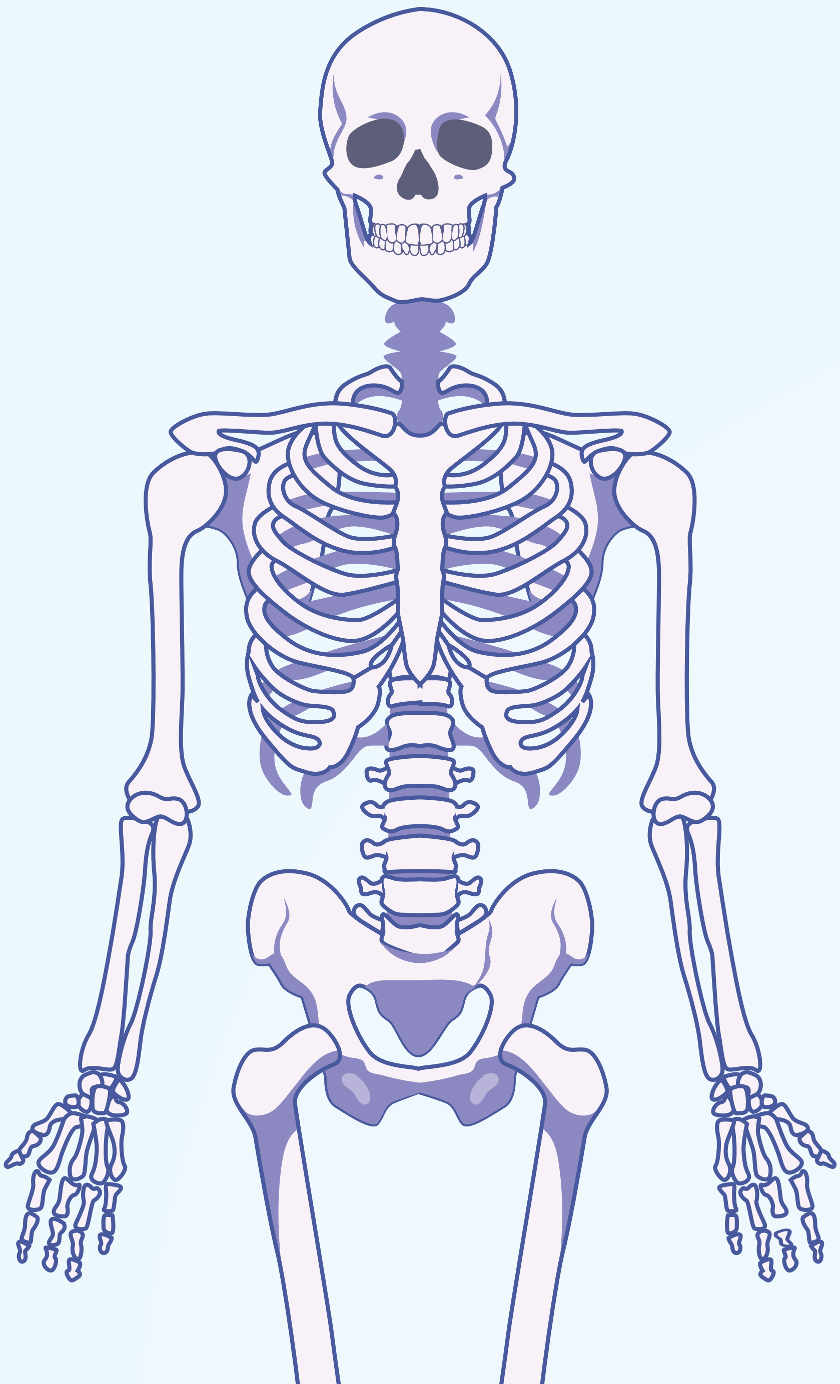
Anatomy



Found in:
- Pancreatic acinar cells → Digestive enzymes
- Fibroblast → Collagen
- Plasma cells → Immunoglobulin

(Ref: Junquerira's /14th edition/P-30)

Ribosomes

Functions:
- Free ribosomes are involved in the synthesis of proteins for intracellular use (cytosolic protein).
- Attached ribosomes are involved in the lysosome enzymes, exportable proteins (enzymes or hormones) and membrane proteins.

❖ Organelles involved in protein synthesis:	❖ Organelles involved in Post-Translational Modification of Proteins:
1. Mitochondria 2. Rough endoplasmic reticulum 3. Ribosome	1. RER 2. Ribosome 3. Golgi apparatus

Lysosomes
The lysosomes are membrane bound organelles formed by the golgi apparatus. They contain a variety of hydrolyzing or digestive enzymes called acid hydrolases -the main function of whose is intracytoplasmic digestion.

Source:
Lysosomal enzymes are synthesized and segregated in rER and transferred to golgi complex, where they undergo post-translational modification, modified and packaged as lysosomes.

Lysosomal enzymes (hydrolases): The most common enzymes are
- Acid phosphatases
- Deoxyribonuclease
- Proteases (cathepsins)
- Sulphatase
- Lipases
- β-glucoronidases

Functions:
- These are the digestive apparatus for cell and digest foreign particles (heterophagy).
- They remove worn out of the cytoplasmic organelles through autophagy (autophagy)- intracellular scavenger.
- Under some conditions they digest the cell itself and thereby destroy the cell, so the name is Suicidal bag:
- Substances in excess are digested by the lysosome e.g. droplets of hormones which are no longer needed are broken down by lysosomes in some cells.

(Ref: Junqueira's/14th edition/P-36)

❖ Centrosome: Functions:	❖ Inclusions:
• Helps in mitosis • Play role in the formation of mitotic spindles of dividing cells.	Cytoplasmic inclusions contain accumulated metabolites or other substance. Commonly seen inclusion are • Lipid droplets • Glycogen granules • Melanin • Lipofuscin • Hemosiderin

4.2 Cartilage

Difference between types of cartilages: ***

Appearance	Hyaline cartilage	Fibrocartilage	Elastic cartilage
Translucency	Blueish white	Dense-white	Yellow
Perichondrium	Present, except in the articular cartilage of joints	Absent	Present
Identifying characteristics	Type II collagen basophilic matrix, chondrocytes usually arranged in groups	Type I collagen, acidophillic matrix, chondrocytes arranged in parallel rows between bundles of collagen, always associated with dense collagenous connective tissue and/or hyaline carting	Collagen type II and an abundance of elastic fibers
Calcification	Frequent	Never	Rare
Sites	Costal cartilage, articular cartilage epiphyseal cartilage etc.	Intervertebral disc symphysis pubis, articular disc etc.	Pinna of the external ear, eustachian tubes, epiglottis etc.
Main function	Provides firm structural and flexible support	Provides tensile strength or compression	Confers structural support as well as increased flexibility

05. Tissues of the Body

5.1 Circle of Willis ***

Definition: it is free arterial anastomosis formed by the major arteries of the brain at the base of the brain in the interpeduncular fossa.

Formation:

- ✪ **Anteriorly**: by anterior communicating artery, which links the two anterior cerebral arteries
- ✪ **On each side**: by posterior communicating artery, which connects the internal carotid artery with posterior cerebral artery
- ✪ **Posteriorly:** by the terminal bifurcation of basilar artery into the posterior cerebral arteries.

Functions:

1. Equalization of blood pressure between the two sides of the brain
2. It also furnishes collateral circulation

5.2 Cranial Nerves *****

- ➢ **There are 12 pairs of cranial nerves. Some are purely sensory; some are purely motor & some are mixed.**
  - ✓ Purely sensory- 1,2,8
  - ✓ Purely motor- 3,4,6,11,12
  - ✓ Mixed nerves- 5,7,9,10

Muscles of respiration:

A. Inspiration
In quite inspiration
- The diaphragm (75%)
- External intercostal muscle

In forceful inspiration:
The above muscles + additional muscles:
- Sternocleidomastoid muscles
- Scaleni
- Anterior serrati
- Scalenus posterior
- Latissimus dorsi muscle

B. Expiration:
1. In quite expiration: Does not involve any muscle
2. In forceful expiration: (Additional muscles)
   - Rectus abdominis
   - Internal intercostal
   - Serratus posterior inferior muscle

Muscles common in both inspiration and expiration:
1. Intercostal
2. Serratus posterior

Hemodynamic effects of respiration:
JVP and BP fall in inspiration, **Heart rate accelerates** and **second heart sound (S2) splits**

Surfactant begins to secrete at 28th week of intrauterine life
Secreted by **type II alveolar epithelial cells**

Surfactant:
a) Decreases surface tension of fluid lining alveoli
b) Increases compliance and stability of the lung
c) Reduces elastic recoil pressure and
d) Decreases work of breathing

At the lung apex:
a) Intrapleural pressure more negative
b) large alveoli
c) less blood flow
d) PO_2 highest, PCO_2 lowest
e) VA/Q highest
f) Alveolar size larger

❖ **During Inspiration:**
1. Fall of intra thoracic pressure
2. Promotion of venous flow into the chest
3 Increase in the flow of blood through the Rt heart
4. sequestration of a substantial volume of blood in the chest as the lungs expand

Glucose transporter

Type	Characteristics
GLUT 1	Basal glucose uptake (ercs, muscle cells at resting conditions, brain, vessels…)
GLUT 2	Liver, β cells of pancreas, kidney
GLUT 3	Neurons, placental cells
GLUT 4	Muscle, adipocytes-dependent on insulin
GLUT 5	Transport of fructose, small intestine
GLUT 7	Intracellular transport liver

07. Renal Physiology

Filtration membrane

Components of filtration membrane or filtration barrier:

1) Fenestrated capillary endothelium
2) Glomerular basement membrane and
3) Filtration slit-pores of podocytes

Process of urine formation

- Glomerular filtration
- Tubular secretion
- Tubular reabsorption

What percentage of filters reabsorbed by renal tubules?

- Around 99**%** (GFR →120 ml/min (170-180L/day)

GFR is 125 mL/min or 180 L/ day

Factors affecting GFR:

1. **Glomerular capillary hydrostatic pressure:** It is normally 60 mm Hg. It increases GFR.
2. **Glomerular capillary colloidal osmotic pressure:** It is 32 mm Hg. It decreases GFR.
3. **Bowman's capsule hydrostatic pressure:** It is 18 mm Hg. It decreases GFR.
4. **Bowman's capsule colloidal osmotic pressure:** It increases GFR.
5. **Glomerular filtration coefficient (Kf):** ↑Kf ↑ →GFR.
   Kf= permeability x surface area of glomerular capillary
6. **Renal blood flow (RBF):** ↑renal blood flow → ↑GFR.
7. **Sympathetic stimulation:** It decreases GFR.
8. **Permeability of glomerular capillaries affect GFR.**
9. **Arterial pressure**: ↑or ↓arterial pressure → auto regulation of renal blood flow →GFR remains relatively constant.
10. **Constriction of afferent arteriole:** It causes ↓RBF→ ↑ glomerular pressure → ↓GFR.
11. **Constriction of efferent arteriole:**
    - Mild constriction causes ↑ in resistance to outflow of blood →↑glomerular pressure→↑ GFR.
    - Moderate and severe constriction causes accumulation of blood into glomerulus for a long time and plasma colloid osmotic pressure increases which decreases GFR.
12. **Change in the total glomerular capillary bed:** ↓ Size of capillary bed → ↓ GFR.

Q. Linear growth is determined by *(42nd Special BCS)*
a) Calcium b) Phosphate c) Vitamin-D d) IGF-1
Answer: D

Q. During sleep there is fall in the circulating level of hormone except: *(39th Special BCS)*
a) Growth hormone b) Insulin c) Adrenaline d) Cortisol
Answer: A

Oxytocin ***

Stimuli that cause oxytocin release:
1) Primary stimuli → Stimulation of nipple
2) Secondary stimuli → Uterine & vaginal distension
3) Stressful stimuli

Functions:
1. No metabolic & electrolyte function
2. General function: On pregnant uterus &On breast -help in parturition & **help in milk ejection**
3. Special function: On non-pregnant uterus -Receptive contraction & facilitates sperm transport.

On corpus luteum: Luteolysis -Regression of corpus luteum.
Therapeutic oxytocin: Used to induce labor

Endocrine
 # Functions of ACTH:
1. Growth of adrenal cortex
2. Stimulates melanocytes and causes skin pigmentation
3. Stimulation of glucocorticoid secretion and mild stimulation of adrenal androgen secretion

ACTH has no effect on aldosterone secretion

 # Circulatory change caused by Epinephrine and Norepinephrine

Norepinephrine	Epinephrine
1. Predominant α-adrenergic action	Predominant β-adrenergic action
2. Vasoconstriction	Vasodilation
3. Increases both systolic and diastolic BP	Increases systolic BP but decreases diastolic BP

 # Hormones act on female breast:
- **Estrogen**: causes growth of ductal system and stroma
- **Progesterone**: stimulates growth of lobules and alveoli
- **Prolactin**: stimulates milk secretion into alveoli
- **Oxytocin**: stimulates milk ejection from alveoli into ducts
- **Human chorionic somatomammotropin (HCS):** It is lactogenic
- **Growth hormone:** These hormones are important in growth of the ductal system
- Growth glucocorticoids
- Insulin

Q. Milk ejection in female is caused by *(39th Special BCS)*
a) Prolactin b) Oxytocin c) Oestrogen d) Progesterone
Answer: B

Bilirubin	5.1 – 22 µmol /L	0.3 – 1.3
Total cholesterol	3.9 – 5.7 mmol /L	150 – 220
Triacylglycerol (TAG)	< 2.5 mmol /L	< 200
HDL		> 40
LDL		< 160
S. total protein	67 – 86 g/L	6.7 – 8.6 g/dl
S. albumin	40 – 50 g/L	4.0 – 5.0 g/dl
S. iron	7 – 25 µmol /L	41 – 141 µg/dl
S. calcium	1.0 – 1.4 mmol /L	9 – 11 mg/dl
S. phosphate	0.8 – 1.4 mmol/L	2.4 – 4.1 mg/dl

Plasma protein

Plasma proteins with their normal values:

Name of plasma protein	Normal value (gm/dl)
Albumin	4.8
Globulin (α1, α2, β) γ-globulin (or antibody)	2.3
Fibrinogen	0.3
Prothrombin	0.1

Functions of plasma proteins:

Plasma Proteins	Functions / Importance
1) Albumin	• Maintains 80% colloidal osmotic pressure of blood. • Maintains viscosity of blood. • Acts as buffer & maintains acid-base balance. • Acts as a carrier for hormones, bilirubin, fatty acids, bile salts, amino acids, heavy metals & some drugs.
2) Globulin	1. Maintains 20% colloidal osmotic pressure of blood. 2. Maintains viscosity of blood. 3. α1-globulin transports lipid & steroids. 4. α2-globulin transports Cu as ceruloplasmin. 5. β-globulin transports Fe as transferrin. 6. γ-globulin acts as antibody for defensive action.
3) Fibrinogen	• Essential for blood coagulation. • Maintains the viscosity of blood. • Increases ESR.
4) Prothrombin	• Helps in blood coagulation.

Interpretations of thyroid function tests:

Most likely interpretation(s)	T_4	T_3	TSH
Thyrotoxicosis / hyperthyroidism			
Primary thyrotoxicosis	Raised	Raised	Undetectable
Subclinical thyrotoxicosis	Normal	Normal	Undetectable
Secondary thyrotoxicosis (e.g. TSH-secreting pituitary tumour) Thyroid hormone resistance	High	High	Elevated

Hypothyroidism			
Primary hypothyroidism	Low	Low	Elevated > 20 mU/l
Subclinical hypothyroidism	Normal	Normal	Mildly elevated 5–20 mU/l
Secondary hypothyroidism (i.e. pituitary or hypothalamic disease)	Low	Low	Undetectable

Diarrheal Diseases

Organisms that cause watery diarrhea
• Enterotoxigenic Escherichia coli (ETEC) • Vibrio cholerae • Staphylococcus aureus • Bacillus cereus • Listeria monocytogens • Norovirus • Rotavirus • Giardia lamblia • Cryptosporidium hominis
Organisms that Cause Bloody diarrhea
• Shigatoxin –producing Escherichia coli (STEC) • Shigella species • Salmonella enteridis • Campylobacter jejuni • Clostridium difficile • Yersinia enterocolitica • Entamoeba histolytica

Food poisoning***

Toxin mediated:

- Staph. aureus
- C. Botulinum
- C. Perfringens
- E. Coli (Verodoxin producing)
- B. Cereus

Non-toxin mediated:

- S. typhi
- S. enteritidis
- C. jejuni
- Listeria

Cause of genital ulcers

Syndrome	Pathogen
Genital herpes	HSV-2
Syphilis	Treponema pallidum
Chancroid	Haemophilus ducreyi
Lymphogranuloma venereum	Chlamydia trachomatis
Granuloma inguinale	Klebsiella granulomatis

Causes of urethritis***

1. Gonococcal- N. gonorrhoeae

2. Non-gonococcal-

- Chlamydia
- Mycoplasma
- Ureaplasma
- HSV-2

Zinc	Red meat, seafood	Dairy produce, wholemeal bread
Iodine	Edible seaweeds	Milk and dairy products
Selenium	Fish, wheat grown in selenium-rich soils	Fish
Copper	Shellfish, liver	Bread, cereal products, vegetables
Fluoride		Drinking water, tea
Potassium	Dried fruit, potatoes, coffee	Fresh fruit, vegetables, milk
Sodium	Table salt, anchovies	Processed foods, bread, bacon

B. Protein Energy Malnutrition

WHO classification of PEM:

	Body wt. as % of Standard	Edema	Deficit in wt. for height
• Kwashiorkor	80-60	+	+
• Marasmic Kwashiorkor	<60	+	++
• Marasmus	<60	0	++
• Nutritional dwarfing	<60	0	Minimal
• Undrweight child		0	+

Complications of PEM:*****

1. Acute watery diarrhea
2. Acute respiratory tract infection (ARI)
3. Tuberculosis
4. Urinary tract infection (UTI)
5. Hypothermia

Difference between marasmus & kwashiorkor **

Triats	Marasmus	Kwashiorkor
Cause	Decreased energy intake	Decreased protein intake
Onset	Gradual (Months or years)	Rapid (eg, weeks), often associated with stress such as infections
Essential features:		
1. Edema	None	Present in lower legs, sometimes face or generalized
2. Hypoalbuminemia	Mild if present	Present and may be severe
3. Wasting	Marked	Less obvious, often masked by edema
4. Muscle wasting	Severe	Absent or mild
5. Growth retardation	Severe	Less severe
6. Body fat	Absent	Diminished
7. Mental changes	Usually, nil	Usually, present
Variable Features:		
1. Appetite	Usually, good	Usually, poor
2. Diarrhoea	Common	Common
3. Skin changes	Usually none	Often, diffuse pigmentation
4. Hair changes	Texture may be modified	Often sparse, straight and silky
5. Moon face	None	Often
6. Hepatic enlargement	None	Frequent

Activities precipitating angina***

Common	
• Physical exertion • Cold exposure	• Heavy meals • Intense emotion
Uncommon	
Vivid dreams (nocturnal angina)	• Lying flat (decubitus angina)

Acute coronary syndrome
Acute coronary syndrome is a term that encompasses both unstable angina and myocardial infarction.

Criteria for diagnosis of a prior myocardial infarction
- Pathological Q waves with or without symptoms in the absence of non-ischaemic causes
- Imaging evidence of a region of loss of viable myocardium that is thinned and fails to contract, in the absence of a non-ischaemic cause
- Pathological findings of a prior myocardial infarction

Common arrhythmias in acute coronary syndrome**	
• Ventricular fibrillation • Ventricular tachycardia • Accelerated idioventricular rhythm • Ventricular ectopics • Atrial fibrillation	• Atrial tachycardia • Sinus bradycardia (particularly after inferior myocardial infarction) • Atrioventricular block

Late management of myocardial infarction**

Risk stratification and further investigation Lifestyle modification	
• Diet (weight control, lipid-lowering, 'Mediterranean diet')	• Cessation of smoking • Regular exercise
Secondary prevention drug therapy	
• Antiplatelet therapy (aspirin and/or clopidogrel) • β-blocker • ACE inhibitor/ARB • Statin	• Additional therapy for control of diabetes and hypertension • Mineralocorticoid receptor antagonist
Rehabilitation Devices	
• Implantable cardiac defibrillator (high-risk patients	
(ACE = angiotensin-converting enzyme; ARB = angiotensin receptor blocker)	

Relative contraindications to thrombolytic therapy **

- Active internal bleeding
- Previous subarachnoid or intracerebral haemorrhage
- Uncontrolled hypertension
- Recent surgery (within 1 month)
- Recent trauma (including traumatic resuscitation)
- High probability of active peptic ulcer
- Pregnancy

Q. Prednisolone 5 mg is equivalent to: ***(39th BCS Question)***
a) Dexamethasone 2mg b) Dexamethasone 8mg c) Hydrocortisone 40mg d) Hydrocortisone 20mg
Answer: D

Previous BAEC Question

Q. Most common cause of Cushing syndrome: Ans: Exogenous steroids
Q. Cushing disease: Ans: Pituitary ACTH excess

Causes of adrenocortical insufficiency***

Secondary (↓ACTH)	
• Withdrawal of suppressive glucocorticoid therapy • Hypothalamic or pituitary disease	
Primary (↑ACTH) **Addison's disease**	**Rare causes**
• **Autoimmune: Sporadic Polyglandular syndromes** • **Tuberculosis** • **HIV/AIDS** • **Metastatic carcinoma** • **Bilateral adrenalectomy**	• Lymphoma • Intra-adrenal haemorrhage (Waterhouse–Friderichsen syndrome following meningococcal sepsis) • Amyloidosis • Haemochromatosis
Corticosteroid biosynthetic enzyme defects	
• Congenital adrenal hyperplasia • Drugs: Metyrapone, ketoconazole, etomidate	
(ACTH = adrenocorticotrophic hormone)	

Clinical and biochemical features of adrenal insufficiency

	Glucocorticoid insufficiency	Mineralocorticoid insufficiency	ACTH excess	Adrenal androgen insufficiency
Withdrawal of exogenous glucocorticoid	+	-	-	+
Hypopituitarism	+	-	-	+
Addison s disease	+	+	+	+
Congenital adrenal hyperplasia (21-hydroxylase deficiency	+	+	+	-
Clinical features	Weight loss, anorexia Malaise, weakness Nausea, vomiting Diarrhoea or constipation Postural hypotension Shock	Hypotension Shock Hyponatraemia (depletional) Hyperkalaemia	Pigmentation of: Sun-exposed areas Pressure areas (e.g. elbows, knees)	Decreased body hair and loss of libido, especially in females

Previous BAEC Question

Q. Asthma pathology:
Answer: Reversible airway obstruction.

7.6 Acute and Chronic Respiratory Failure

How to interpret blood gas abnormalities in respiratory failure***

Type I			Type II		
Hypoxia (PaO_2 < 8.0 kPa (60 mmHg)) Normal or low $PaCO_2$ (≤ 6 kPa (45 mmHg))			Hypoxia (PaO_2 < 8.0 kPa (60 mmHg)) Raised $PaCO_2$ (> 6 kPa (45 mmHg))		
Acute		Chronic	Acute		Chronic
H+	→		→	↑	→ or ↑
Bicarbonate	→		→	→	↑
Causes	Acute asthma Pulmonary oedema Pneumonia Lobar collapse Pneumothorax Pulmonary embolus ARDS	COPD Lung fibrosis Lymphangitic carcinomatosis Right-to-left shunts	Acute severe asthma Acute exacerbation of COPD Upper airway obstruction Acute neuropathies/paralysis Narcotic drugs Primary alveolar hypoventilation Flail chest injury		COPD Sleep apnoea Kyphoscoliosis Myopathies/muscular dystrophy Ankylosing spondylitis
(ARDS = acute respiratory distress syndrome; COPD = chronic obstructive pulmonary disease)					

7.7 Neoplasm of the lung.

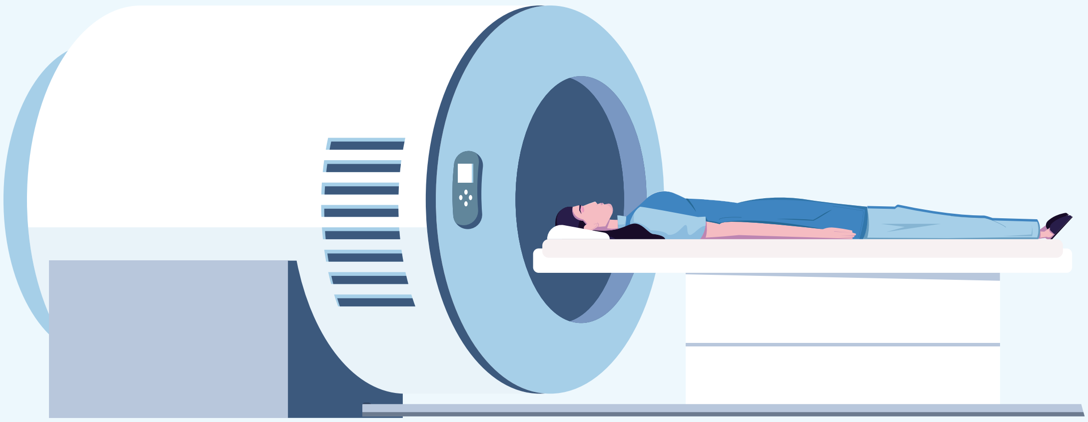
Common cell types in lung cancer***	
Cell type	%
Adenocarcinoma	35–40
Squamous	25–30
Small-cell	15
Large-cell	10–15

Differential diagnosis of finger clubbing**

Congenital or familial (5–10%)

Acquired	
• **Chronic suppurative conditions:** Pulmonary tuberculosis, Bronchiectasis, Lung abscess, Empyema, Cystic fibrosis	• Tumours: Lung cancer, Mesothelioma, Fibroma • Pulmonary fibrosis
Cardiovascular	
• **Cyanotic congenital heart disease** • Infective endocarditis	• Arteriovenous shunts and aneurysms
Gastrointestinal	
• Cirrhosis • Inflammatory bowel disease	• Coeliac disease
Others	
• Thyrotoxicosis (thyroid acropachy)	• Primary hypertrophic osteoarthropathy

Radiology & Nuclear Medicine



Radiology & Nuclear Medicine

01. Basic Radiology

1.1. Basic Physics

All of the physical sciences have in common a firm basis in mathematics. This is no less true of radiologic physics, an important branch of the physical science.

Physics, as an Exact Science, requires a precise vocabulary in which each term has a clear and definite meaning. Not only does this simplify the learning process, but it also facilitates the organization of concepts and their accurate communication to others.

A unit is a quantity adopted as a standard of measurement by which other quantities of the same kind can be measured. The standard units employed in physics consist of two general types, the simpler fundamental units dealing with length, mass, and time and the more complicated derived units, obtained by various combinations of the fundamental units.

1. **Area** is the measure of a given surface and depends on length. Thus, a square or rectangle has an area equal to the product of two sides. The area of a circle equals the radius squared times π.

by square meters for larger surfaces and square centimeters for smaller ones. Square centimeters are abbreviated either as sq. cm or cm2 .

2. **Volume** is a measure of the capacity of a container and is derived from length. The volume of a cube equals the product of three sides. In metric units, volume may be expressed in cubic centimeters (cc) or milliliters (ml). One liter exactly equals 1000 ml and is very slightly larger than 1000 cc—approximately one quart.

3. **Density** is the mass per unit volume of a substance and may be expressed in kg per cubic meter (kg/m3).

4. **Specific gravity** has no units. It is the ratio of the density of any material to the density of water. The density of water is 1.

5. **Velocity** is speed in a given direction and can be expressed in m per sec,cm per sec, or km per sec, or some other convenient units.

Fundamental Quantities and Units

	Usual Symbol for Quantity	Defining Equation	SI Unit	Relationships and Special Units
Fundamental Units				
1 mass	m	Basic physical unit, defined arbitrarily and maintained in standardization laboratories	kilogram (kg)	
2 length	l		meter (m)	
3 time	t		second (s)	

4 current	I		ampere (A)	
Derived Units				
5 velocity	v	$v = \Delta l/\Delta t$	$m\ s^{-1}$	
6 acceleration	a	$a = \Delta v/\Delta t$	$m\ s^{-2}$	
7 force	F	$F = m\ a$	newton (N)	$1\ N = 1\ kg\ m\ s^{-2}$
8 work or energy	E	$E = F\ l = 1/2\ m\ v^2$	joule (J)	$1\ J = 1\ kg\ m^2\ s^{-2}$
9 power or rate of doing work	P	$P = E/t$	watt (W)	$1\ W = 1\ J/s$
10 frequency	f	number per second	hertz (Hz)	$1\ Hz = 1\ s^{-1}$
Electrical units				
11 charge	Q	$Q = I\ t$	coulomb (C)	$1\ C = 1\ A\ s$
12 potential	V	$V = E/Q$	volt (V)	$1\ V = 1\ J/C$
13 capacity	C	$C = Q/V$	farad (F)	$1\ F = 1\ C/V$
14 resistance	R	$V = I\ R$	ohm (Ω)	$1\ \Omega = 1\ V/A$

6. Temperature is a measure of the average energy of motion of the molecules of matter. Two systems are commonly employed today. In the metric system, temperature is expressed in degrees Celsius (centigrade), but still the Fahrenheit system is the one generally used in the United States. The following data exemplify the differences between these systems:

Celsius:
0°C = freezing point of water
100°C = boiling point of water

Fahrenheit:
32°F = freezing point of water
212°F = boiling point of water

7. Acceleration-

When an object's velocity changes—either because it speeds up, slows down, or changes direction—it undergoes acceleration. Acceleration is mathematically defined as the rate of change of velocity over time.

Acceleration, a = v/t

Unit =m/s^2

8. Force

Force is measured in Newtons (N). One Newton is the force needed to accelerate a 1-kilogram mass at a rate of 1m/s^2

F = m x a

F is Force, m is mass, and a is acceleration

9. Work/Energy

The SI unit of energy is the Joule (J). One Joule equals the work done by a force of one Newton moving an object a distance of one meter.

Energy, W= F x s

10. Power

Power is the rate at which work is done or the rate at which energy is transferred over time.
Power, P = W/t
Unit Joule / second = Watt.

11. Frequency

All electromagnetic waves such as radio, heat, light, x-rays and gamma rays have the same general form and travel with the same constant speed as light—3×10^8 m,
3×10^{10} cm, or 186,000 miles per second in a vacuum or air. However, they differ in wavelength—**the distance between two successive crests in the wave**, such as A to B in Figure 12.2.

The number of crests or cycles per second is the frequency of the wave, the unit of frequency being the hertz defined as one cycle/second.

C=f x lambda
where c= speed of x-rays or light in vacuum or air ($3 \times 10°$ m/s)
f= frequency in hertz or Hz (cycles/ second)
(Greek lambda) = wavelength in m (meter)
Since c, the speed of all electromagnetic waves, is constant in a given material, an increase in frequency must always be accompanied by a corresponding decrease in wavelength and, conversely, a decrease in frequency by an increase in wavelength.

Frequency is inversely proportional to wavelength.

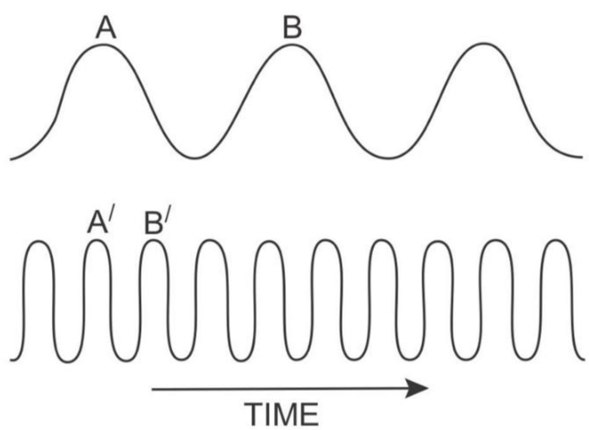


Figure 12.2 explains electromagnetic waves. The upper and lower waves have different wavelengths. The lower wave has a shorter wavelength, so it has more crests or cycles in the same time because both waves travel at the same speed. Therefore, shorter wavelength means higher frequency, measured in hertz (Hz).

Table 2.1 summarizes the units that are relevant to nuclear radiology. The abbreviations will be used in this book.

Barium enema- 6 mSv
Upper GI study with barium- 6 mSv
Dental Xray- 0.005 mSv

Maximum Permissible dose
Occupational Worker-
Effective dose- **20 mSv a year**, averaged over defined periods of 5 years with no single year >50 mSv

Equivalent dose-
Lens- 20 mSv a year, averaged over defined periods of 5 years with no single year >50 mSv (previously – 150 mSv/yr)
Skin- 500 mSv in a year
Hand and feet- 500 mSv in a year
Abdomen of reproductive women- 13mSv/ three consecutive months
Fetus of pregnant employee- 1 mSv

Non- occupational worker-
Effective dose
1 mSv a year (higher values are permitted if the average over 5 years is not above 1 mSv a year)

The equivalent dose to the lens of the eye
15 mSv a year the equivalent dose to the skin
50 mSv a year

4.3. Nuclear binding energy

Nuclear binding energy is the energy that would be required to disassemble the nucleus of an atom into its component parts.

These component parts are neutrons and protons, which are collectively called nucleons.
Hence more is the energy required to break the nucleus, the more stable it is.

The binding energy for stable nuclei is always a positive number

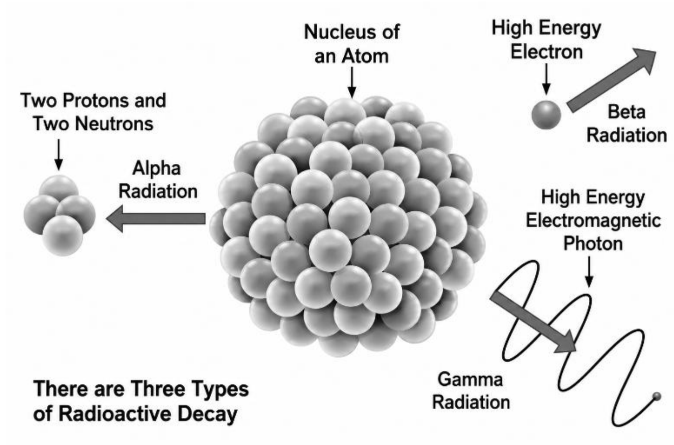
If binding energy =0, means the nucleus can break without any energy.
Also, if binding energy is negative, means that the energy is obtained by breaking the nucleus, which means that the nucleus is highly unstable, hence cannot exist.

4.4. Radioactivity

Radioactive decay or radioactivity is the process by which an unstable atomic nucleus disintegrate spontaneously and emits energy.

The emission of energy from radioactivity is always accompanied by alpha, beta, and gamma radiation
The becquerel or Bq is the SI unit for radioactive decay, measuring the activity of a substance
One Bq is defined as one nucleus decaying per second

One curie (1 Ci) is equal to 3.7×10^{10} radioactive decays per second
Which is equal to 3.7×10^{10} becquerels (Bq)



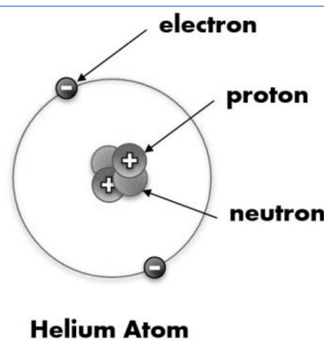
Alpha Decay

- Alpha particles are large particles ejected by the heavier nuclides.
- Alpha decay is probable for nuclides with (Z > 82).
- An alpha particle contains two protons and two neutrons (no electrons); therefore, it is essentially a helium nucleus.
- As a result, the atomic number decreases by 2 and the mass number decreases by 4.

Example of alpha decay:

$$^{238}_{92}\mathrm{U} \rightarrow ^{234}_{90}\mathrm{Th} + ^{4}_{2}\mathrm{He}$$

Basic=



Properties of alpha

Alpha particle can travel only a few centimeters in air
High ionization, low penetration
Can be stopped only by paper

Beta deacy

Beta Decay is a type of radioactive decay in which a proton is transformed into a neutron or vice versa inside the nucleus of the radioactive sample.
If a proton is converted to a neutron, it is known as β+ decay. Similarly, if a neutron is converted to a proton, it is known as β–decay

Mass number is not changed. Proton number/atomic number change by one (increase or decrease)
Beta minus decay

In beta minus, a neutron is transformed to yield a proton, causing an increase in the atom's atomic number. The nucleus in the process also produces a negative beta (same as high speed electron/ Negatron) and an antineutrino.

Occurs in neutron rich molecule

$$^{90}_{38}Sr \longrightarrow ^{90}_{39}Y + ^{0}_{-1}\overline{\beta} + \overline{\nu}$$

$$N = p + e^{-} - \overline{\nu}$$

Beta plus decay
In beta plus decay, the proton disintegrates to yield a neutron causing a decrease in the atomic number of the radioactive sample. The nucleus experiences a loss of proton but gains a neutron.

In this process, a beta plus (Positron) and neutrino is produced.

$$^{18}_{9}F \rightarrow ^{o}_{+1}\beta + ^{18}_{8}O$$

Gamma decay:
Gamma decay refers to the release of a gamma (γ) ray photon, a form of high energy electromagnetic radiation
It differs from alpha and beta decay in that it does not involve a change to a different daughter nuclide
Gamma rays have energies far greater than that of similar atomic process and therefore have high penetration depths

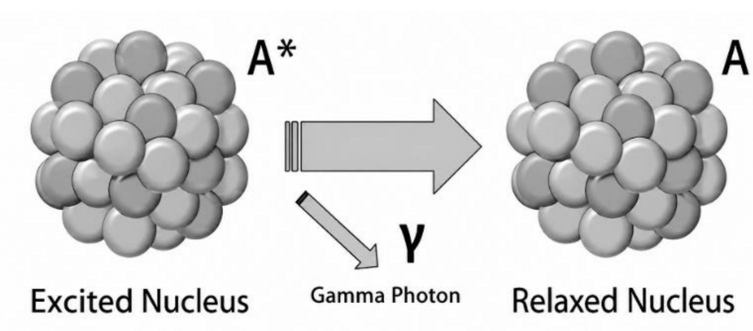
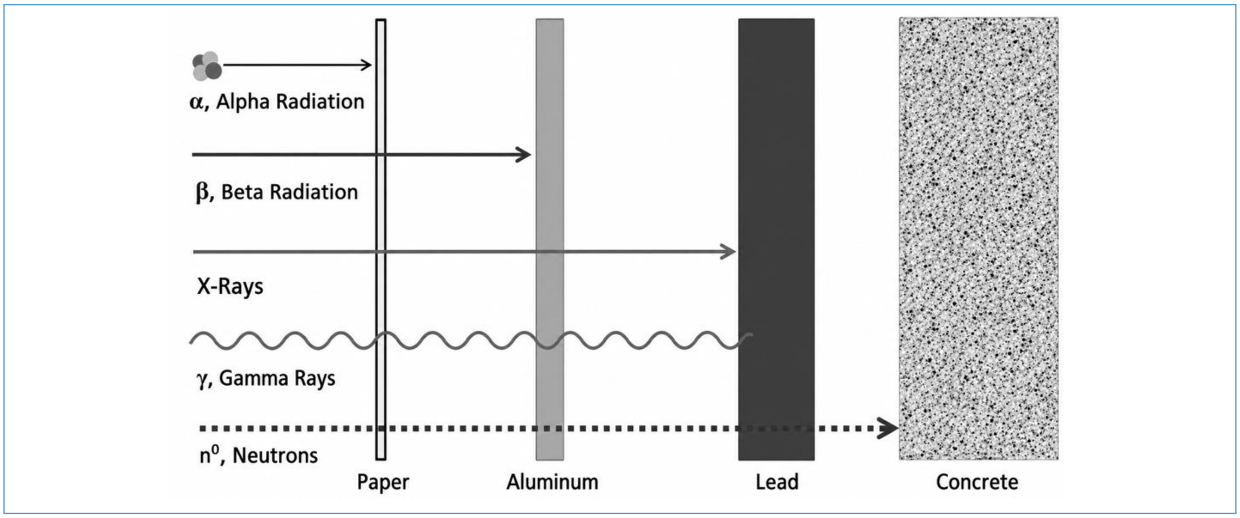


Figure 2. Diagram showing gamma decay of a nucleus.

USE-
Tc- 99m (Half life 6 hours) is used in SPECT
Emits gamma ray that is detected by gamma camera
Penetration ability of alpha, beta and gamma=

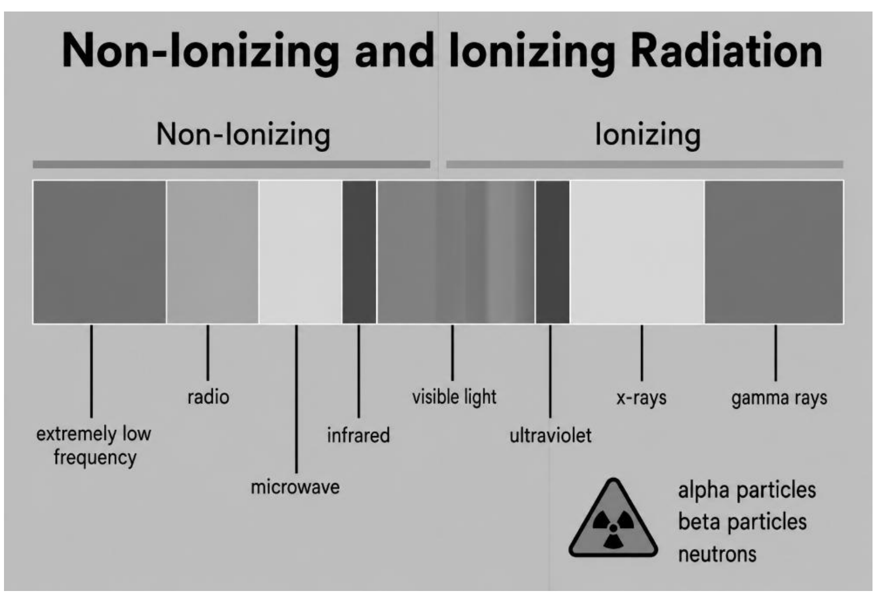


Difference in a Chart

	Alpha	Beta	Gamma
Definition	Simple Helium Nuclei	High energy electron or Positron	Electromagnetic radiation (EMR)
Speed	1/10 to 1/20 speed of light	Can upto close to speed of light	Same to light speed
Ionization	High	Lower	Lowest
Penetration	Lowest	Higher	Highest
Mass	6.67×10^{-4} Kg, 4 amu	9.1×10^{-31} kg, 1/2000 amu	0
Charge	3.2×10^{-19} C	1.6×10^{-29} C	0

**Alpha and Beta particles are ionizing radiation, but not electromagnetic radiation
***Xray, Gamma, part of ultraviolet ray are ionizing radiation and electromagnetic radiation
***All electromagnetic radiations have same speed (speed of light), no mass, no charge

Basic: Electromagnetic spectrum=

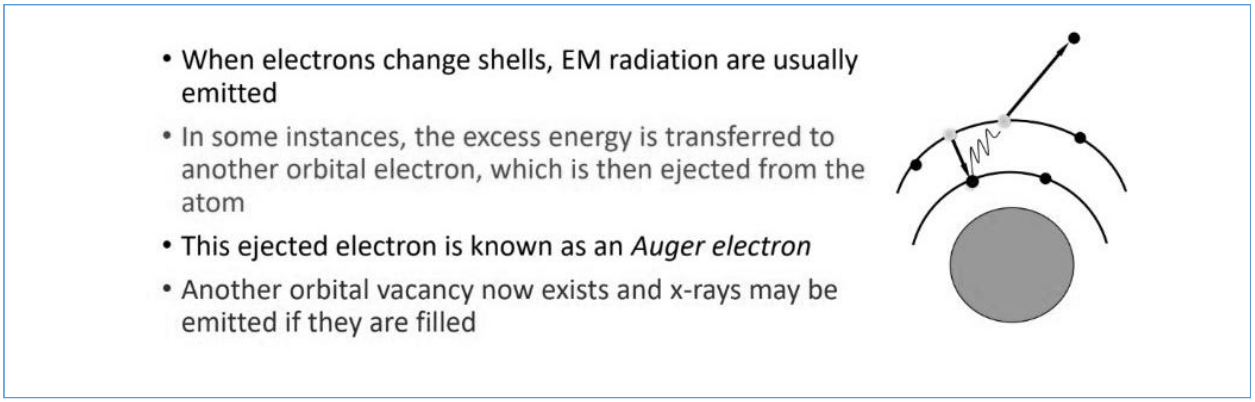


4.5 Electron capture

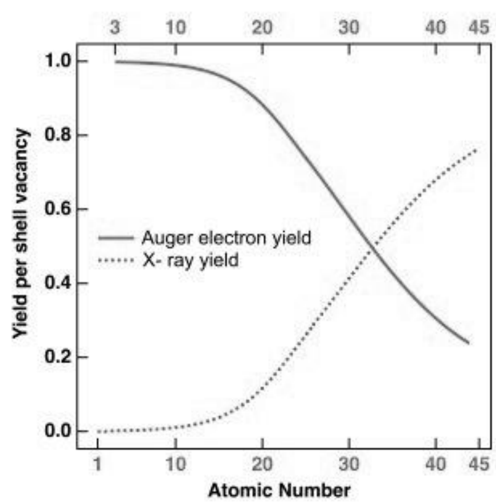
In electron capture, the nucleus of the atom actually captures its own electron found in the orbital around that nucleus. When this electron enters the nucleus, it readily combines with a proton, transforming the proton and electron into a single neutron and in the process releasing a neutrino into the surroundings.

Occurs alongside Beta plus decay. Both process is almost same and compete with each other.
An isotope making use of electron capture is iodine-123 (atomic number- 53) as a tracer in thyroid imaging which decays by electron capture to tellurium-123 (atomic number- 52) which emits a lowenergy gamma ray for detection

4.6 Auger electron



Auger electrons (AEs) are very low energy electrons
Usually associated with electron capture.
Result in high linear energy transfer (LET) that is potent for causing lethal damage in cancer cells
Also used in spectroscopy to determine composition of substance.
The probability that an Auger electron will be emitted is called the Auger yield for that shell.
The Auger yield decreases with increase of atomic number (the number of protons in the nucleus), and at atomic number 30 (zinc) the probabilities of the emission of X rays from the innermost shell and of the emission of Auger electrons is about equal



Pair Production:
This process only occurs when the incident photon energy is at least 1.022 MeV. Does not occur in diagnostic radiology.

Previous question

01. Equivalent dose SI unit
a) Sievert
b) Gray
c) Roentgen
d) Curie
Answer: A

02. Absorbed dose SI unit
a) Sievert
b) Gray
c) Roentgen
d) Becquerel
Answer: B

03. Background radiation source- Options?
Answer: Cosmic rays

04. Radioactive decay is: Answer: Exponential
05. SI unit of radioactivity?
a) Rad
b) Roentgen
c) Curie
d) Becquerel
Answer: D

06. X-rays used for
Answer: Imaging

07. CT scan uses:
Answer: X-rays

08. Half life of a substance is 12 hours. How much it will decay after one day?
a) 50%
b) 75%
c) 100%
d) 25%
Answer: B

09. Half-life a radioactive material is 08 hours. After 01 day, remaining portion is-
a) 25%
b) 6%
c) 15%
d) 12.5%
Answer: D

10. Gamma rays are:
Answer: High energy photons

11. Half-life definition:
Answer: Time to decay half
12. Speed of light:
Answer: 3×10^8 m/s

05. Basic of Nuclear Medicine & Radiotherapy

5.1 Nuclear Medicine

Nuclear medicine is a specialized medical field that uses small, safe amounts of radioactive materials (radiopharmaceuticals) to diagnose, manage, and treat various diseases, including cancer, heart disease, and neurological disorders.

How Image is Generated
A tiny amount of the radionuclide is used during the procedure. The radionuclide is also known as a radiopharmaceutical or radioactive tracer. It is absorbed by body tissue.

There are several different types of radionuclides. Common radio isotope that has been used in this field is technetium, iodine, thallium, gallium. The type of radionuclide used will depend on the type of study and the body part being checked. After the radionuclide has been given and has collected in the body tissue under study, radiation will be given off. A radiation detector can pick up this radiation. The most common type of detector is the gamma camera. Digital signals are made and stored by a computer when the gamma camera detects the radiation.

Aspects of Nuclear Medicine

- **Diagnosis (Molecular Imaging):** Patients swallow, inhale, or are injected with a radiotracer, which travels to specific organs or tissues. A specialized camera (PET or SPECT) detects the radiation emitted from within the body to create images of organ function.
- **Treatment:** Radioactive substances are used to treat diseases by delivering radiation directly to diseased tissue, such as destroying thyroid cells in cancer patients.

Applications: Common procedures include

- Thyroid Scan (Tc-99m/ I123)
- Parathyroid Scan/MIBI Scan (Tc-99m SESTAMIBI)
- Renal Scan (Tc-99m with DMSA)
- Bone Scan (Tc-99m with MDP)
- Whole Body Iodine Scan/Large Dose Scan(Lds) with I131
- Radio Active Iodine Uptake Test with I131
- Renogram (DTPA/MAG3)
- Hida scan (Tc-99m with HIDA)
- Meckels scan(Tc-99m)
- Spect (Tc-99m, I123 and I131)
- Spect –CT (Tc-99m, I123 and I131)
- MPI (SPECT and PET)
- PET-CT (18F with FDG)

Safety: While radioactive, these procedures are considered safe, with radiation doses comparable to many common diagnostic X-ray or CT scans.

Scintigraphy

Scintigraphy (from Latin *scintilla*, "spark"), also known as a **gamma scan**, is a diagnostic test in nuclear medicine, where radioisotopes attached to drugs that travel to a specific organ or tissue (radiopharmaceuticals) are taken internally and the emitted gamma radiation is captured by gamma cameras, which are external detectors that form two-dimensional images in a process similar to the capture of X-ray images. In contrast, SPECT and positron emission tomography (PET) form 3-dimensional images.

Examples: ***

- Thyroid scan
- Parathyroid scan
- Bone scan
- Renal scan
- Renogram
- Whole body scan
- Lung scintigraphy (V/Q scan)
- Myocardial perfusion imaging (MPI)
- Lymphoscintigraphy
- Phleboscintigraphy

Difference between nuclear medicine and radiology:
The primary difference between nuclear medicine and radiology is that nuclear medicine creates images using internal radiation waves from inside the body while radiology develops images through apply external energy waves to the body.

5.2 Radio Isotopes

ISOTOPE
Atoms with the same number of protons but different numbers of neutrons are called isotopes.

$$^{99}\mathrm{Mo} \xrightarrow{\beta^-} {}^{99m}\mathrm{Tc} \xrightarrow{\gamma} {}^{99}\mathrm{Tc}$$

Nice to Know:
Isobar, isotone

Radioisotope	Nuclide notation	Radioactive emission	Half-life
Tritium-3	$^{3}_{1}\mathrm{H}$	β	12.33 years
Carbon-14	$^{14}_{6}\mathrm{C}$	β	5730 years
Sodium-24	$^{24}_{11}\mathrm{Na}$	β, γ	15 hours
Cobalt-60	$^{60}_{27}\mathrm{Co}$	β, γ	5.27 years
Technetium-99m	$^{99m}_{43}\mathrm{Tc}$	γ	6.01 hours

Radioisotope	Nuclide notation	Radioactive emission	Half-life
Iodine-131	$^{131}_{53}\mathrm{I}$	β, γ	8 days
Bismuth-213	$^{213}_{83}\mathrm{Bi}$	α	46 minutes
Polonium-212	$^{212}_{84}\mathrm{Po}$	α, γ	45.1 s
Americium-245	$^{245}_{95}\mathrm{Am}$	α	7370 years

How are radioactive isotopes produced?

1. Some radioisotopes exist naturally. Uranium-235 and uranium-238 are two naturally occurring radioisotopes of uranium.

2. Radioisotopes can also be produced artificially when certain nuclides are bombarded by high energy particles or gamma rays.

3. ***The human body naturally contains small amounts of radioisotopes—mostly

Potassium-40 (40K) and Carbon (14C). Few others are **Polonium-210(210Po), Radium-226(226Ra).**
4. (a) One of the earliest radioisotopes to be produced artificially was phosphorus-32. It is produced when sulphur-32 is bombarded by neutrons.