PUBLIC HEALTH FOUNDATION OF INDIA

ASSOCIATION OF HEALTHCARE PROVIDERS INDIA

Indian Institute of Science

Indian Institute of Space Science and Technology

Certificate Course in Healthcare Technology (CCHT)

Module 4: Technology led advancements and innovations in healthcare

Robotics and biomechanics in healthcare

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Robotics and biomechanics in healthcare

Detailed reading content:

The field of *biomechanics* and the technology of *robotics* have started playing significant roles in healthcare. This is a brief introduction of these two fields to healthcare professionals. This write up supports the video presentation and slides, and is to be read along with the slides in which figures and images are provided. It would be perhaps better to read this after listening to the presentation and seeing the slides. Biomechanics and robotics portions are roughly equal, and can be studied separately, if needed.

1. Biomechanics in Healthcare

Biomechanics is the study of the *structure* and *behaviour* of human body and its components, using the principles of *mechanics*. It helps healthcare professionals to go beyond a qualitative type of understanding of the behaviour of the human body, to quantitative analyses using which the causes of normal and abnormal behaviours, and outcomes of interventions, can be assessed more accurately. Such accurate analysis is possible because the field of mechanics and its techniques have reached a high level of maturity. Mechanics is the study of the behaviour of objects subjected to forces.

The objects of study in biomechanics are the body parts and organs, and fluids like blood, and even the air that go in and out of our lungs. How these objects move, accelerate and develop velocity, how they develop internal pressure and stresses, and deform, etc., when they are subjected to forces, are the issues of interest in biomechanics.

In biomechanics we use principles of mechanics to understand the behaviour of objects of interest. Newton's three *laws of motion*, and the various ways forces are generated, are fundamental to mechanics. *Conservation of mass and energy* are some of the other important principles used in mechanics. Biomechanics has been used in many areas in healthcare. Some of them are (a) stress, strain, and fracture analysis of various bones and groups of bones, like femur, spine, etc., (b) motion analysis of people with disabilities to plan improved rehabilitation and use of prosthetic and orthotic devices, (c) motion analysis of sports activities and exercises to improve performance without causing injuries, (d) analysis of heart function and blood flow, and lymphatic transport, (e) modeling and analysis of cochlear and vestibular apparatus, etc. We discuss two areas, namely *bone mechanics*, and human *gait analysis*, in some detail.

1.1 Bone Mechanics

Bones fracture under various conditions in healthy individuals, and they could function sub optimally when there are deformities and diseases which affect the bone.

The question, what causes a bone to fracture suddenly, can be answered at a superficial level, by saying that a load greater than the bone could support, got applied on the bone. Such an answer only raises more questions like (a) what is the maximum load that a particular bone can carry, (b) does the limit load depend on how the load gets applied and where it is applied, (c) would the limit load depend on the size of the bone or the age of the individual, etc. The field of *Solid Mechanics*, an important sub-discipline in *Civil, Mechanical,* and *Aerospace Engineering*, has developed approaches and tools to answer such questions, in the case of components of engineering structures, and have been used for analyzing bones too. One of the simplest ways in which force gets applied on an object, is when we pull it. We say that the object is subjected to a *tensile* force. When we push, it is subjected to *compressive* force. When

Pulled, the object elongates, and when the tensile force is too high, it breaks. The elongation and force at which the breaking happens, depend on the material and shape of the object. The behaviour can be pegged down as a material characteristic if we look at how tensile stress and strain are related (see the plot in slides), instead of tensile force and elongation. From such a plot we can abstract out material parameters like *Young's modulus*, *ultimate strength*, *toughness*, etc., and use them to predict reasonably accurately, how prismatic bars of that material, of various shapes and sizes, would behave under tensile force. In the above discussion we talked about tensile stress and strain. In the simple situation of uniaxial tensile forcing of a prismatic bar, stress we refer to, is just the force per unit cross sectional area, and strain is just the elongation per unit length. Stress and strain at a point inside a body are more complex quantities than that. Stress varies with the plane considered through the point, and it can be normal to the plane or tangential. Nevertheless, both stress and strain at a point are fully represented by a finite number of stress and strain parameters. For elongated bodies like the ulna and radius, more than tensile and compressive forces along the length, what are likely to cause fracture, are forces called *bending forces*, which are in the transverse direction. They cause the bones to *bend* and break. Due to bending, certain regions on the outer surface develop high tensile stresses, and when this is more than what the bone material can sustain, it fractures. Different materials fail in different ways, and with different conditions arising in the material. *Failures theories* specify these conditions for various materials. To predict whether a body would fail under specific forces, we calculate the stress and strain distributions in the body, and examine whether the failure condition for that particular material has been reached anywhere.

For a body of complex shape, subjected to a complex system of external forces, stress and strain have very complex distributions inside the body, and depend on certain properties of the material, like Young's modulus. Even in such complex cases, it is possible to determine stresses and strains with a great deal of accuracy. One analysis technique which has become very popular for such calculations is the *Finite Element Method*, or FEM in short. Sophisticated software packages are available, which help us model bodies, boundary conditions and forces, and calculate stresses and strains throughout the body. They are now used very widely in engineering for analysing structures, and also in healthcare for analysing stresses and strains in bones and groups of bones. One complication in the analysis of bones is that the bone material, like many biological materials, is very complex, much more so than most engineered materials. For most bones there is an outer harder *cortical bone*, and an inner softer core called *trabecular bone*. The harder cortical bone carries most of the loads, and is responsible for the strength of the bone. The bone has a certain structure at the nano level, and other structures at higher levels, forming a hierarchical *material*. These structures are formed in such a way as to give appropriate material properties in various regions and various directions, typical of *composite materials*. This enables the bone to handle the spectrum of loading it encounters in normal activities. The bone also has the property of *viscoelasticity* which enables it to absorb and convert energy to lessen the effects of shock loading. Because of its complex hierarchical structure, stress and strain analysis of bones is not very easy. Two specific examples of analysis of bone groups, done in IIST [] are discussed in the slides. In one, the pelvic group of bones is analysed during two phases of walk. In the other, stresses generated in two adjacent vertebrae which are fused at a couple of contact points, is compared with the case where these contacts are allowed to slide. Both these analyses were performed using a commercial FEM software package on a workstation level computer. It was possible to perform these analyses only after significantly reducing the size and complexity of the problems by using several simplifying assumptions.

1.2 Human Gait Analysis

The human walk is a complex sequence of coordinated limb movements, called the gait.

Disabilities cause significant changes in the gait patterns. A detailed study of gait is very useful for effective rehabilitation, and choice of orthotic and prosthetic devices. As healthcare professionals know, each cycle of walk has a double support phase when both feet are in contact with ground, and a single support phase when only one foot is in contact with the ground. The stance phase of a foot occupies roughly 60% of the gait cycle, with the swing phase occupying the remaining 40%. Maintaining balance and expending minimum energy, are key features of the walk.

While several aspects of the human body from the central nervous system to the muscles and bones of the body play crucial roles in achieving walk, biomechanics essentially focusses on the role of the muscelo-skeletal system in the walk. The human skeleton forms the basic rigid link mechanism of the body which allows the limbs and the torso to move in certain restricted ways with respect to each other. Of particular importance in the skeleton, are the joints between various bones. Ball and socket joints at the hips and the shoulders allow rotation about a point, while knee and elbow joints allow rotation about an axis. They are analogs of the spherical and revolute joints in man made mechanisms. The specific motions allowed by a joint are dependent on the ways in which the bones of the joint are shaped at the contacting surfaces. Joints are usually secured by ligaments. Actuators which move the joints to give various motions

to the human body, are the muscles. One group of muscles move a joint in one direction, while another group of muscles are needed to move the same joint in the opposite direction. This is so, because muscles move joints primarily by applying pulling or tensile forces, and cannot generate power through compressive forces Simulation and dynamic analysis of the human walk is not an easy problem. There are software
tools which can be used for such analysis. However, experimental method of gait analysis is currently more popular. For this the subject is made to walk along a walk-way. Several markers are fixed to the subject's body. Several infrared cameras are used to track these markers. From the videos of the marker motions generated by the cameras, absolute and relative motions of various body segments can be obtained with accuracy. From this, joint motions are extracted. In addition to capturing motion, gait analysis systems also capture the interaction of feet with the ground. For this, force plates are laid on the ground. When the subject's foot is placed fully on a force plate during the walk, the force plate senses all the forces between the foot and the ground,
and logs them. Variation of foot forces is also important data for gait analysis. Deviations over normal motion and foot force patterns are associated with disabilities and pathological conditions. A simple example of application of biomechanics is that of analysing the causes for falling while climbing staircases, the possibility of which increases in old age. It has been observed that such falls are more frequent during the single support phase, after the toe off by one foot. It can be seen that at toe off, the leg on the upper step is highly flexed at the hip, knee and ankle. This brings on additional forces on the muscle. This is also the moment when dynamic balance is needed. Both
these factors place extra demands on the elderly, and increase the chances of losing balance and falling. While biomechanics has been able to provide deeper and more detailed understanding of various aspects of human activities, it should be noted that most activities require a multidisciplinary approach for fuller understanding. For example, in the human walk and many such activities, the central nervous system and proprioceptive feedback play very important roles. Focussing only on the mechanics aspects would provide only a limited understanding of the total activity.

2. Robotics in Healthcare

Robotics is making inroads into surgery and other healthcare areas. Here we look at robotic surgery in some detail. Before describing a robot used for surgery, we see robotic manipulators and mastern slave manipulators more closely. The field of robotics has made major strides in recent decades. While industrial manipulators, one of the first type of robots to be developed for commercial use, have become more sophisticated, the area of mobile robots has seen significant growth and diversification. As industrial manipulators are more relevant for surgery, we focus our attention on them.

2.1 Industrial Manipulators

Industrial manipulators are used for various applications in factories, ranging from simple pick and place operations, to assembly, welding, spray painting, etc. The core function of an industrial manipulator is to manipulate objects, or in other words, to move and orient objects for various purposes. There are two classes of industrial manipulators, the serial chain manipulator, and the parallel chain manipulator. In serial chain manipulators the links are connected in series, while in parallel chain manipulators there are one or more loops. Most manipulators used in surgery are of the serial chain type. Most serial chain manipulators are similar to the human arm, which also is a serial chain. The body can be regarded as the manipulator's stationary base. The first joint, the shoulder joint, is a ball and socket joint allowing rotation about a point for the upper arm with respect to the torso. Then the elbow allows the lower arm to rotate about an axis with respect to the upper arm. Then there is the wrist which can be regarded as a joint which allows the hand to rotate about a point with respect to the lower arm. This is achieved using a more complex arrangement thn the ball and socket. Then we have hand which is an immensely capable multipurpose tool at the end of the arm. As all of us know, no joint of the arm can rotate fully, 360 degrees, and so the arm, without considering the motions of the fingers, has seven degrees of freedom ("degrees of freedom" refers to the number of independent ways in which something can be moved). Also, amazingly, nature has perfected the design in a way to enable maximum reach for the arm. And this perfection is seen not just in the arm, and not just in human beings. Like the human arm, a six degrees of freedom articulated manipulator has a stationary base. In one of its popular configurations, the industrial manipulator has a shoulder like joint composed of two rotary joints in series. That is one degree of freedom less than our shoulder. Then there are the elbow and wrist joints which are very similar in function to the human arm's elbow and wrist. The last link could be a gripper with two or three fingers, usually of much lower capability than the human hand. In place of the gripper, we can mount tools like the welding gun or the spray painting nozzle. Needless to say, this configuration of the serial chain manipulator, has been modelled after the human arm. It is a distant poor cousin of the human arm in manipulating capability. But makes up for this with its high precision, and willingness to do a programmed task repeatedly, with great repeatability.
It should be noted that what is described abouve is just one configuration of industrial manipulators. They come in different sizes, shapes, and configurations. By configuration what is meant is the type of joints and their arrangement in connecting different parts of the manipulator. In place of muscles which actuate (meaning, move) the joints of the human arm, there are actuators which move the joints of the industrial manipulator. Hydraulic actuators are usually used for very high force requirements, while pneumatic actuators are usually used for low power requirements and for less complicated motion tasks. The most common actuator used in robotics is the electric motor. They come in many varieties. As most of them are high speed low force actuators, they are coupled with a speed reducer to reduce the speed and increase the force. It has to be mentioned that most actuators are simple compared to the very

complex ways in which muscles are arranged on the human body to move joints. For example, there is no single actuator capable of actuating a ball and socket joint. On the human arm, the shoulder which is a ball and socket joint, is actuated by a group of muscles which are place on the body and connected to bones in very complex ways. What provides the remarkable precision and repeatability to the industrial manipulator, is feedback control. In broad terms, a feedback controller compares the current state of the manipulator with the current desired state, and then based on this information, applies the appropriate voltage (in the case of the electric motor) to drive the actuator which drives the joint. By “state” we mean the angle of the joint or its speed. Sensing accurately is very important, and there are many types of sensors used. To sense the rotation of a shaft, rotary optical encoders are common. The controller is a microprocessor with some additional features to take in sensor signals and put out command signals to drive the motor. As these controller output signals are usually low in power, their power is boosted by an amplifier, which is also called a motor driver.

Feedback control is actually present in our own body, and is very prevalent in nature at various levels of organization, from the simple joint of an animal, to various processes in society, like the management of the economy. A typical example is the temperature control of warm blooded animals. One of the most capable sensors used by human beings is their eyes, whose capability when coupled with the brain, is far superior to the most sophisticated machine vision system available today. The study and design and use of feedback control is a very important subdiscipline in engineering.

In most industrial manipulators, the desired motion is programmed in by an operator beforehand, and then the manipulator just follows the programmed motion, usually in a repeated fashion. We now see a different real time way of providing the desired motion.

2.2 Master-Slave Manipulators

A special type of manipulator, called the master-slave manipulator, is used in nuclear power plants. The slave manipulator is inside the radioactive environment, carrying out various manipulation tasks. It is controlled by the operator who is in an outside room protected from radiation. The operator moves the end effector of a master manipulator, and thereby controls the motions of the end effector of the slave-manipulator. Master slave-manipulators have been developed by BARC of Department of Atomic Energy.
The master and slave are identical or scaled versions of each other. In a purely mechanical masterslave manipulator, the motions of the master manipulator’s joints are transmitted to corresponding joints of the slave, using pulley and wires. While this has the advantage that the system can work without any electric power, there are significant disadvantages like friction and stiffness of joints, and the need for the operator to be close enough to see through a window, what is happening to the slave manipulator.

A master slave manipulator which uses electric signals to transmit control commands, has a simple configuration. The slave manipulator can be a regular industrial manipulator of the type described earlier. The desired motions of the joints of the manipulator can be generated by the operator by moving something like a control stick. The motion of the control stick can generate several motion outputs which is interpreted by the controller as the desired end effector motion, and then converted by the controller to desired motion of each joint of the manipulator, which is then fed to the joint feedback controller. In the above system, the control stick is usually a small simple device with many degrees of freedom, and is usually not identical to the slave manipulator. When the operator moves the control stick, the slave manipulator and its end effector moves in a way decided by the mapping programmed in the controller, between the control stick and slave manipulator. This arrangement has the advantage that the control stick is a small handy device which is easy to operate. It has the disadvantage that some training is required before an operator can learn how to move the slave effectively. The popular versions of surgical robots are such master slave robots.

2.3 Master-Slave Manipulators in Surgery

The main use of surgical robots so far has been in minimally invasive surgery. The most successful commercial surgical robot so far, the da Vinci® surgical system, is a master slave robotic system operated by the surgeon and the surgery team. The da Vinci® system is described here. It can be seen in much more detail in the company's website, and several YouTube videos which show then system and its operation.
Two of the major subsystems of the da Vinci system is a patient cart on which several slave manipulators are mounted, and one or more surgeon consoles. The patient cart is placed near the patient who is on the operating table and prepared for surgery. The surgeon consoles could be in the same room or some other room far away. A team of healthcare specialists are needed for setting up the patient cart and associated subsystems before the procedure, and for changing tools, etc., during the procedure. There are typically four or more manipulators on the patient cart. Each is inserted into the cavity in which operation takes place, through small incisions. The manipulators are slightly different in configuration from the industrial manipulator which was described earlier.
The manipulators are manipulated in such a way that a remote center is used so as to cause minimal stress and strain at the incisions, but still afford significant motions for the end tools within the cavity. A surgeon may operate one or two manipulators at a time. The movements of the surgeon's fingers and hand are translated to movements of the surgical instruments within the cavity in which the procedure is done. One of the major facilitators of effective execution of the procedure is the depth vision camera and the realtime video images seen by the surgeon at the console. The visibility within the cavity is significantly enhanced by the camera system. The other major facilitator is the instrument into which the surgeon inserts fingers so as to manipulate the surgical instruments which directly execute the surgery. The instruments are capable of capturing very subtle motions of the surgeon's hand and the controller translates them

to appropriate motions of the surgical tools. As already mentioned, if the internet bandwidth is sufficient, a surgeon sitting in a different continent can operate on a patient using the internet. Apparently this has happened. Master slave surgical systems apparently have provision for the touch sense to be conveyed back to the surgeon. This could make the system even more capable. We now briefly see how the touch sense is typically conveyed to an operator.

2.4 Haptics

Haptics is the word associated with the conveying of the touch sense to a remote operator. In one of the slides, schematics for master slave systems without and with touch/force sense, are shown. The system is for conveying the turning motion of a master knob, to the turning of a slave shaft. This is easily achieved by using an encoder to sense the knob rotation and give that as a commanded motion to be replicated by the slave shaft. The controller uses feedback of the shat rotation to achieve this accurately. But a problem happens when the sfat comes up against a stop and cannot physically rotate further. But the operator does not sense that the shaft is seeing a resistance, and so may rotate the shaft farther, causing serious damage to the system. In the system with force feedback, a force sensor is placed on the shaft. This sensor will pick up any resistance the shaft sees, and send that to the controller. The controller then generates this force on the operator’s hand by using an actuator like the electric motor. Here too, a feedback system is used to ensure that the force seen by the operator is a true replica of the force seen by the shaft. Haptics has been used in many applications. Use of haptics in surgery would definitely enhance the effectiveness of robot assisted surgery. Several surgical procedures have been executed using the master slave surgical robot systems. Some of them are listed in the slides. A more up to date list can be compiled from the websites of various surgical robot vendors. 3. Conclusion We summarise the discussion here. Biomechanics is the attempt to use the principles and tools of the field of mechanics to arrive at deeper understanding of the human body and its working. Such insights have led to improvements in healthcare, particularly for rehabilitation, and sports performance enhancement.

Master slave robots have been extensively used to assist surgeons. They have made a significant impact in minimally invasive surgeries. Effective and innovative use of such advanced technological tools, and their further development, requires teams of healthcare professionals and engineers to work together.

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6. K C Kim (Ed.), Robotics in General Surgery, Springer, New York, 2014.
7. P Gomes (Ed.), Medical Robotics : Minimally Invasive Surgery, Woodhead Publishing, Oxford,2012.

YouTube Videos:

Physics - Mechanics: Stress and Strain (4 of 16) Bone Strength : https://www.youtube.com/watch?v=FT8Xg98uw1o Understanding & Analyzing Gait For **The Clinician :** https://www.youtube.com/watch?v=KsdrmyxOyxM
Human Movement System : https://www.youtube.com/watch?v=DsBvYWu6Mhs
The Biomechanics of Basketball : https://www.youtube.com/watch?v=Yen0ryYmbu4
Hope called Jaipur Foot : https://www.youtube.com/watch?v=GchWUvPfnzc
Robotic Surgery Unlocks a New Era of Medicine: https://www.youtube.com/watch?v=_aJhNXXWmq0
Da Vinci SP Surgical System : https://www.youtube.com/watch?v=TGjnb86HndU
da Vinci Robotic Surgery – Minimally Invasive Hernia Repair : https://www.youtube.com/watch?v=KAvQsRL-jeo

Presentations

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HEALTHCARE TECHNOLOGY

Dr K Kurien Issac

Senior Professor of Aerospace Engineering,
Indian Institute of Space Science and Technology,
Thiruvananthapuram, Kerala

Prof Kurien Issac joined Department of Aerospace Engineering at IIST in 2009. Before that, he was a faculty of Mechanical Engineering at IIT Bombay for about twenty one years. He was Associate Dean R&D in IIT Bombay for one term, and Head of the Department of Aerospace Engineering, and Dean of Intellectual Property Rights & Continuing Education in IIST. His education, from bachelor to doctoral levels, was in Mechanical Engineering, specializing in the area of Theory of Machines. His research interests have been in Optimal Design, Kinematics and Dynamics, Control, Robotics, Automobiles, and Aids for People with Mobility Issues.

At IIST Prof Kurien Issac and his team of students have been doing research on (a) improving mobility of wheeled rovers for planetary exploration, (b) designing unfurlable antennas and solar sails, (c) designing and operating satellite docking and berthing systems, (d) planning motions for robotic systems for non-destructive testing, (e) design and control of legged robots, etc.

Biomechanics and Robotics in Healthcare

Subtopics

Biomechanics

- Definitions and some principles
- Applications of biomechanics

Robotics

- Anatomy of industrial manipulators
- Master slave manipulators
- Robot surgery

Definitions

***Biomechanics*:**
Study of the *structure and behaviour of human body and its components* using the principles of *mechanics*.

***Mechanics*:**
Study of the *behaviour* of *objects* subjected to *forces*.

Mechanics

Study of the *behaviour* of *objects* subjected to *forces.*

***Objects*:**
Made up of matter – occupying space and having mass.
Occur in solid or liquid or gaseous form.

Examples: tennis ball, femur, water, blood, air, ...

***Behaviour*:** movement (speed), deformation, pressure, ...

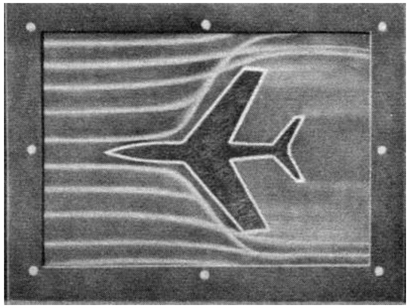
***Force*:** Defined using its effect – acceleration.

Typical Questions in Mechanics

When a racquet hits a tennis ball with a certain speed, how fast will the ball move?

If I open the tap at the bottom of a tank, what will be the flow rate of water coming out?

If an object moves in air at a given speed, what will be the force applied by air on it?



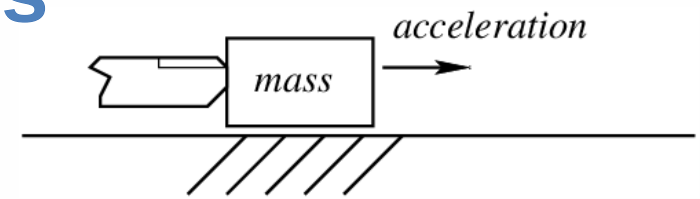
How do we Answer these Questions

When a racquet hits a tennis ball with a certain speed, how fast will the ball move?

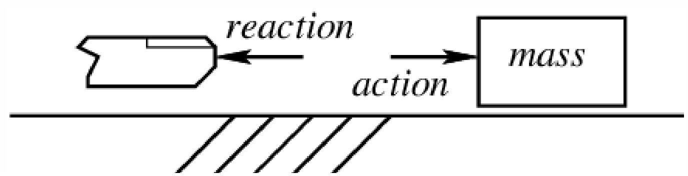
The rebound speed will depend on the racquet string material properties, tensions in the strings, where the ball hits the racquet, material properties of the ball, pressure of gas inside, how firmly the racquet is held, relative velocities between the racquet and the ball, ...

Principles of Mechanics

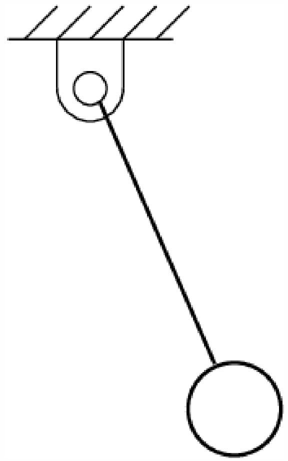
Force = mass x acceleration



Reaction = - Action (Force)

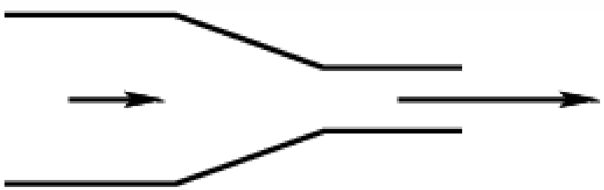


Lever principle



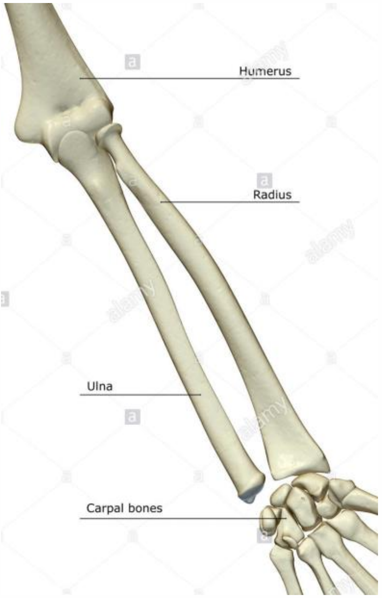
Energy conservation

Mass conservation

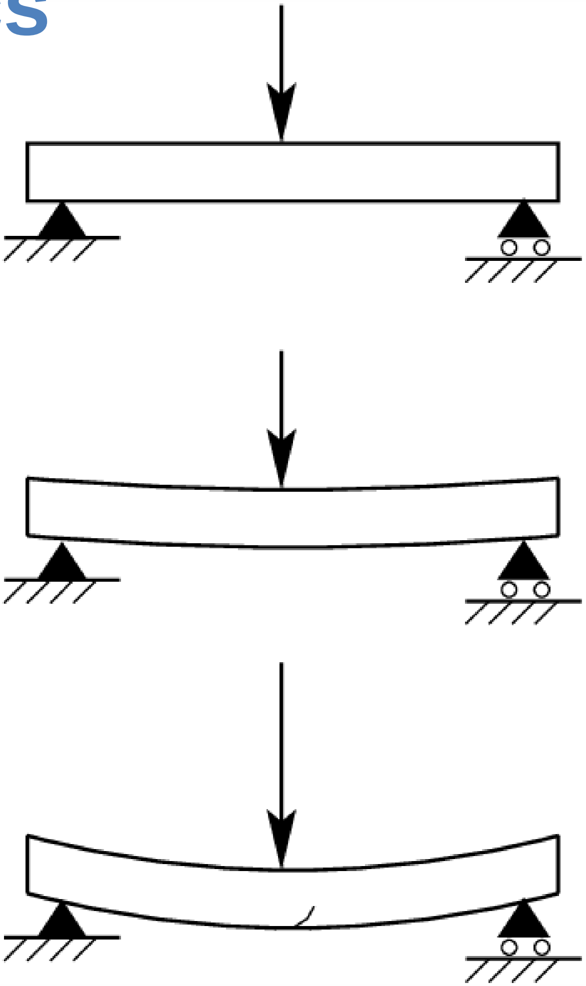


Applications of Biomechanics

1. How Strong is the Bone?

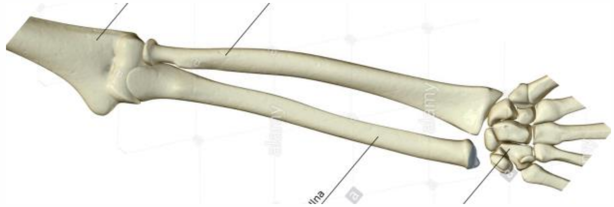


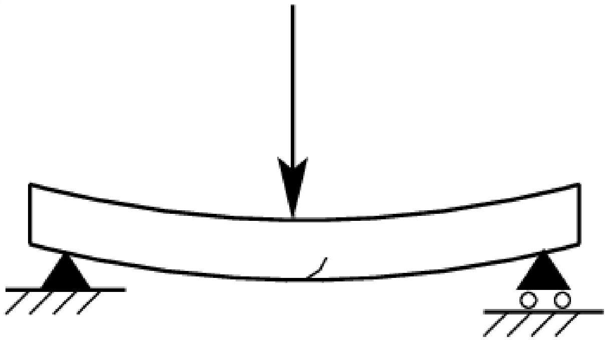
A simple analog:
Beam – **bending**
and
breaking



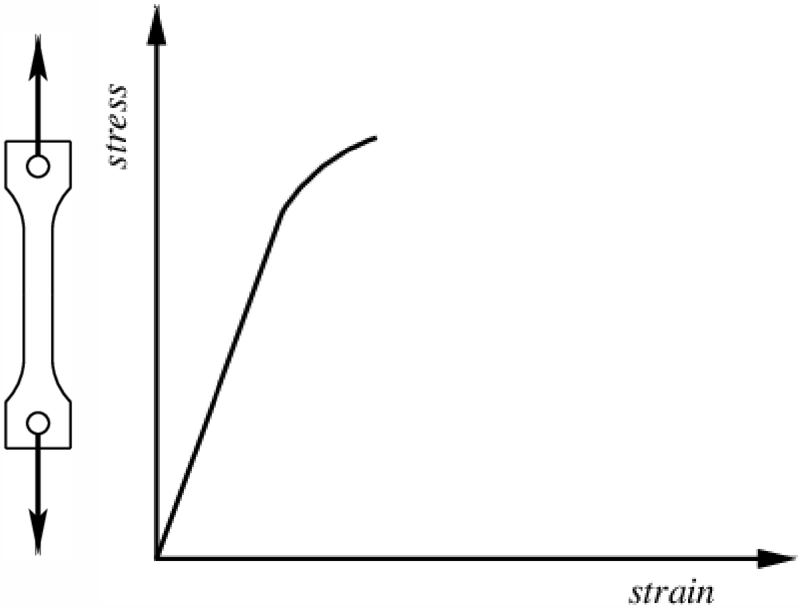
Ulna and Radius
Often fractured in childhood

1. How Strong is the Bone





Fracture at region of high tensile stress



Tensile test

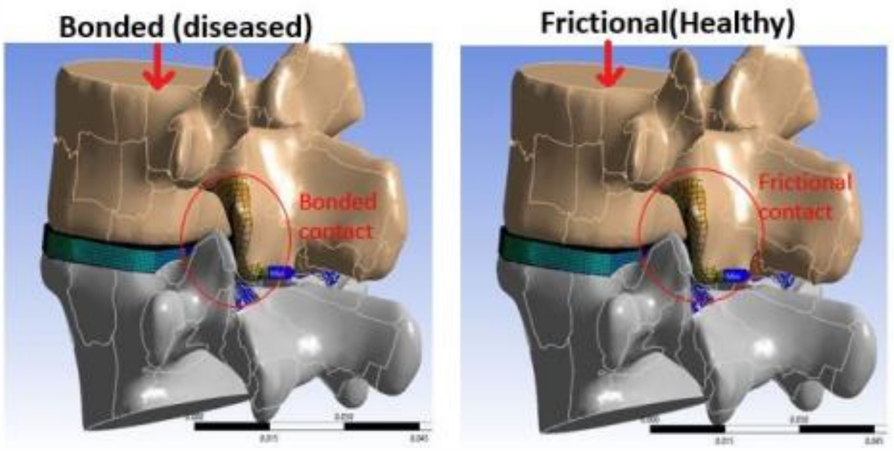
Failure theories

Stress: force per unit area

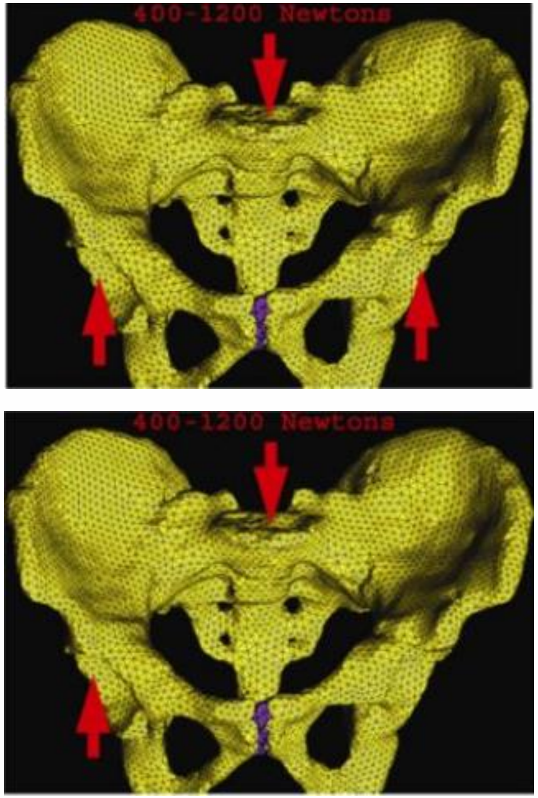
Strain: deformation per unit length

Bone : Analysis of Stress and Strain

Tool for analysis:
Finite Element Method

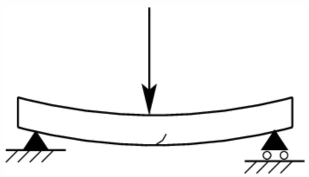


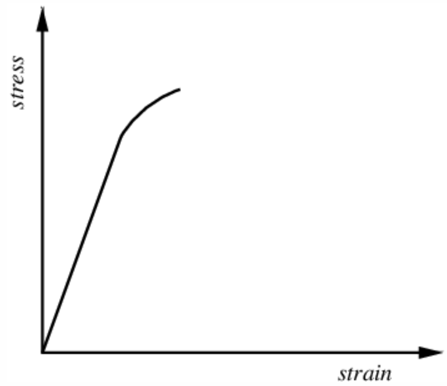
Sresses on vertebrae

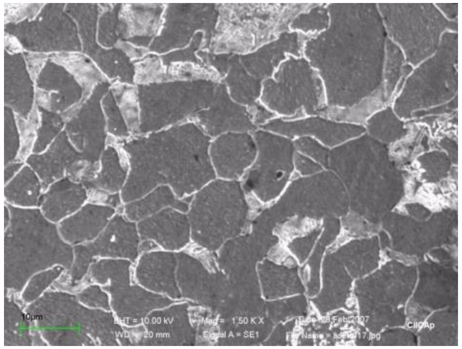


Pelvic stresses
Standing & walking

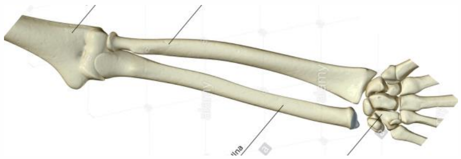
How Strong is the Bone Material

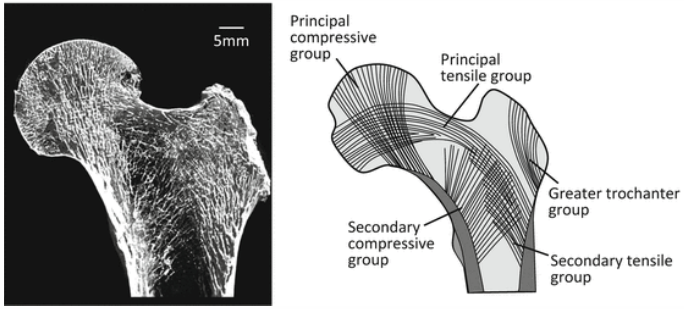


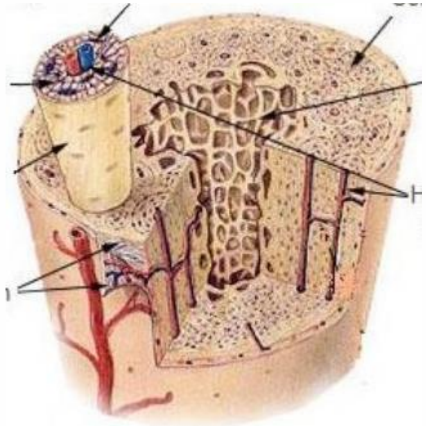




Typical microstructure of steel





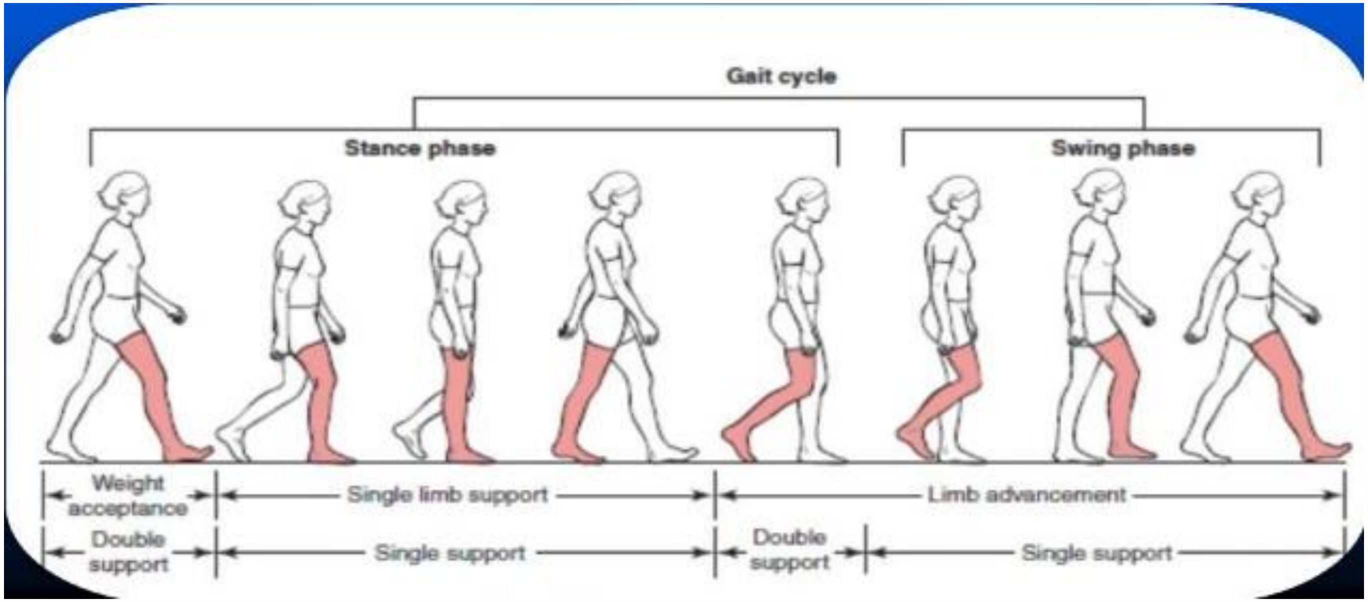


Composite & hierarchical
Viscoelastic

Applications of Biomechanics

2. Mechanics of Human Walk

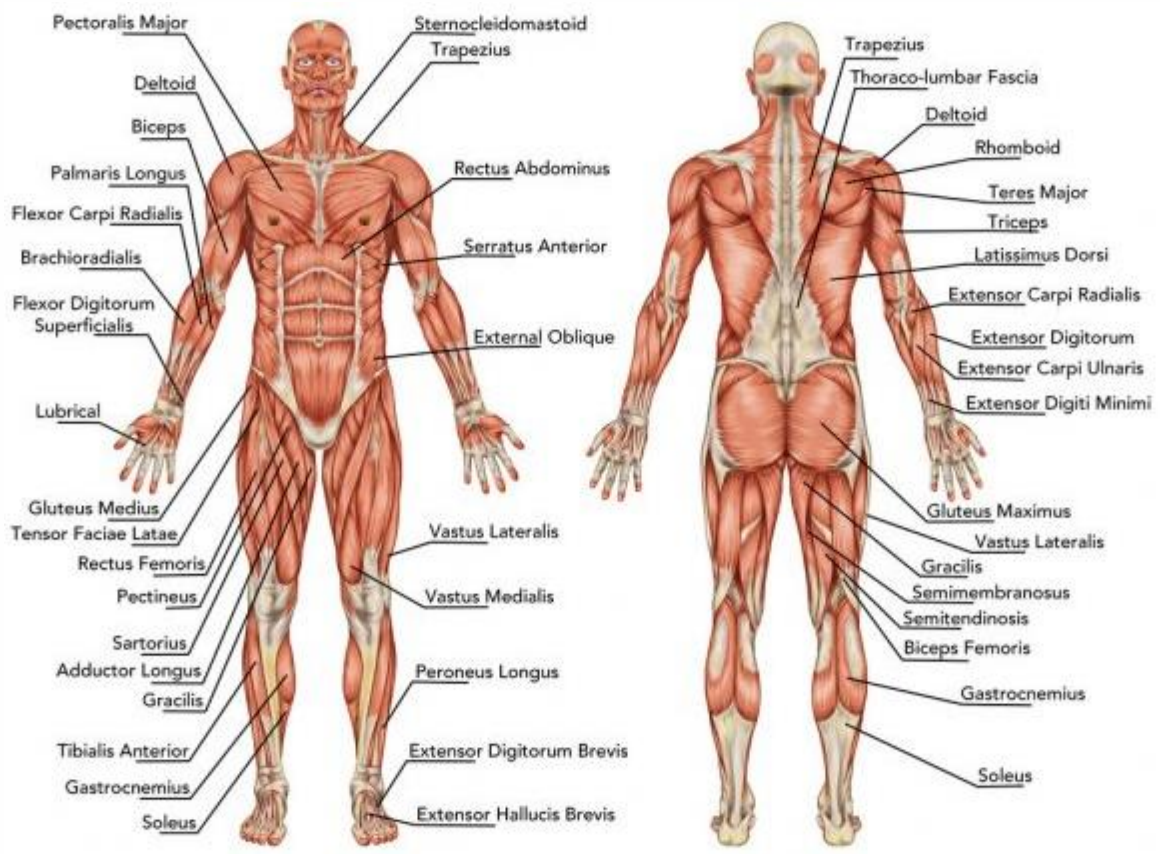
Balance, speed, effort, energy, ...



Change due to pathology

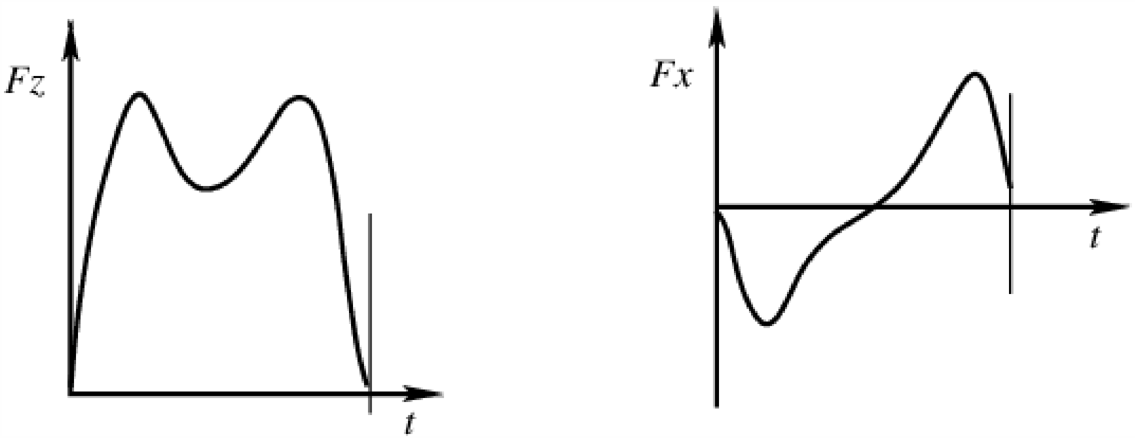
Sequence of leg motion

2. Mechanics of Human Walk



Mechanism and motors : Muscelo-skeletal system

2. Mechanics of Human Walk

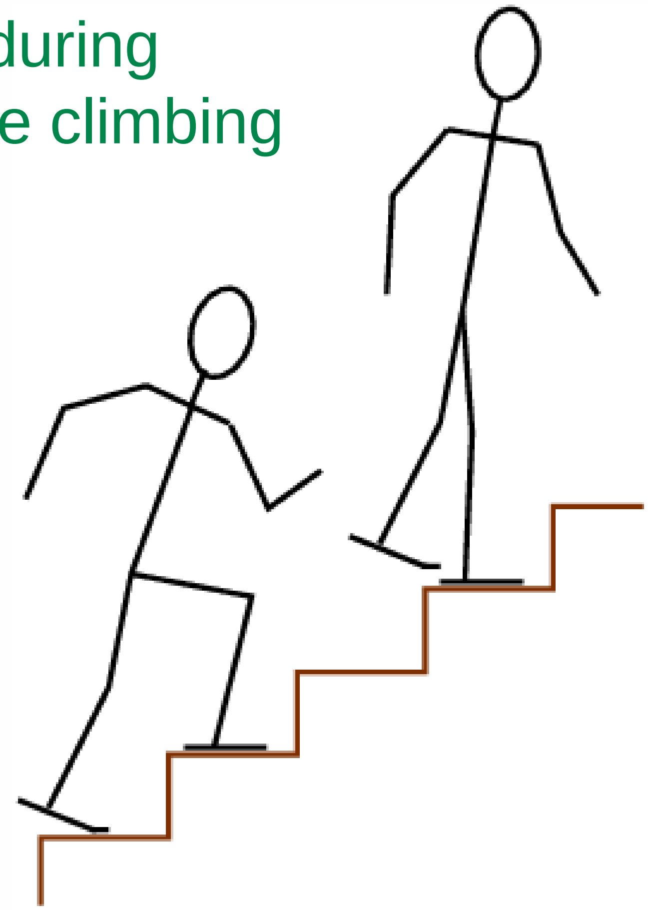


Foot ground interaction forces

Tools for **gait analysis**:
Video cameras and **markers**
Force plates

An Issue for the Elderly

Falling during staircase climbing



At toe off:

Three joints under flexion together.

High muscle forces.

Loss of balance.

Applications of Biomechanics in Healthcare

Finite element models for stress and strain analysis: Lumbar spine, femoral fracture, impact and fatigue, ...

Motion analysis of various patient groups: To understand musceloskeletal pathology for better rehabilitation, including uses of prostheses and orthoses, better design and management of sporting and exercise activities, ...

Heart, blood flow, etc: Cardiac biomechanics, macrocirculatory hemodynamics, deformability of hematocytes, lymphatic transport, cellular biomechanics, molecular transport, ...

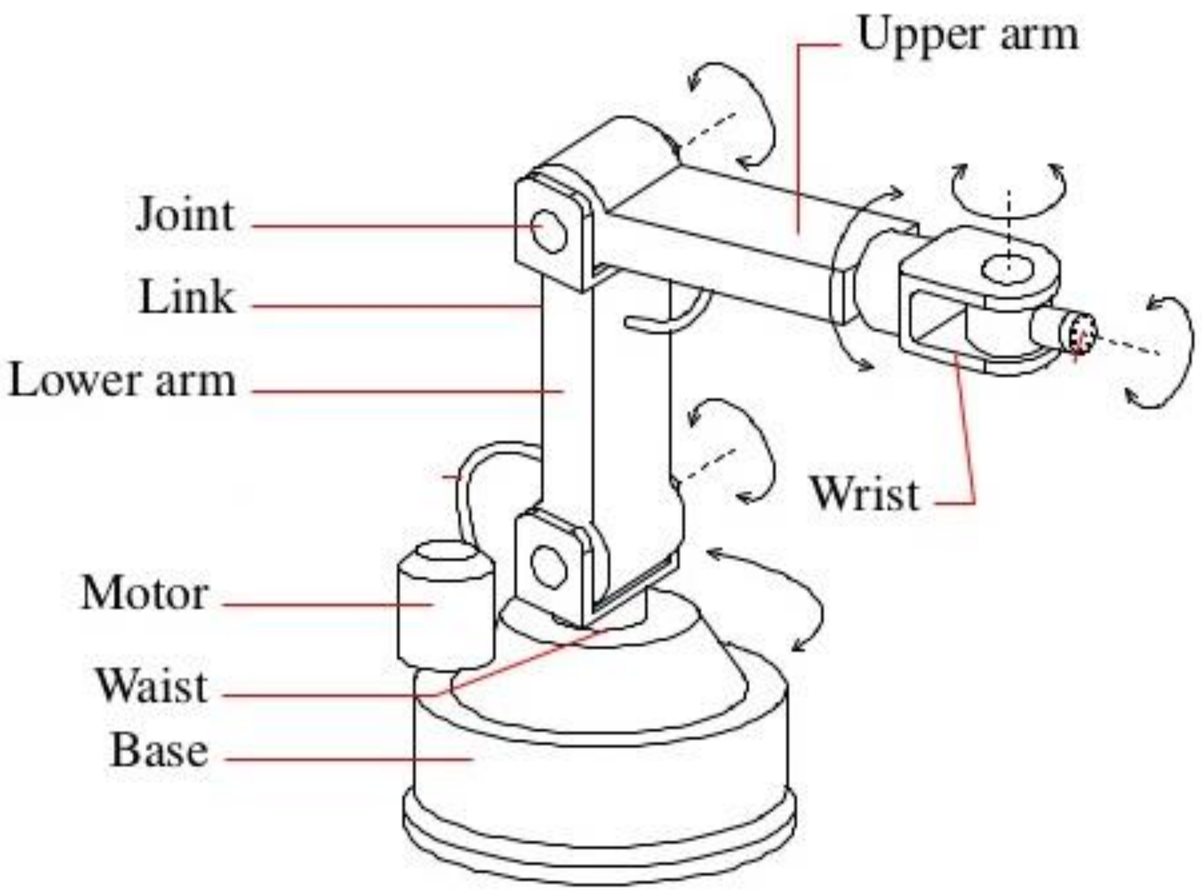
Ear and balance: Cochlear mechanics, vestibular mechanics, ...

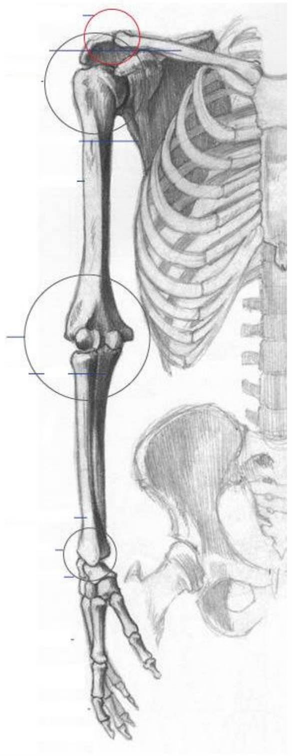
Robotics in Healthcare

Anatomy of industrial manipulators
Master slave manipulators
Robot surgery

Robot Manipulators : Anatomy

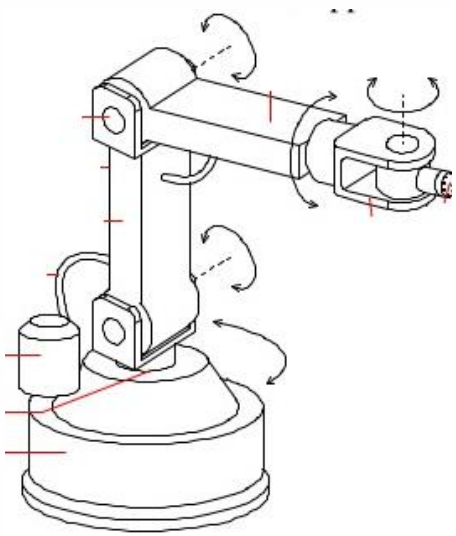
Robots: Mobile Robots and Industrial Manipulators

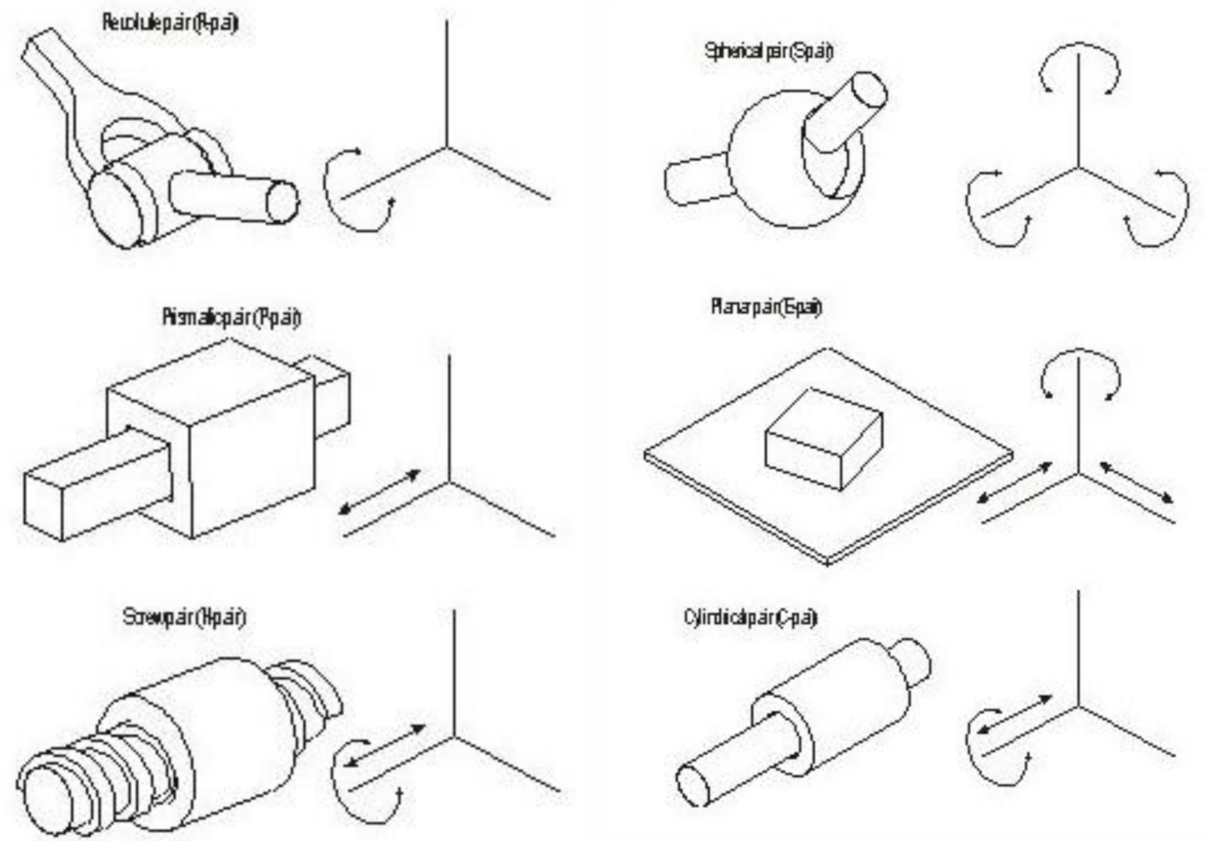




Robot Manipulators : Anatomy

Mechanism, Actuators, Sensors, Controller

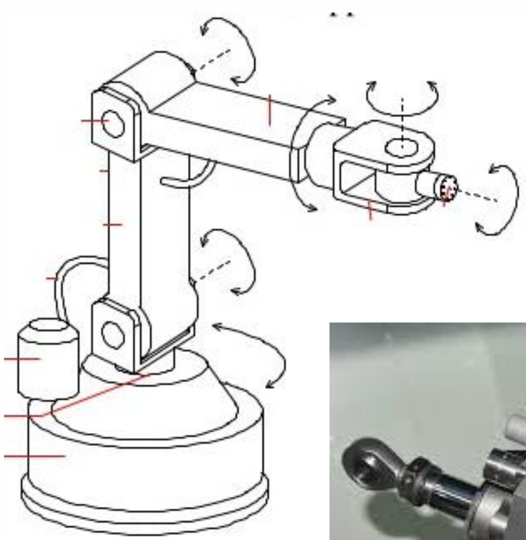




Mechanism (skeleton) : Links & Joints

Robot Manipulators : Anatomy

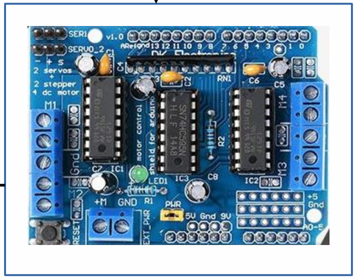
Mechanism, **Actuators, Sensors, Controller**



Hydarulic actuator

Electric motor with encoder

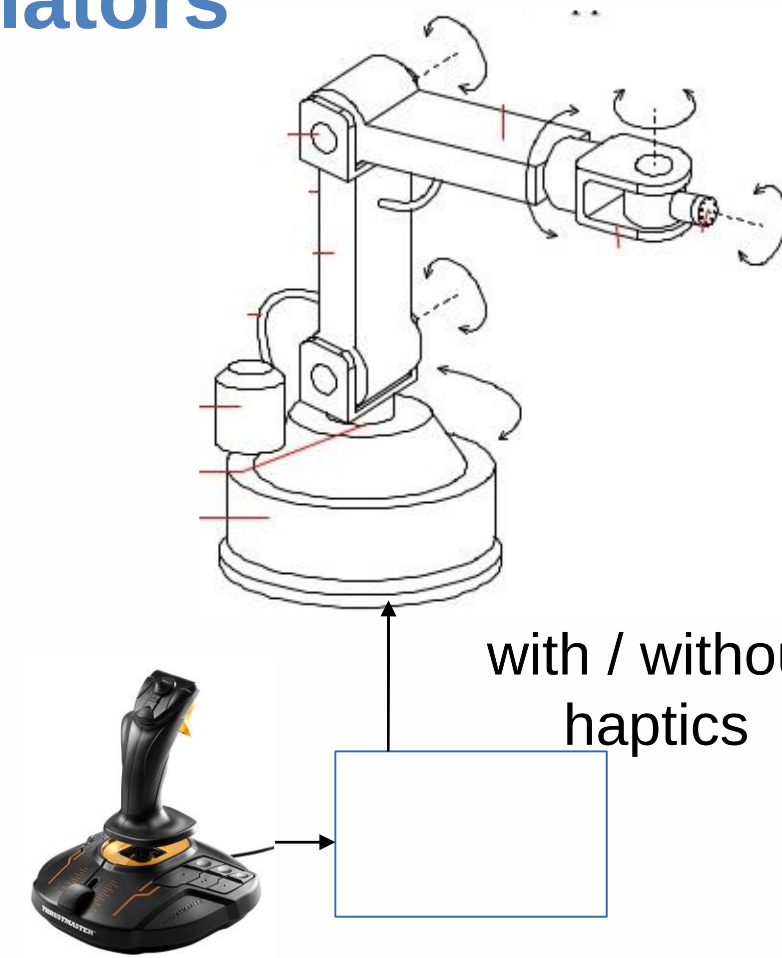
Feedback controller



Driver

Master-Slave Manipulators

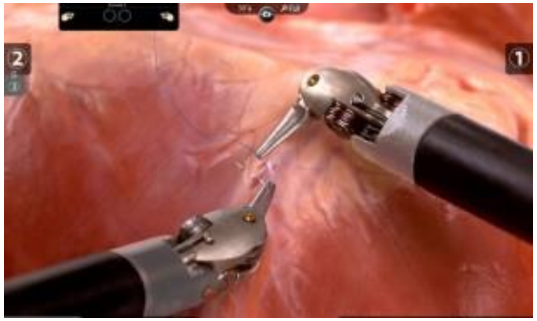
BARC
Cable driven



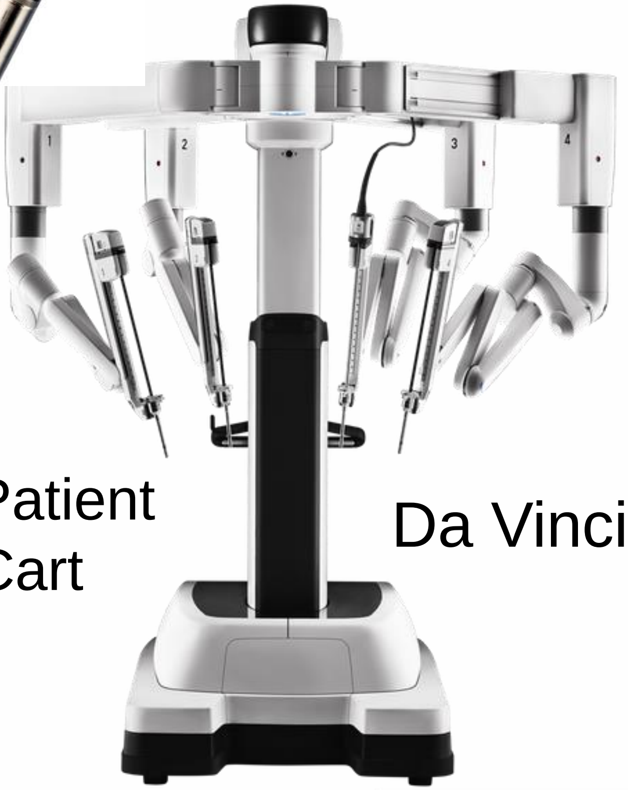
A Master-Slave Surgical System

Da Vinci®

A Master-Slave Surgical System



Tools



Patient Cart

Da Vinci®

Wristed instruments

Surgeon Console

Master-Slave Surgical Systems

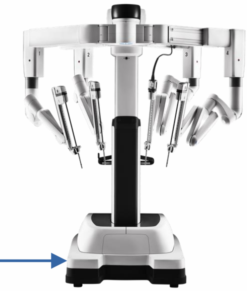
Advantages:

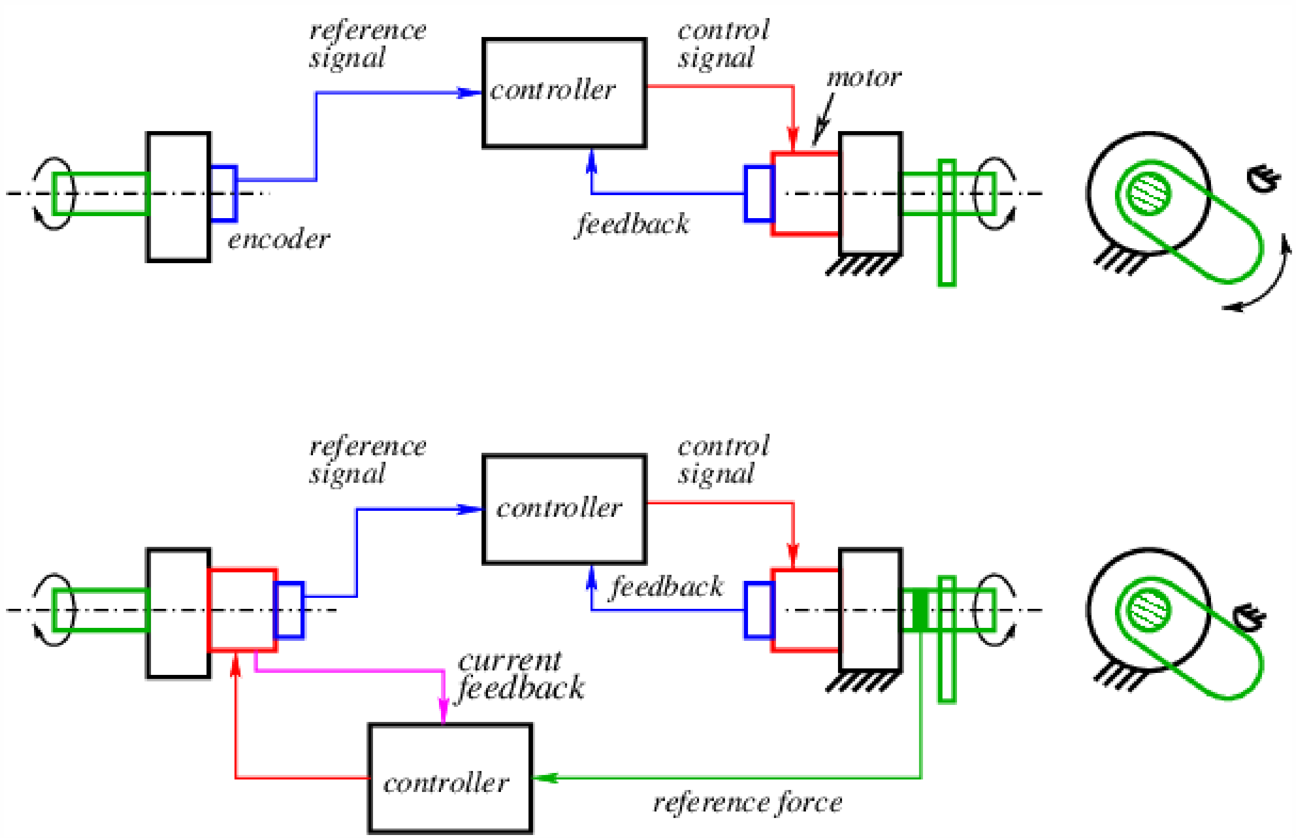
- 3D stereoscopic vision of operative field
- Maneuverability of articulating wrist instruments (7 DoF)
- Tremour filtering
- Remote operation

Disadvantages:

- Decreased tactile feedback sense
- Long set up time

Master-Slave Systems and Haptics





Procedures Performed with Robot Systems

Esophagus: Esophagectomy, Gastroesophageal Reflux

Thoracic: Lobectomy, Pulmonary Resection

Stomach: Gastrectomies, Lymph Node Dissection

Bariatric: Roux-en-Y Gastric Bypass, Biliopancreatic Diversion

Colon and Rectum: Right and Left Colectomy, Low Anterior Resection, Abdominoperineal Resection

Endocrine: Thyroidectomy, Radical Neck Dissection, Adrenalectomy

Solid Organ: Donor Nephrectomy & Kidney Transplant, Splenectomy

Microsurgery: Male Infertility, Chronic Orchialgia

To Conclude

Developments in engineering and technology have benefited healthcare. Two of them are **biomechanics** and **robotics**.

Biomechanics helps us understand **mechanics related aspects of functioning of the human body and its components**, and develop **better procedures for rehabilitation, surgeries, patient care**, etc.

Master slave robots have helped in developing several successful **minimally invasive surgical procedures**.

To fully exploit such technologies for healthcare, it is **imperative that healthcare professionals and engineers work together**.

Thank You

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3. Y Hirasawa, C B Siedge, and S L-Y Woo (Eds.), Clinical Biomechanics and Related Research, Springer-Verlag, Tokyo, 1994.
4. Tung-Wu Lu and Chu-Fen Chang, Biomechanics of human movement and its clinical applications, Kaohsiung Journal of Medical Sciences (2012) 28, S13-S25.
5. D Maurya, Stress and strain analyses on spinal and sacral region for pathological condition, Mtech Thesis, IIST, 2018,
6. K C Kim (Ed.), Robotics in General Surgery, Springer, New York, 2014.
7. P Gomes (Ed.), Medical Robotics : Minimally Invasive Surgery, Woodhead Publishing, Oxford, 2012.

Videos (from YouTube):

Physics - Mechanics: Stress and Strain (4 of 16) Bone Strength : https://www.youtube.com/watch?v=FT8Xg98uw1o

Understanding & Analyzing Gait For The Clinician : https://www.youtube.com/watch?v=KsdrmyxOyxM

Human Movement System : https://www.youtube.com/watch?v=DsBvYWu6Mhs

The Biomechanics of Basketball : https://www.youtube.com/watch?v=Yen0ryYmbu4

Hope called Jaipur Foot : https://www.youtube.com/watch?v=GchWUvPfnzc

Robotic Surgery Unlocks a New Era of Medicine : https://www.youtube.com/watch?v=_aJhNXXWmq0

Da Vinci SP Surgical System : https://www.youtube.com/watch?v=TGjnb86HndU

da Vinci Robotic Surgery – Minimally Invasive Hernia Repair : https://www.youtube.com/watch?v=KAvQsRL-jeo

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For more Information please contact

Program Secretariat – CCHT
Public Health Foundation of India
Plot No. 47, Sector 44, Institutional Area, Gurgaon -122002, India
Tel: 0124-4781400 (Extn. 4511,4596,4512) Fax: 0124- 4722971
Mobile No.: +91- 9582215659, 9958158787
Web: www.phfi.org, ccht@phfi.org