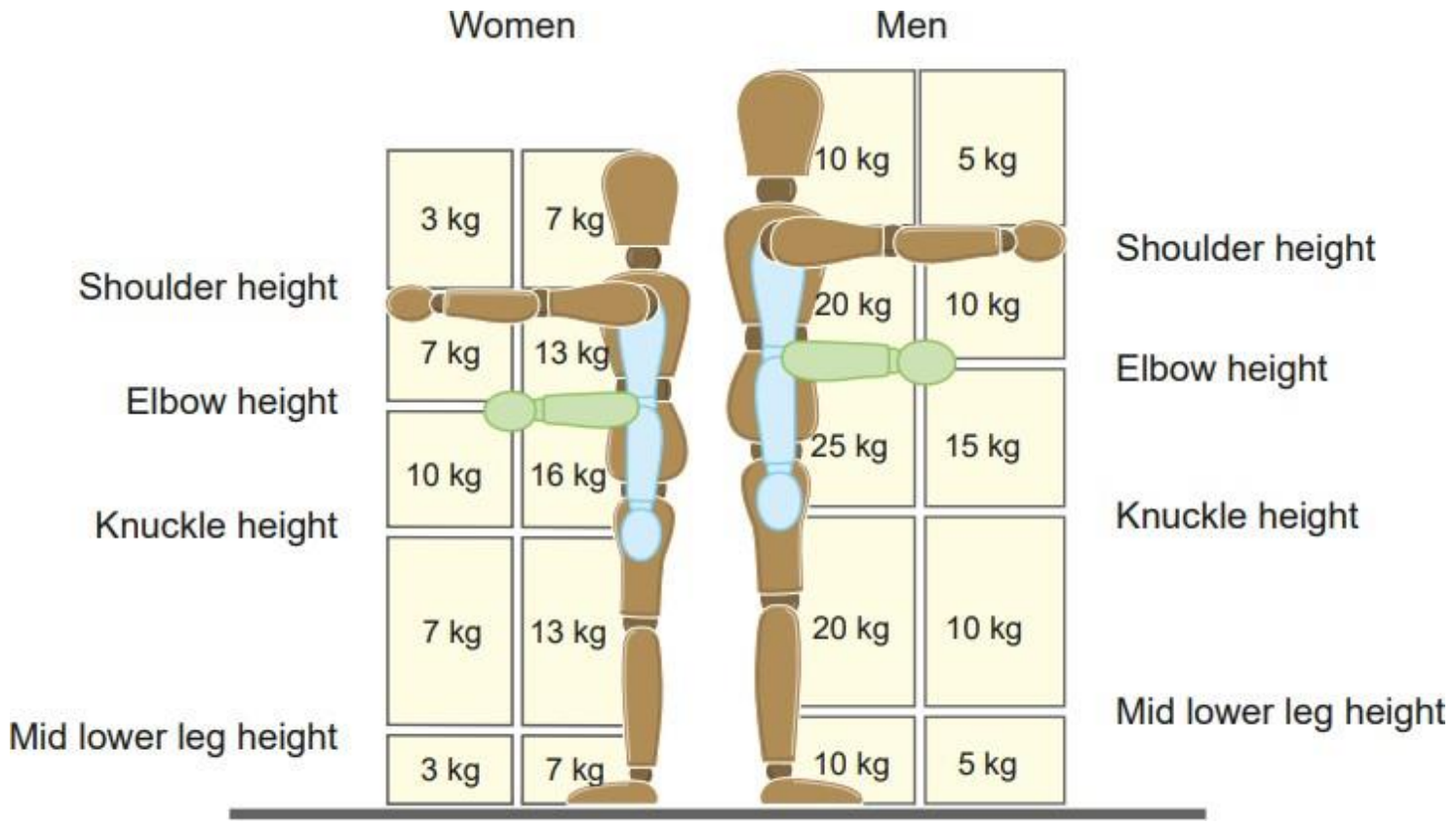




MANUAL LIFTING

- This picture gives the idea how much weight men and women can carry in the office with out causing injuries

- Each box in Figure contains a filter value for lifting and lowering in that zone.



Work techniques to prevent Manual Lifting Injuries

A. Planning the lift

- Check clear pathways
- for over 16kg use mechanical aids
- consider your own capacity

B. Performing the lift

- check the weight of the load
  start with smaller loads
- use whole hand grip
- for good balance, support with feet shoulder width apart
- hold the load close to the body
- Keep back straight when moving the load
- use hip and knee joints to bend to the object
- do not twist or bend the back sideways

S.M.A.R.T Lifting

Size up that load

- Assess the load (shape, size and weight)
- Determine where the load needs to be moved and placed

Move the load as close to the body as possible

- Carry the load as close to the body as possible
- Secure your grip

Always bend your knees

- Keep feet apart, in a comfortable position (usually in line with the hips)
- Minimise lower back bending
- Bend knees (squat or semi-squat position

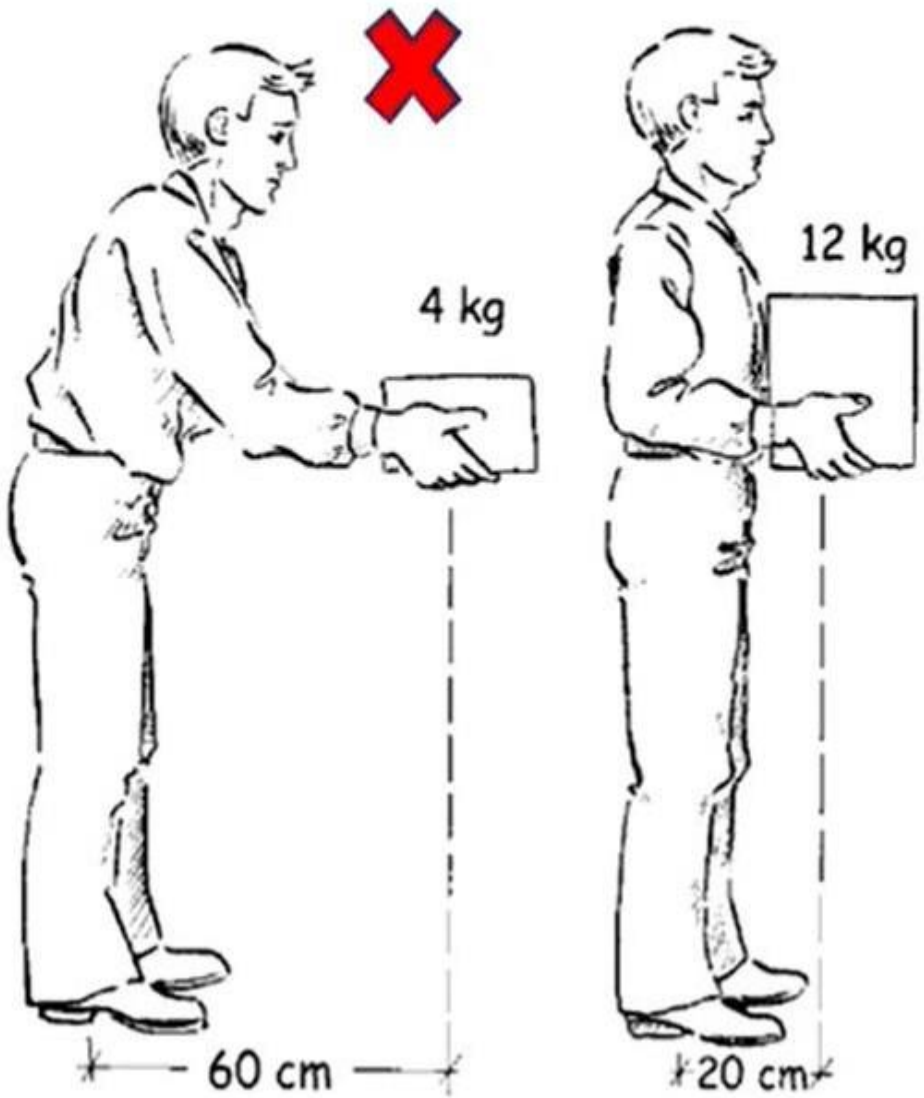
Raise the load with your legs

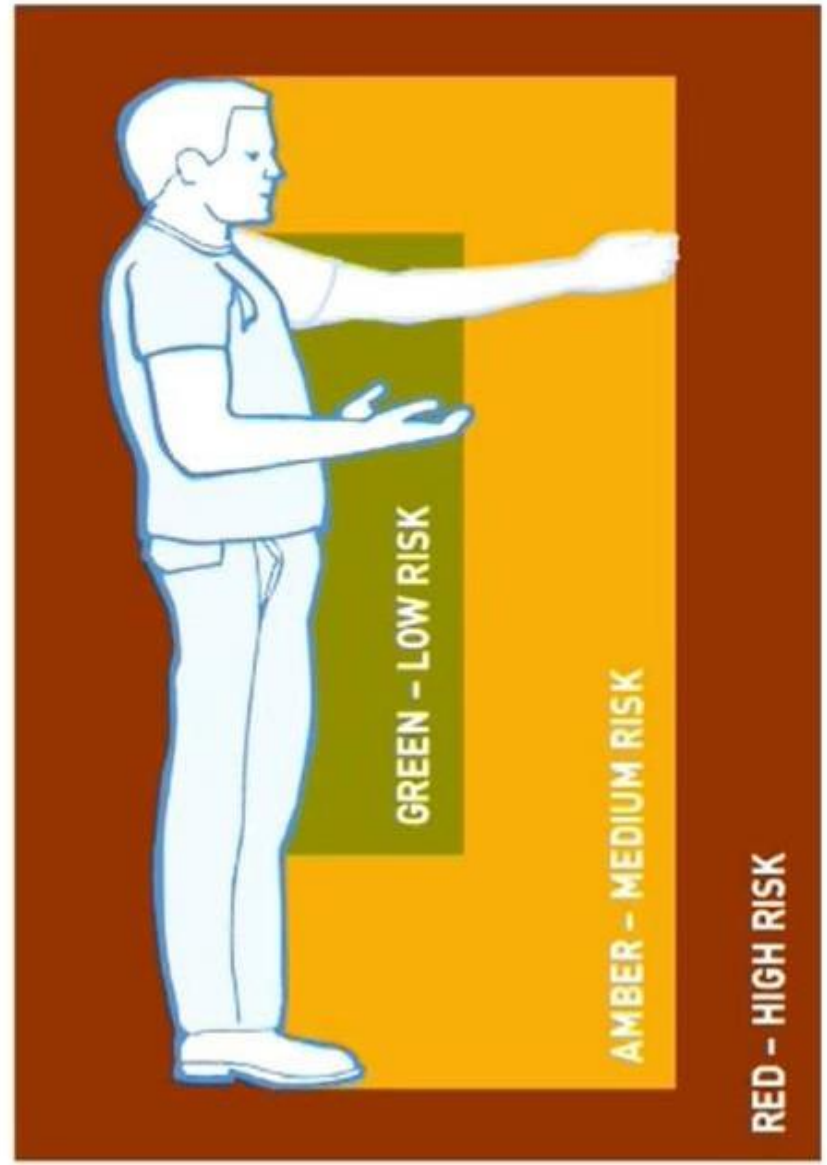
- Lift the load with your legs, not your back, in a smooth motion (avoid twisting or jerky movements)
- Maintain normal curvature of the spine

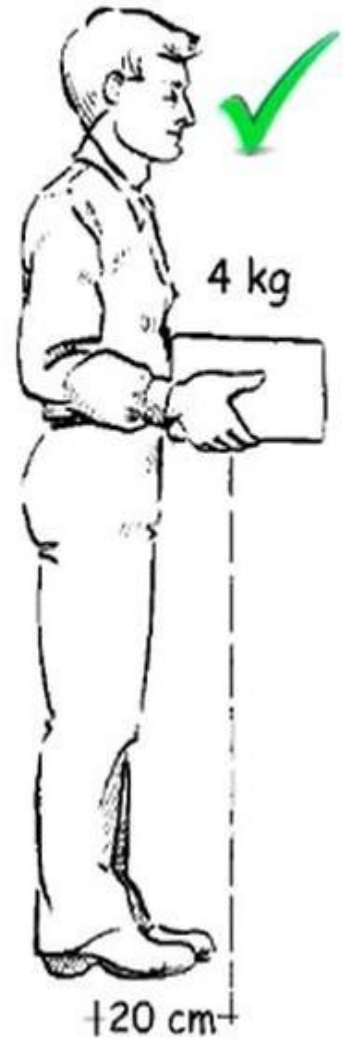
Turn your feet in the direction you want to move

- Change direction by pointing your feet and not twisting your back
- To set the load down, squat down, keep your head up and allow your legs to carry the weight

S.M.A.R.T Lifting







Team Lifting

Consider:

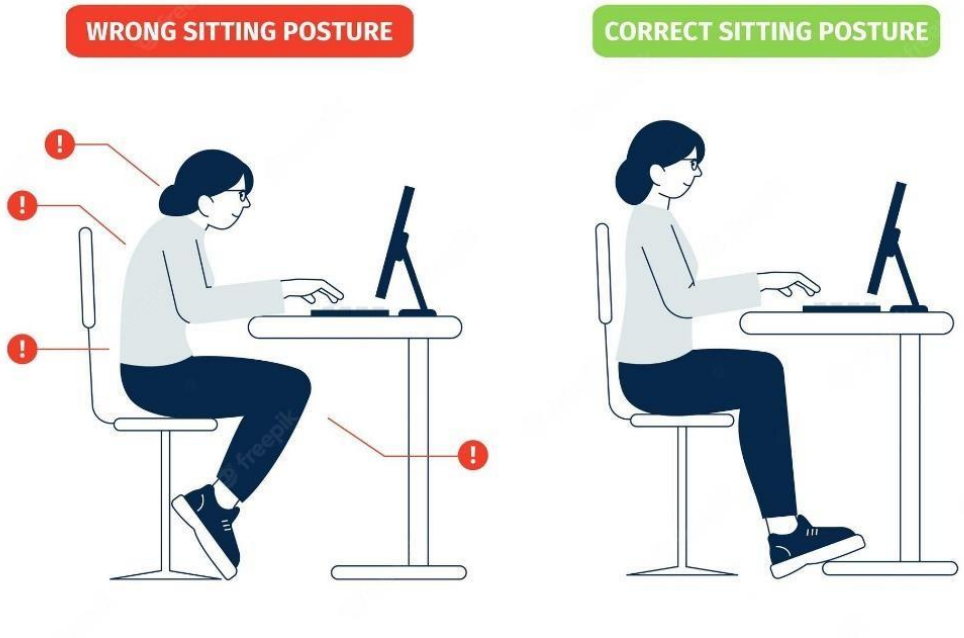
- Are there enough people?
- Are all persons of the same size with similar strength?
- Are there any known pre-existing injuries?
- Who is coordinating the lift?
- Is there a plan, and has been communicated to those involved?

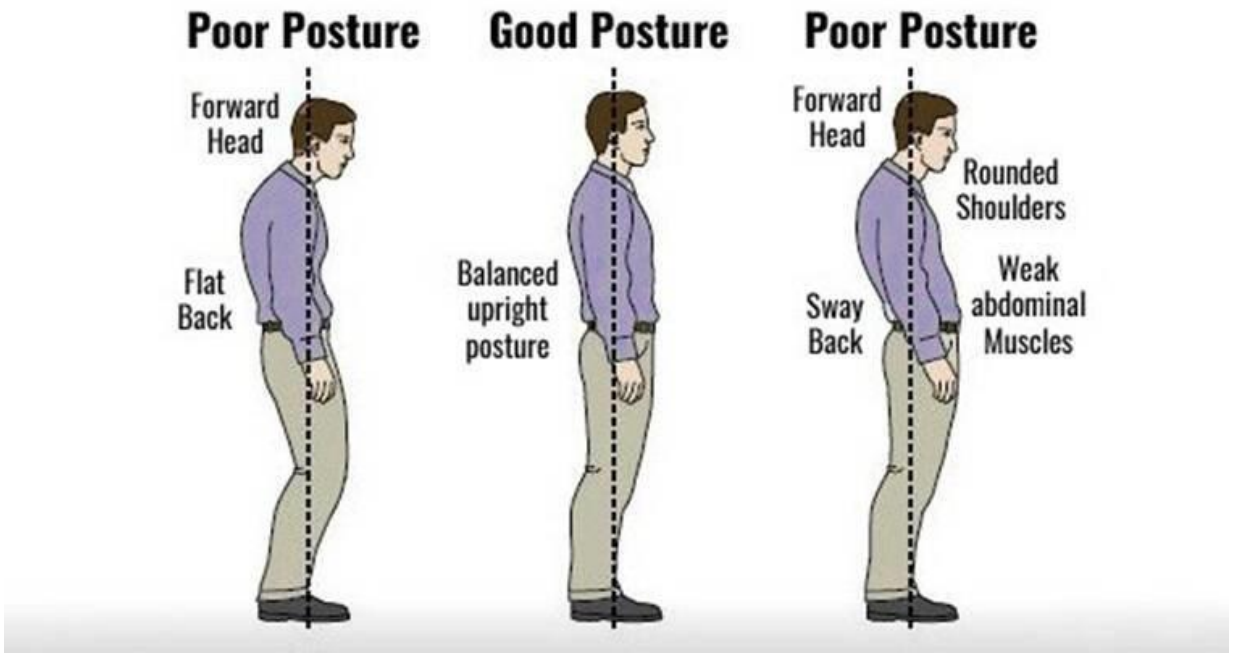
Proper Lifting Technique

WORK POSTURE

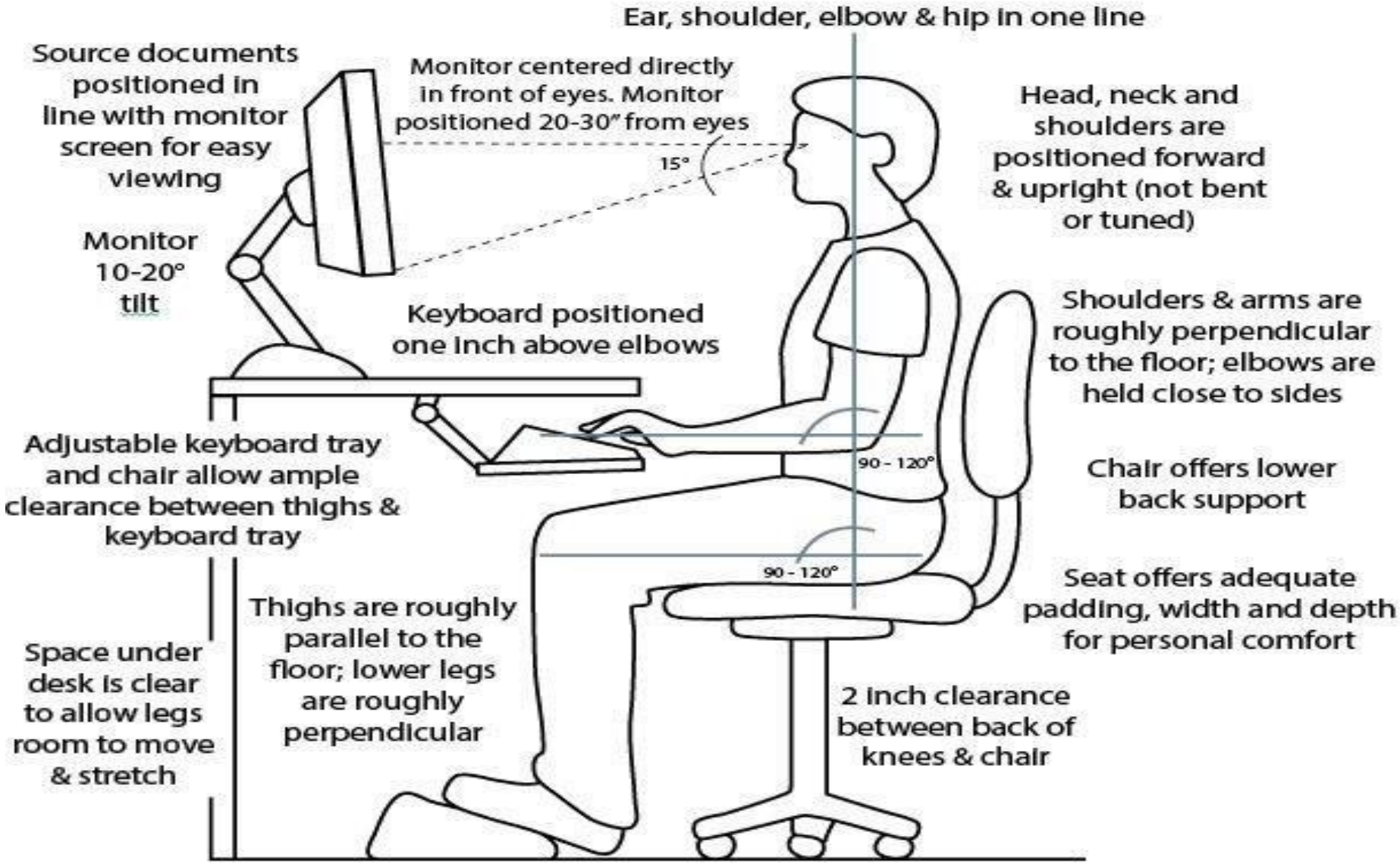
- Work posture is the **position and condition of the body** or body parts during the performance of work.

- Good work posture is as important for the performance of tasks as it promotes health and minimizes stress and discomfort during work.





THE ERGONOMIC WORKSTATION



Key points for ideal sitting position

- Keep your back straight, in particular:
  - Avoid rounding your shoulders forward (for this, you must have your screen at your eye level)
  - Avoid rounding (or arching) your lower back
- Keep your shoulders relaxed and back
- Place your elbows so that they form an angle of 90-100 degrees (never less)
- Keep your knees at a height of your hips (the thighs should form an angle of 90-100 degrees with the torso)
- Leave your legs relaxed, bent at about 90-100 degrees, leave your feet resting on the ground and do not cross your legs.

REPETITIVE MOTION

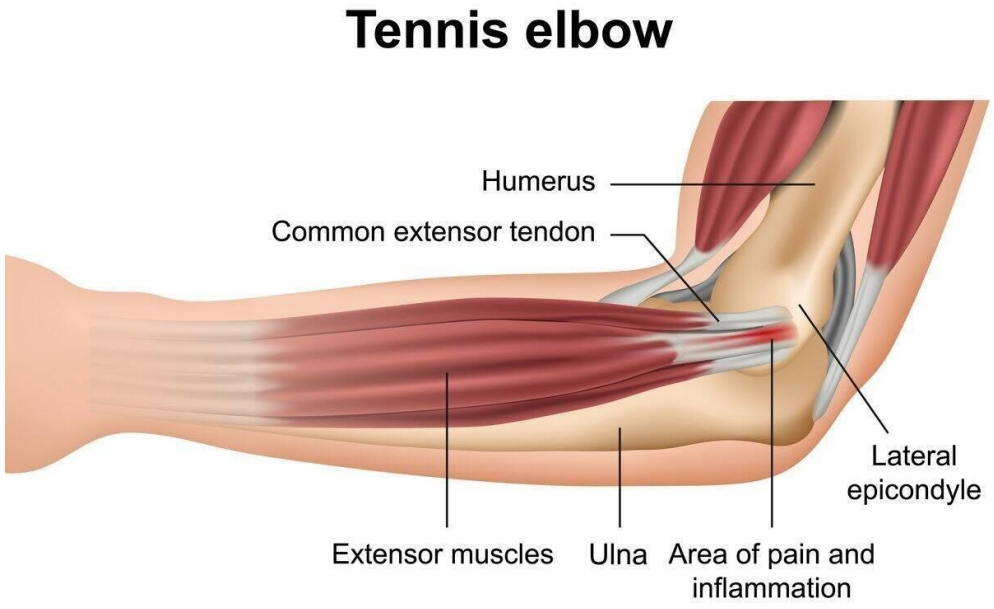
- Doing the **same motion over and over** or using certain types of positions or grips can cause pain and inflammation

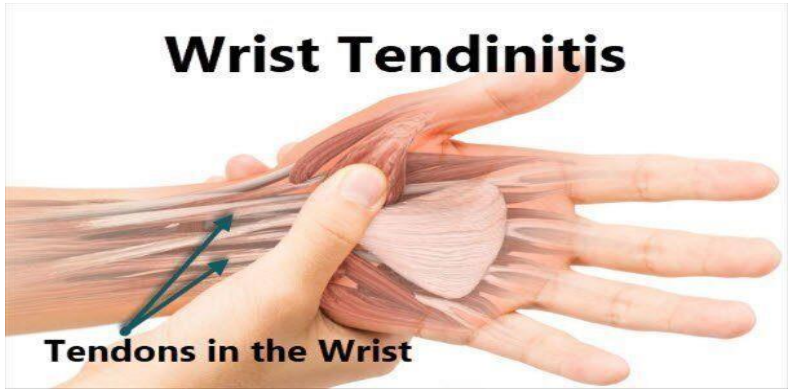
- Examples can include **bending, twisting, grasping and reaching**.

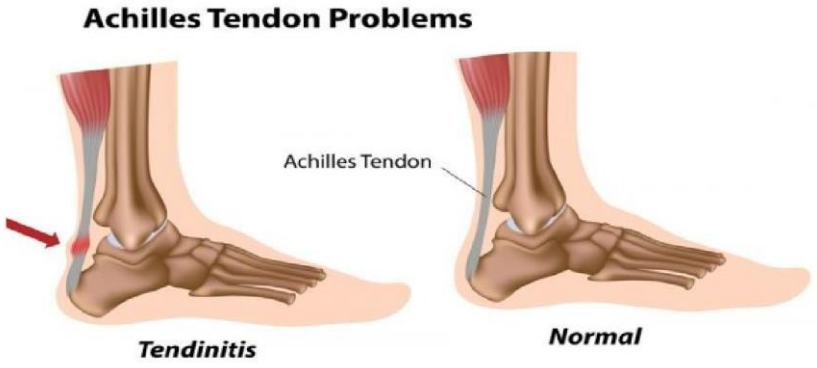
- Many occupations involve repetitive movements, which can cause injuries such as **tendinitis**, **bursitis**, and **nerve entrapment syndromes**.

Tendinitis

- Tendinitis is **inflammation of the thick fibrous cords that attach muscle to bone**

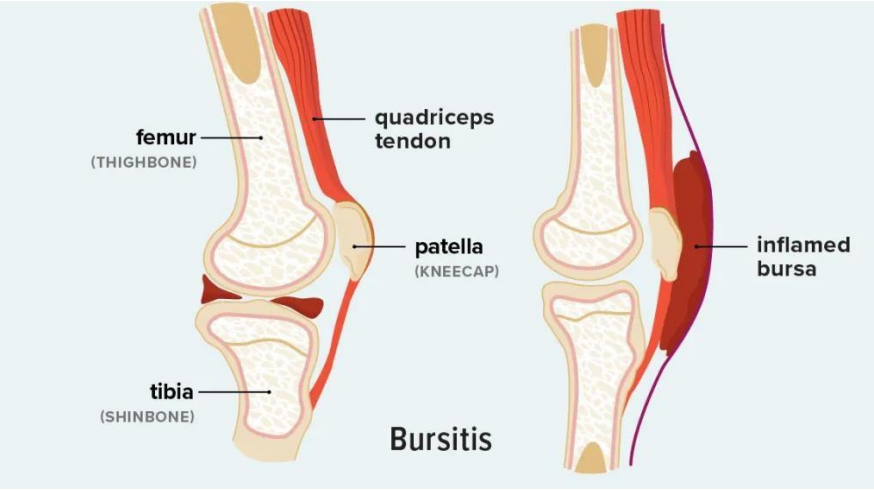


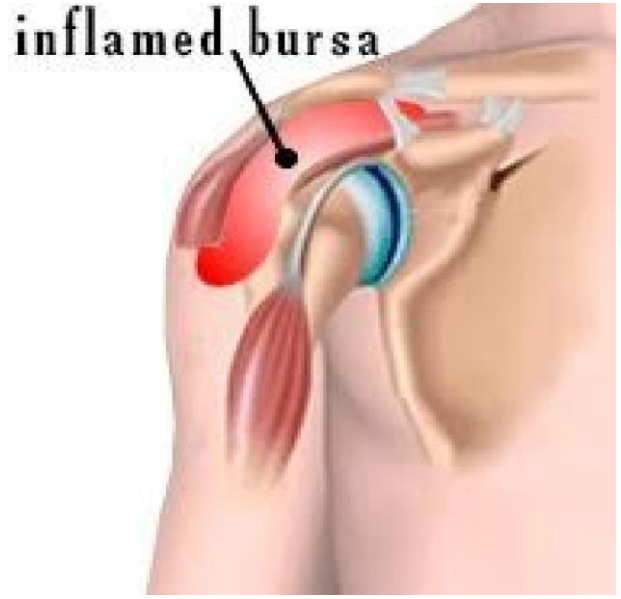




Bursitis

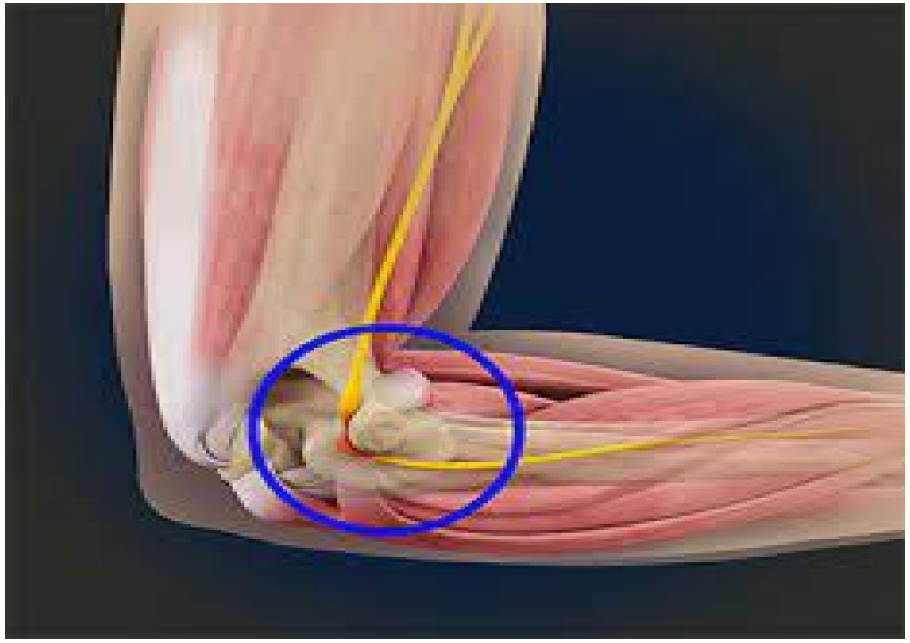
- **Bursitis** (bur-SY-tis) is **a painful condition that affects the small, fluid-filled sacs — called bursae (bur-SEE) — that cushion the bones, tendons and muscles near your joints**.
- Bursitis occurs when bursae become inflamed.
- The most common locations for bursitis are in the shoulder, elbow and hip

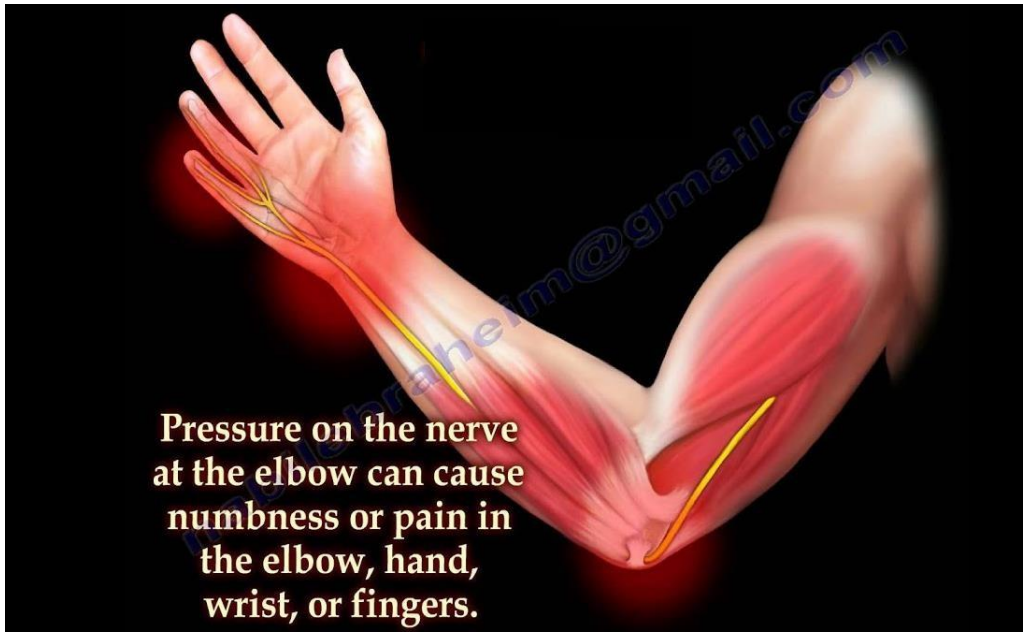




Nerve entrapment

- Nerve Entrapment is **a condition in which a nerve becomes compressed, or entrapped, between two other structures in the body**.
- Usually, the nerve is compressed between a ligament and a bone.
- Repetitive motion can cause the ligament and bone to press or rub against the nerve.



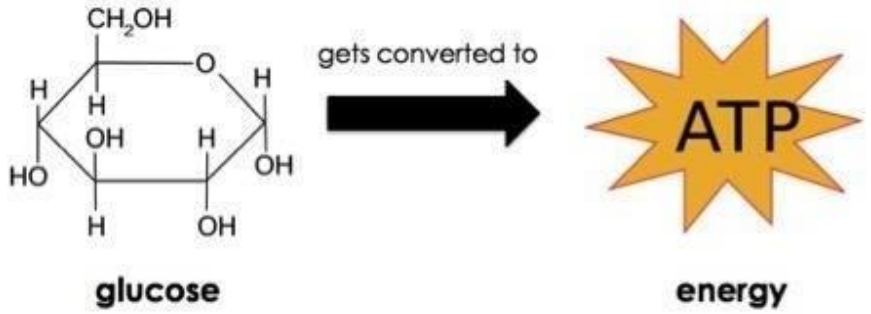


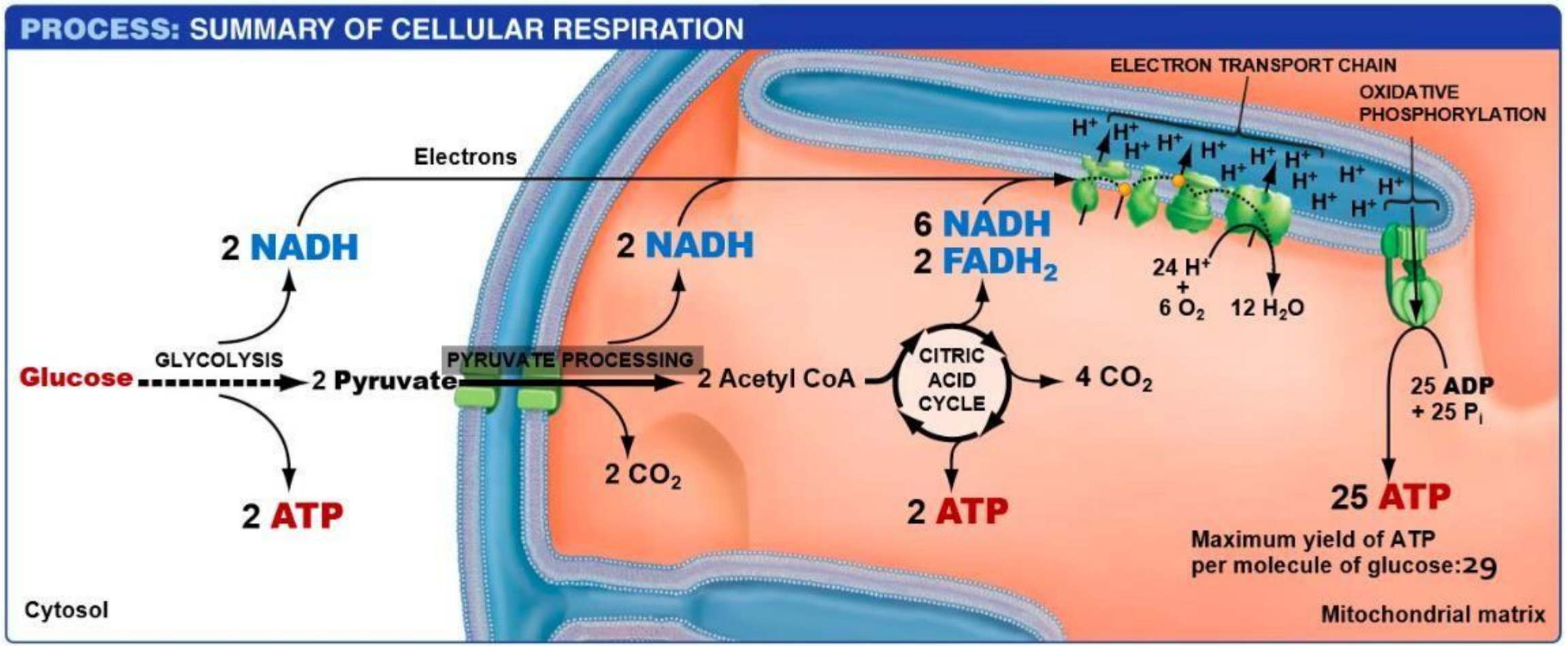
Repetitive motion injury prevention

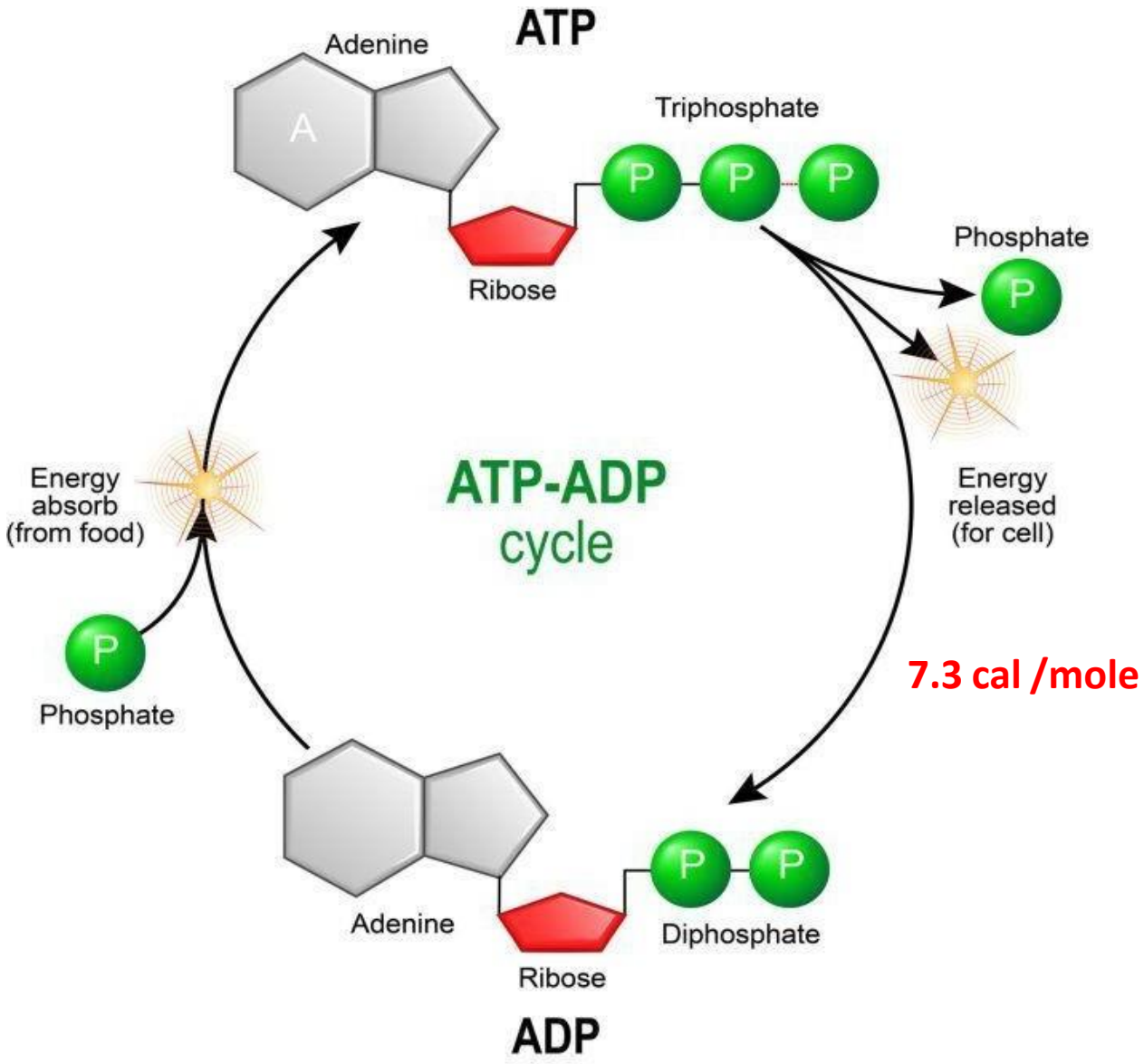
- Pacing - reducing the number of repetitions per hour.
- Breaks - providing short rest periods to relieve fatigue.
- Job rotation - rotate periodically to a different task involving different movements.
- Exercise – Exercise keeps people fit and Fit people are less likely to experience physical problems and are more likely to recover quickly when they do.

PROVISION OF ENERGY FOR MUSCULAR WORK

- **Energy** is required for a **muscle to contract and stretch**
- **Energy for muscle action** is provided by the **foods we eat** and **digest**, primarily the carbohydrates and fats.
- **Proteins** are used principally to **maintain tissues**.
- **Glucose** is readily available source of energy
- **Glucose gets converted to ATP** in mitochondria of the cell
- **ATP gets** converted into ADP with release of energy which can be readily used by the cells.


CH2OH
O
H
H
H
OH
H
OH
HO
H
OH
gets converted to
ATP
glucose
energy


PROCESS: SUMMARY OF CELLULAR RESPIRATION
ELECTRON TRANSPORT CHAIN
OXIDATIVE PHOSPHORYLATION
Electrons
2 NADH
2 NADH
6 NADH
2 FADH2
24 H+ + 6 O2
12 H2O
GLYCOLYSIS
Glucose
2 Pyruvate
PYRUVATE PROCESSING
2 Acetyl CoA
CITRIC ACID CYCLE
4 CO2
2 CO2
2 ATP
2 ATP
25 ADP + 25 PI
25 ATP
Maximum yield of ATP per molecule of glucose: 29
Cytosol
Mitochondrial matrix



7.3 cal /mole

- ATP stands for [adenosine triphosphate](), and is **the energy** used by **an organism** in its daily operations.
- It consists of an ***adenosine*** **molecule** and three **inorganic *phosphates***.
- After a simple reaction **breaking down ATP to *ADP*,** the **energy released from the breaking of a molecular bond** is the energy we use to keep ourselves alive.
- **ADP again absorbs energy** by digesting food and reforms ATP
- This cycle continues and keeps the body functioning

1 mole = 6.02214076×10^{23} elementary entities.

Calorie chart of commonly used Indian food

Snacks	Name	Quantity	Calories
	Burger	1 pcs	325
	Pizza	1 portion	375
	Samosa/Kachori	1 pcs	256
	Pakoda	1 pcs	200
	Potato Chips	10 pcs	110
	Dahi Wada	1 pcs	364
	French Fries	10 pcs	235

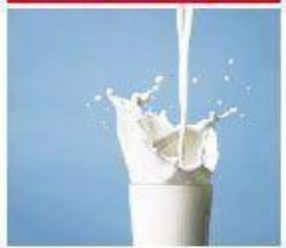
Name	Quantity	Calories	Meat / Poultry
Chicken	1 cup	220	
Tandoori Chicken	2 pcs	450	
Mutton (Boiled)	1 cup	100	
Fish (Boiled)	1 cup	100	
Crab	1 cup	33	
Egg (Fried)	1 pcs	100	
Omlette	1 pcs	110	

Fruits	Name	Quantity	Calories
	Apple	100 gms	56
	Banana	100 gms	95
	Mangoes	100 gms	70
	Orange	100 gms	53
	Chikoo	100 gms	94
	Papaya	100 gms	32
	Peach	100 gms	50

Name	Quantity	Calories	Bread / Rice
Bread	1 slice	60	
Chapati	1 pcs	100	
Parantha	1 pcs	280	
Rice	100 gms	325	
Wheat Flour	100 gms	341	
Maize Flour	100 gms	355	
Veg. Oil	1 tbsp	130	

Vegetables	Name	Quantity	Calories
	Potato	100 gms	97
	Peas	100 gms	93
	Cauliflower	100 gms	30
	Cabbage	100 gms	45
	Carrot	100 gms	48
	Mushroom	100 gms	18
	Onion	100 gms	50

Name	Quantity	Calories	Sweets / Misc
Barfi	1 pcs	100	
Gulab Jamun	1 pcs	100	
Jalebi	1 pcs	200	
Rasgulla	1 pcs	150	
Sugar	1 tbsp	60	
Honey	1 tbsp	30	
Jam	1 tbsp	100	

Milk & Milk Pdts	Name	Quantity	Calories
	Milk	1 cup	100
	Skimmed Milk	1 cup	45
	Curd	1 cup	60
	Butter	1 tbsp	120
	Cheese	1 cup	164
	Ice-Cream	1 scoop	114
	Ghee	100 gms	910

Name	Quantity	Calories	Drinks / Beverages
Cold Drinks	1 bottle	95	
Orange Juice	1 glass	95	
Apple Juice	1 glass	95	
Beer	1 glass	100	
Whisky	1 peg	75	
Rum	1 peg	75	
Tea/Cofee	1 cup	35	

GRADE OF PHYSICAL WORK BASED ON ENERGY EXPENDITURE LEVEL (ASSUMING A REASONABLY FIT ADULT MALE)

Grade of work	Energy expenditure, kcal/mln	Energy expenditure, 8 h (kcal/d)	Heart rate, beats per minute	Oxygen consumption, Umin
Rest (sitting)	1.5	<720	60-70	0.3
Very light work	1.6-2.5	768-1200	65,,:,75	0.3-0.5
Light work	2.5-5.0	1200-2400	75-100	0.5-1.0
Moderate work	5.0-7.5	2400-3600	100-125	1.0-1.5
Heavy work	7.5-10.0	3600-4800	125-150	1.5-2.0
Very heavy work	10.0-12.5	4800-6000	150-180	2.0-2.5
Unduly heavy work	>12.5	>6000	>180	>2.5

Source: Adapted from American Industrial Hygiene Association, 1971. Reprinted with permission by American Industrial Hygiene Association.

HEAT STRESS

WHAT IS IT AND HOW TO PREVENT IT.

WHAT IS HEAT STRESS?

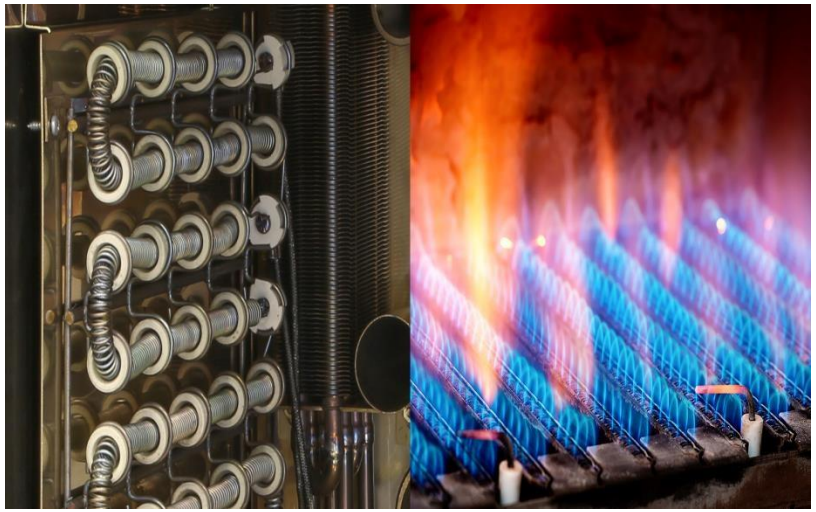
The human body relies on its ability to get rid of excess heat to maintain a healthy internal body temperature through sweating and increased blood flow to the skin. If heat dissipation does not happen quickly enough, the internal body temperature keeps rising, resulting in heat stress.

HEAT STRESS

- The term ‘heat stress’ refers to the body suffering adverse side effects from not being able to cool itself enough to maintain a healthy temperature.
- In hot environments, the body produces **heat and must dissipate** it by convection, conduction, radiation and evaporation.
- **Heat stress** occurs when the body **cannot get rid of excess heat**. When this happens, the body's core temperature rises and the heart rate increases

- Heat stress refers to the net heat load that workers sustain under the combined effect of metabolic heat production, environmental factors (ie. air temperature, humidity, air flow and heat radiation) and clothing requirements.

Sources of heat in industry



Heat-illness symptoms

Vomiting or nausea

Dizzy or weak

Clumsy, light-headed and/or fainting

Heat stress symptoms

Pale, cool, clammy skin

Rapid breathing and shortness of breath

Rapid, weak pulse

Heat stroke symptoms

High body temperature 40C or more

Flushed and dry skin

Pounding, rapid pulse

Conditions caused by heat stress

- **Heat cramps** – painful cramps in muscles, caused by heavy sweating that uses up the body's supply of salt and water.

- **Heat exhaustion** – weakness, fatigue, dizziness, visual disturbance, feeling of intense thirst and heat, nausea, vomiting, palpitations, tingling and numbness of fingers and/ or toes.

- **Heat rash** – an itchy rash of small raised red spots on the face, neck, back, chest and thighs.

- **Heat stroke** – a life threatening condition that requires immediate first aid and medical attention, caused by overexposure to heat and often dehydration.

Symptoms are dry, hot skin, high body temperature (possibly over 41°C) and may include mental confusion which can result in collapse.

Reactions of the Body to Hot Environments

Redistribution of Blood:

- The body **directs blood flow** to the skin.
- The skin vessels are dilated and the **superficial veins fully opened**.
- This can enlarge the blood flow fourfold above the resting level.
- The increased conductance of surface tissues facilitates **energy loss through** convection, conduction, and radiation because all are proportional to the temperature differential between skin and environment.

Reactions of the Body to Hot Environments

- If **not enough heat** can be transferred via a temperature differential, the body's sudomotor system activates **sweat glands** so that evaporation of the produced sweat may cool the skin

Reduction of Muscle Activities

- If heat transfer by **blood distribution** and **sweat evaporation** remains insufficient to keep the body cool enough in a hot environment, the body **must reduce its muscular activities** in order to lower the amount of energy generated through **metabolic processes**.

- This is the final and necessary action of the body if otherwise the **core temperature would exceed a tolerable limit**.

Reduction of Muscle Activities

- If the body has to choose between unacceptable overheating and continuing to perform physical work, the choice will be in favor of core temperature maintenance, which means reduction or cessation of **work** or **exercise**.

Avoiding heat stress

Drink plenty of water throughout the day

Apply sunscreen

Wear clothes that cover the arms and legs

Drink caffeine

Sugary drinks

Wear a hat

Take frequent rest breaks in the shade

Alcohol

ROLE OF OXYGEN PHYSICAL EXERTION

Oxygen plays a critical role in physical exertion, as it is required to produce the energy needed for muscular activity. During physical activity, the body's demand for oxygen increases as the muscles require more energy to contract and perform work.

The body's ability to deliver oxygen to the muscles, and the muscles' ability to use that oxygen, determine how much work can be performed and for how long.

During exercise, the lungs take in more oxygen from the air, which is then transported to the muscles via the bloodstream. The muscles use this oxygen to produce energy in a process called aerobic metabolism.

The more oxygen that is available, the more energy that can be produced, allowing the muscles to contract more forcefully and for longer periods of time.

If the demand for oxygen exceeds the body's ability to deliver it, the muscles may switch to anaerobic metabolism, which does not require oxygen but produces lactic acid as a by product. This can cause fatigue, muscle soreness, and decreased performance.

Therefore, maintaining an adequate oxygen supply during physical exertion is essential for optimal performance and avoiding fatigue.

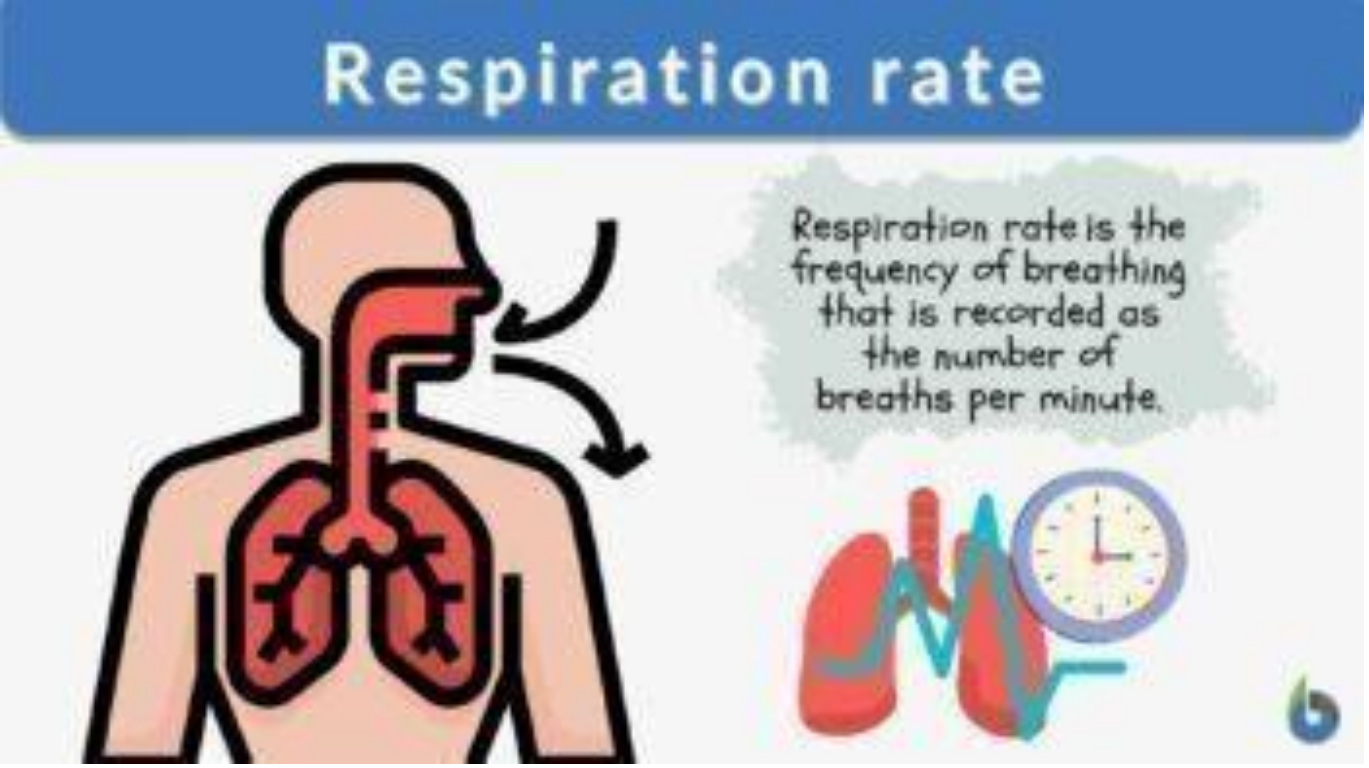
This can be achieved through regular cardiovascular exercise, which can improve the body's ability to transport and use oxygen, as well as by ensuring adequate rest and nutrition to support muscle recovery and growth.

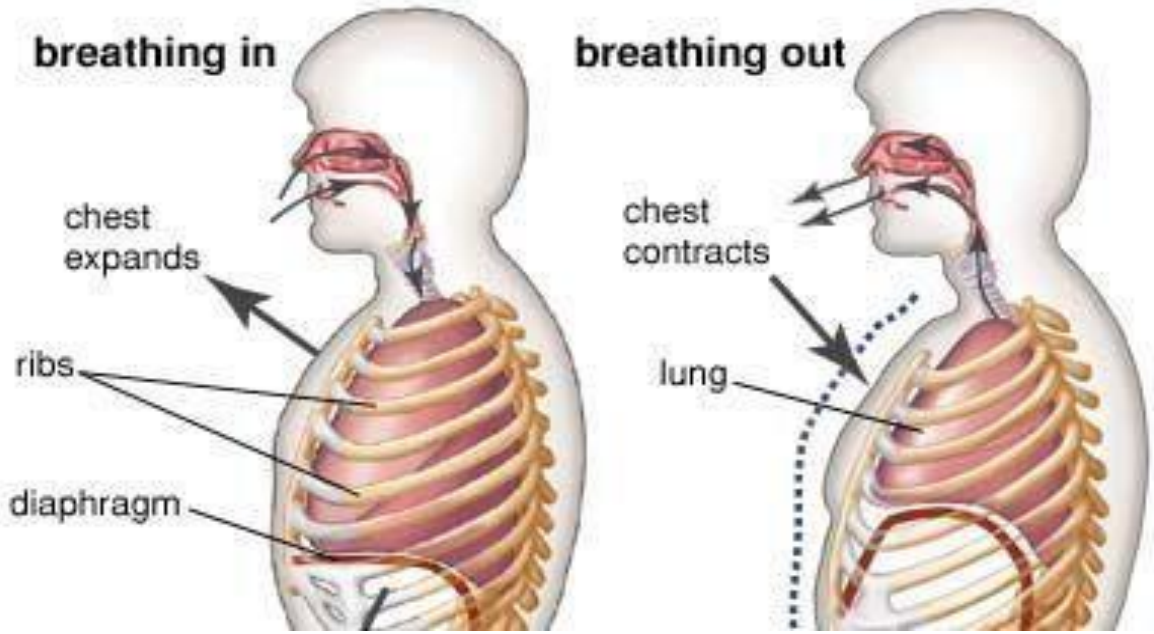
RESPIRATION

"**Respiration** is defined as a metabolic process wherein, the living cells of an organism obtains energy (in the form of ATP) by taking in oxygen and liberating carbon dioxide from the oxidation of complex organic substances."

Respiration consists of 4 distinct processes:

- Pulmonary Ventilation: moving air into and out of the lungs. ...
- External Respiration
- Transport: transport of oxygen and carbon dioxide between the lungs and tissues.
- Internal Respiration: diffusion of gases between the blood of the systemic capillaries and cells.

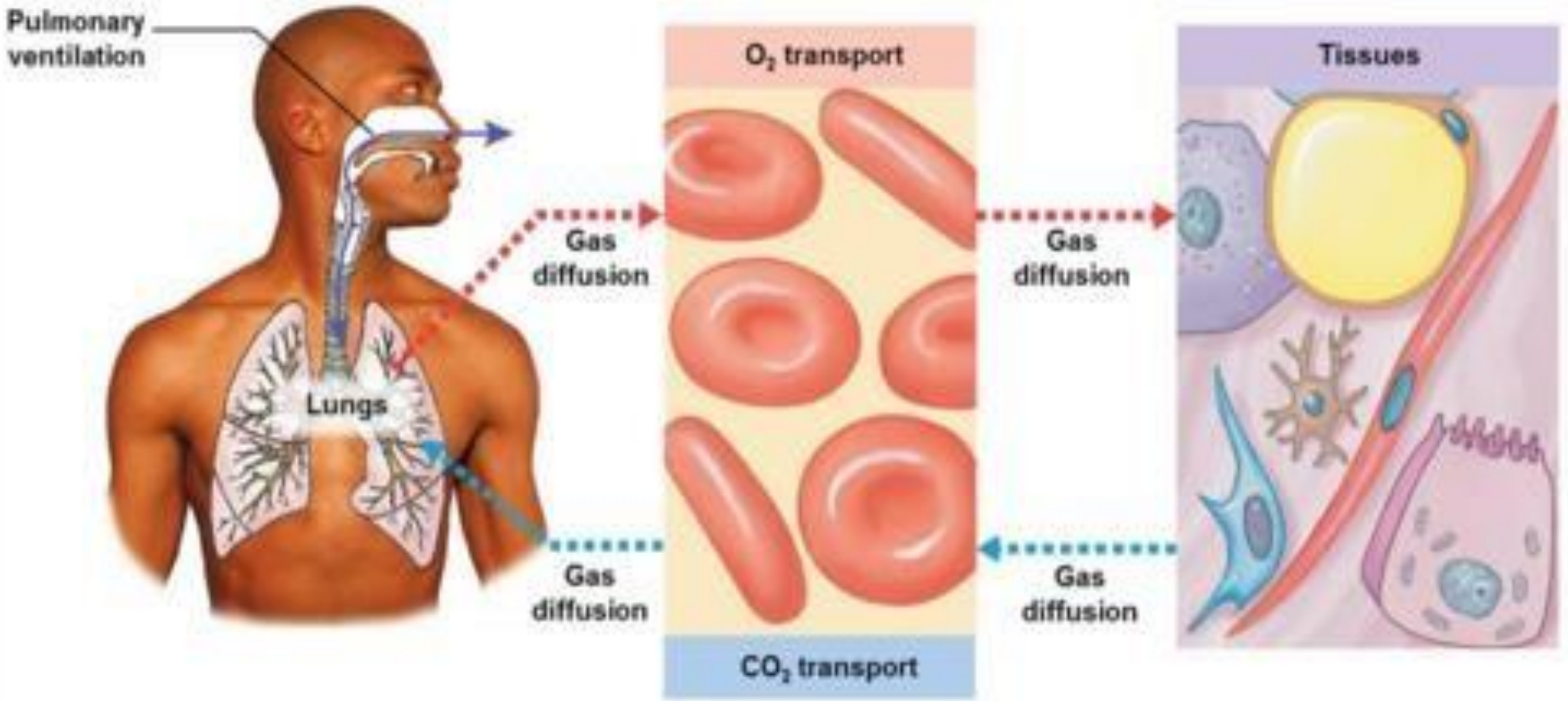

Respiration rate
Respiration rate is the frequency of breathing that is recorded as the number of breaths per minute.


breathing in
chest expands
ribs
diaphragm
breathing out
chest contracts
lung

Respiration

External Respiration

Internal Respiration



Age Group	General Respiratory Rate
New-born and Infants	30 - 60
Infants	24 - 30
Toddlers	20 - 30
Children	12 - 30
Adults	08 - 20

Respiratory Rates in Different Age Groups

Activity Level	Breathing Volume Flow Rate	
	Liters/min	Liters/hour
Resting	6	360
Walking	15	900
Riding a bicycle slowly	15	900
Walking fast	30	1800
Going up-stairs	30~40	1800~2400
Riding a bicycle at high speed	60~100	3600~6000
Running/Racing	60~100	3600~6000

Respiration Rate for Adults as a function of Activity

GRADE OF PHYSICAL WORK BASED ON ENERGY EXPENDITURE LEVEL (ASSUMING A REASONABLY FIT ADULT MALE)

Grade of work	Energy expenditure, kcal/mln	Energy expenditure, 8 h (kcal/d)	Heart rate, beats per minute	Oxygen consumption, Umin
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Unduly heavy work	>12.5	>6000	>180	>2.5

Source: Adapted from American Industrial Hygiene Association, 1971. Reprinted with permission by American Industrial Hygiene Association.

Common Causes of an Increased Respiratory Rate

Fever

COPD

Asthma

Dehydration

Overdose

Acidosis

Infection

Heart conditions

Hyperventilation

Lung conditions

verywell

MEASUREMENT OF ENERGY EXPENDITURE

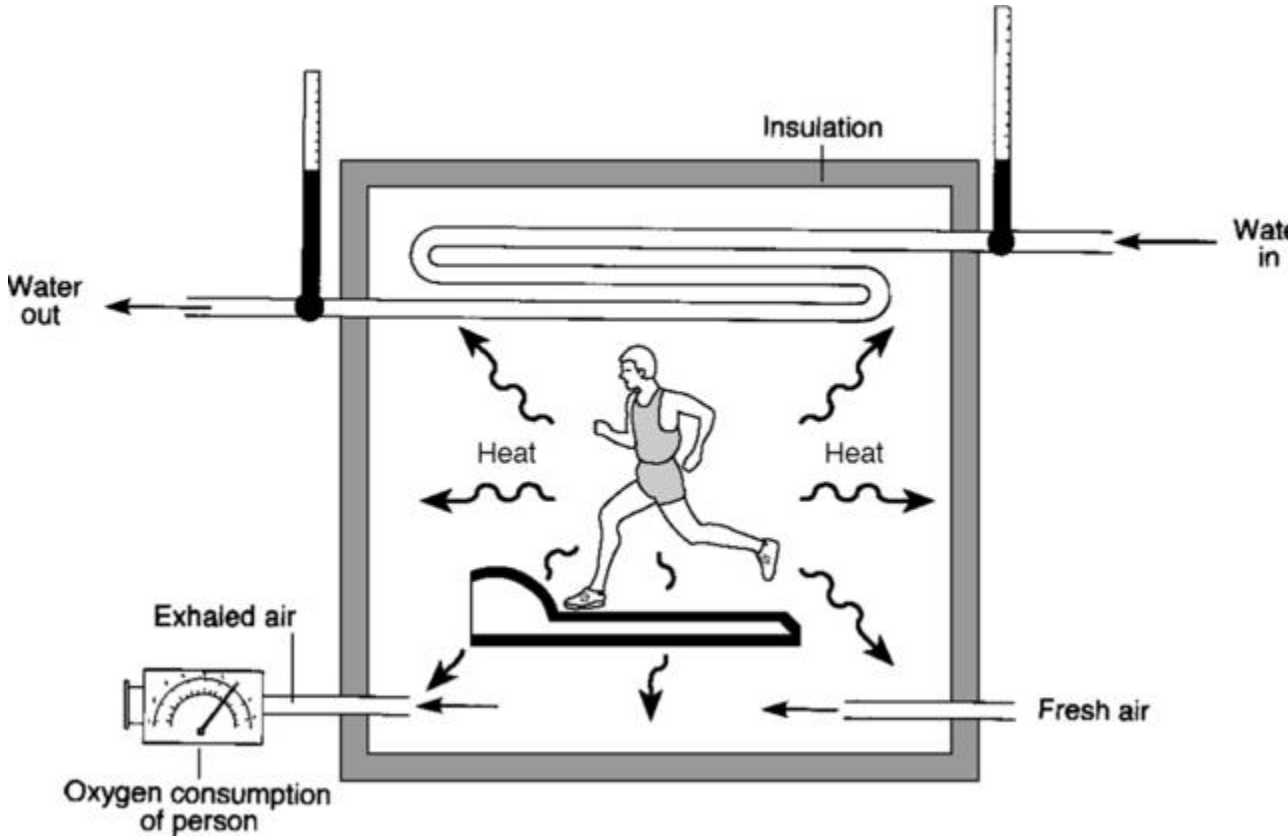
- Energy expenditure can be estimated by **measuring macronutrient or oxygen consumption, or heat production or carbon dioxide production**.

- Energy expenditure is maeasured by

1. Direct calorimetry
2. Indirect calorimetry
3. Doubly Labelled water Technique
4. Computerized Instrumentation

Direct calorimetry

- Direct calorimetry **obtains a direct measurement** of the **amount of heat** generated by the body within a structure **large enough** to permit moderate amounts **of activity**.
- These structures are called whole-room calorimeters.
- Direct calorimetry provides a measure of **energy expended** in the form of heat.



- A calorimeter is an **insulated**, airtight chamber.
- A subject exercises in this chamber and the **heat generated** is transferred to the air and walls of the chamber.
- This **change in temperature** is measured and metabolic rate can be calculated.
- Calorimeters are **extremely expensive** to construct and are slow to generate results.
- The measurements are **extremely accurate** for total energy expenditure; however, direct calorimetry cannot follow rapid changes in energy usage.

Indirect calorimetry

- **Indirect calorimetry** involves the measurement of **respiratory gas exchange** (oxygen consumption and carbon dioxide production) during a variety of controlled physical activities (cycle and treadmill exercise is common).
- This is accomplished via **open-circuit spirometry** using relatively **small gas analysis equipment**
- By **measuring gas exchange** (thus energy expenditure) during specified modes of physical activity, the average energy costs can be obtained for **these activities**.

Indirect Calorimetry: Pros & Cons

Resting energy expenditure (REE) by Indirect Calorimetry (IC) → individual nutritional energy targets

Pros

- Potential improvement in outcome with Indirect Calorimetry guided nutrition therapy
- More accurate than predictive equations
- Gold standard for REE, recommended by international guidelines
- Personalized nutrition during the patient journey

Conditions requiring adjustments

Renal Replacement Therapy

ECMO

Relative Cons

Non-nutritional calories, refeeding syndrome, early phase

Costs, investment, consumables, service, staff

Cons

FiO_2>0.7, PEEP>12 Air leak

Nebulization, wet sensors

NIV & HFNO

Oxygen therapy in non-ventilated patients

Doubly labeled water

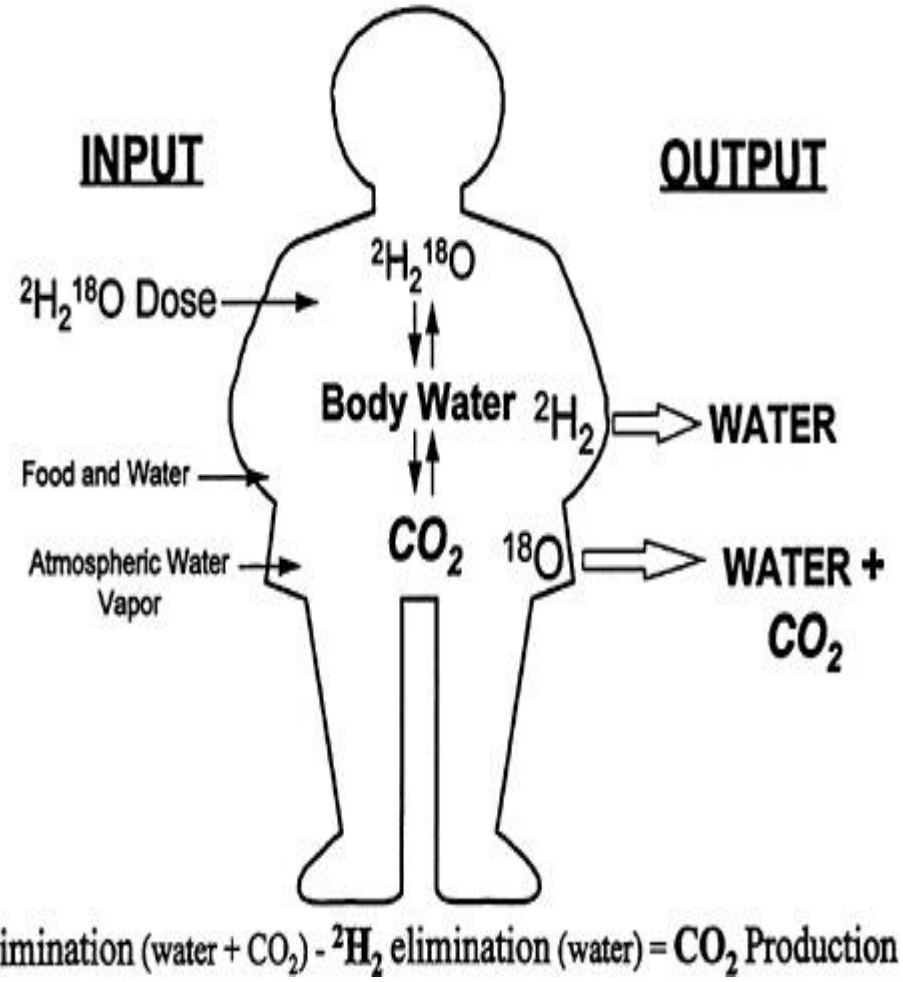
- The doubly labeled water method can be **used to measure** total energy expenditure in unrestrained subjects for 1-4 weeks.
- The method involves **dosing subjects with water** that contains artificially elevated levels of two isotopic tracers, deuterium (^{2}H) and oxygen (^{18}O), hence doubly labeled.
- These are both naturally occurring stable isotopes that have background levels of around **150 ppm for deuterium** and around 2000 ppm for ^{18}O.
- When **individuals drink** a dose of doubly labelled water the levels of these isotopes in their bodies rise to **about 225 ppm and 2150 ppm** respectively.

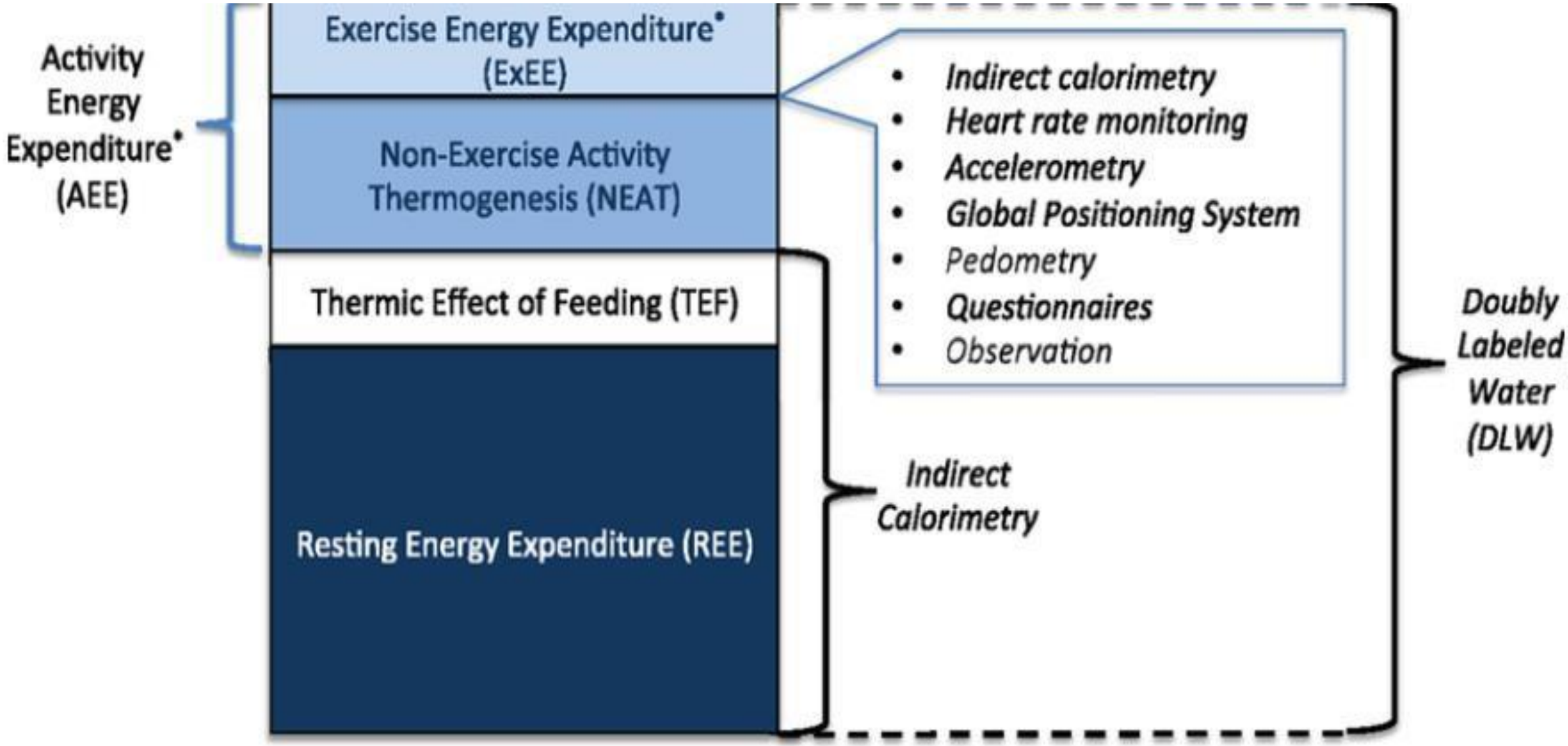
- If a dose of heavy oxygen is ingested, it is primarily **eliminated by the flow** of both water and CO_2 through the body.

- On the other hand, a dose of **deuterium** will be primarily eliminated only by the flow of water.

- Therefore, the **difference in the elimination** of the two isotopes provides a measure of CO_2 production.

- **Doubly labeled water** is currently the most accurate way to measure total energy expenditure and is considered the gold standard.

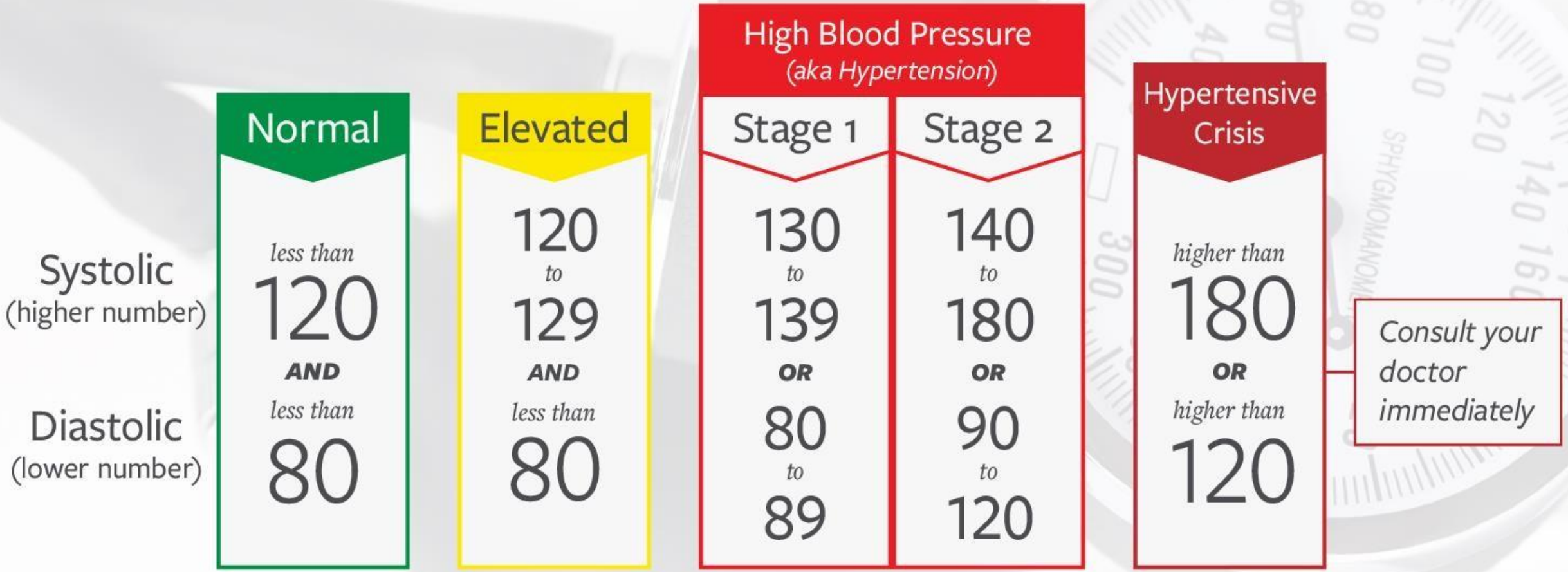




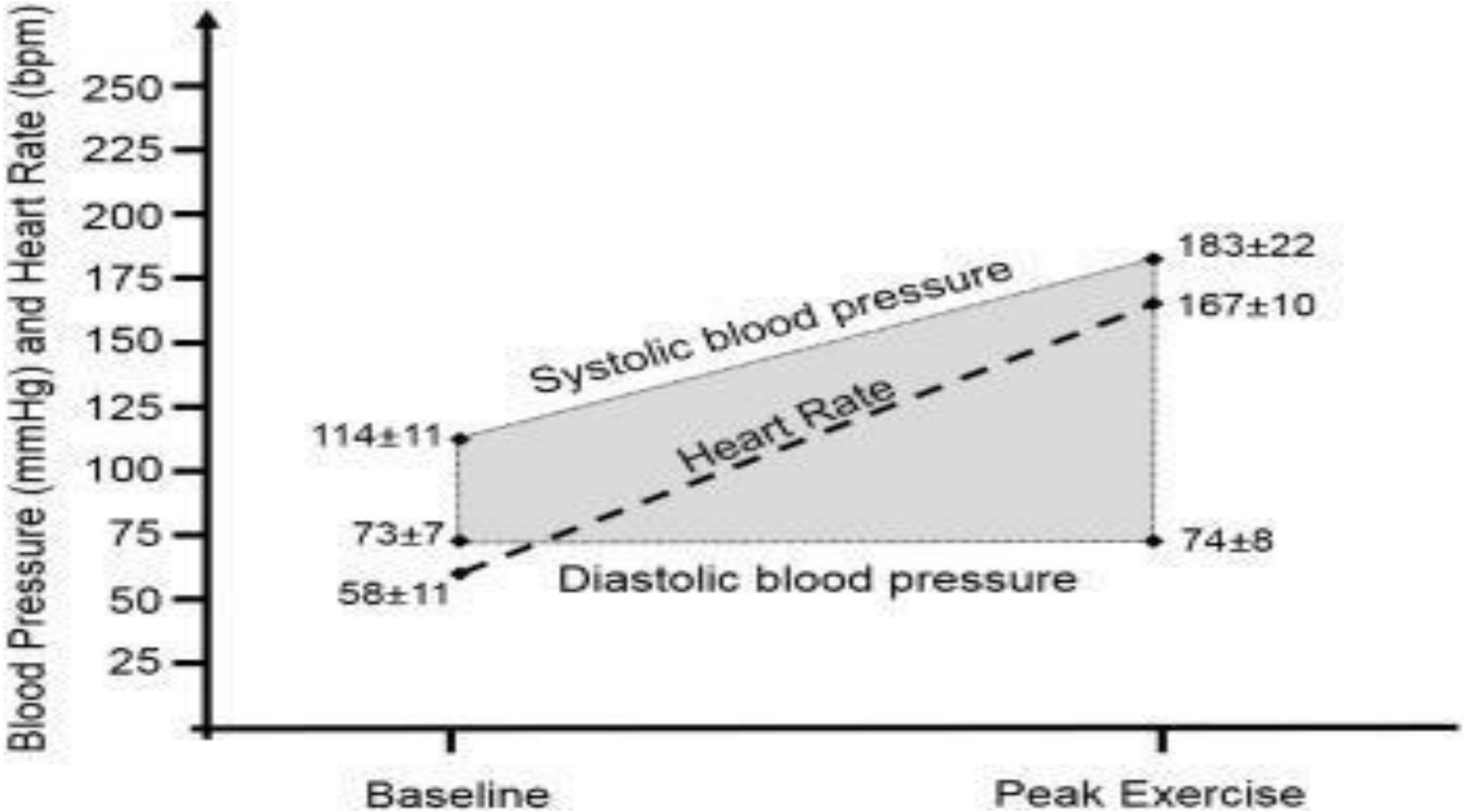
** ExEE and thus AEE are the most variable components of TEE. Therefore, the proportions of TEE and of REE, TEF and AEE differ between individuals.*

BLOOD PRESSURE HEART-FACTS

DO YOU HAVE HIGH BLOOD PRESSURE?



Understand what your blood pressure numbers mean for your health, and what you can do to lower them.


Blood Pressure (mmHg) and Heart Rate (bpm)
250
225
200
175
150
125
100
75
50
25
Systolic blood pressure
Heart Rate
Diastolic blood pressure
114±11
73±7
58±11
183±22
167±10
74±8
Baseline
Peak Exercise

DISTRIBUTION OF BLOOD DURING REST AND WORK SHOWN AS A PERCENTAGE OF CARDIAC OUTPUT

	Blood flow distribution (%)	
Part of body	Resting	Heavy work
Muscles	15-20	70-75
Skin	5	10
Brain	15	3-4
Bones	3-5	0.5-1
Kidneys	20	2-4
Digestive system	20-25	3-5
Heart muscle	4-5	4-5

Source: Adapted from Astrand and Rodahl, 1986. Fig. 4-9. Reproduced with permission of McGraw-Hill.

PHYSICAL WORK CAPACITY

- The **Physical Work Capacity** component evaluates the capacity of an individual **to perform** physically demanding work tasks.
- Physical work capacity is **the ability to perform** maximal physical work.
- As it is a function of the intensity and duration of work, each individual has many different capacities such as **anaerobic, aerobic and endurance capacity,** each with its own limiting factors.
- In practice, aerobic work capacity (VO_2 max) is the capacity most often considered.

PHYSICAL WORK CAPACITY

Aerobic

- *Brisk walking*
- *Swimming*
- *Running*
- *Cycling*
- *Jump rope*
- *Heavy cleaning*
- *Gardening*

Anaerobic

- *Sprints*
- *Weightlifting*
- *Isometrics*
- *Plyometrics*
- *Interval Training*

Aerobic vs. Anaerobic Training

Aerobic activity

Types of Aerobic Exercise Include:

Cardio Machines, Spinning, Running, Swimming, Walking, Hiking, Aerobics Classes, Dancing, Cross Country Skiing, and Kickboxing. There are many other types.

- O_2 Requires the presence of oxygen.
- Primarily works type I muscle fibers.
- Increases muscle endurance and capillary size
- Heart muscle to pump blood more efficiently
- Sustain for an extended period of time
- Heart rate between 120 and 150 BPM

Anaerobic activity

Types of Anaerobic Exercise Include:

Heavy Weight-Lifting, Sprints (running, biking, etc.), Jumping Rope, Hill Climbing, Interval Training, Isometrics

- Does not require the presence of oxygen
- It works the type II muscle fibers, which leads to greater size and strength of muscles.
- You exercise till you gas out
- Oxygen builds up, lactic acid builds up, and you start to feel the burn
- You can't sustain this kind of activity for extended time

ISSA

VO_2 max is the maximum (max) rate (V) of oxygen (O_2) your body is able to use during exercise.

Oxygen is a critical ingredient in the respiratory process that's involved in breathing. As you breathe in oxygen, your lungs absorb and turn it into energy called adenosine triphosphate (ATP).

ATP powers your cells and helps release the carbon dioxide (CO_2) that's created during your respiratory process when you exhale.

Measurement of VO_2

Accurately measuring $\dot{V}O_2$ max involves a physical effort sufficient in duration and intensity to fully tax the aerobic energy system.

In general clinical and athletic testing, this usually involves a graded exercise test (either on a treadmill or on a cycle ergometer) in which exercise intensity is progressively increased while measuring ventilation and oxygen and carbon dioxide concentration of the inhaled and exhaled air.

How to determine VO_2 max METS

The methodology for figuring out what your VO_2 max is as a figure called metabolic equivalents (METS).

That's the official term for how much energy your body uses when it's resting.

Basically, 1 MET equals about 3.5 milliliters (mL) of oxygen (O_2) divided by how much you weigh times a single minute.

That looks like this: 1 MET = 3.5 mL O_2 / kilograms (kg) x minute.

There's no one "good" VO_2 max that every single person should shoot for, but everyone should aim for a good or higher fitness score (60 and higher percentile).

Typical VO_2 max for people born male measured in METS:

Age	20–29	30–39	40–49	50–59	60–69	70–79
Superior	55.4	54	52.5	48.9	45.7	42.1
Excellent	51.1	48.3	46.4	43.4	39.5	36.7
Good	45.4	44	42.4	39.2	35.5	32.3
Fair	41.7	40.5	38.5	35.6	32.3	29.4
Poor	<41.7	<40.5	<38.5	<35.6	<32.3	<29.4

Typical VO_2 max for people born **female** measured in METS:

Age	20–29	30–39	40–49	50–59	60–69	70–79
Superior	49.6	47.4	45.3	41.1	37.8	36.7
Excellent	43.9	42.4	39.7	36.7	33	30.9
Good	39.5	37.8	36.3	33	30	28.1
Fair	36.1	34.4	33	30.1	27.5	25.9
Poor	<36.1	<34.4	<33	<30.1	<27.5	<25.9

How can you increase your VO_2 max?

Increasing your VO_2 max can improve the delivery and use of oxygen by your body, maintaining your **health and physical fitness** well into your later years.

Here are some suggestions:

Perform high intensity interval training (HIIT): This consists of doing several minutes of intense aerobic exercises, like cycling on a stationary bike, reducing the intensity for a few minutes, and increasing the intensity again.

Switch up aerobic activities in a single workout:

Start with cycling, then swimming, then running, and so on. Rest in between each activity.

Perform any cardio activity:

While intensity is what improves VO_2 max levels the most, any cardio exercise that is not a stroll should improve cardio respitory fitness and VO_2 max in sedentary people.