HETEROTROPHICNUTRITION

HETEROTROPHICNUTRITION
Thisisthetypeofnutritioninwhichorganismstakeinready-madeorganicfoodsubstancesmadebyautotrophs(producers).

TYPESOFHETEROTROPHICNUTRITION
(a) Holozoicnutrition
(b) Saprotrophicnutrition(Saprophyticnutrition)
(c) Symbiosis:**(i)**Parasitism**(ii)** Mutualism**(iii)**Commensalism

HOLOZOICNUTRITION
Thisisthetypeofnutritioninwhichcomplexorganicfoodistakeninand brokendowninsidethebodyofanorganismto simplesolublemoleculeswhicharethenabsorbedandassimilated.

BASICPROCESSESINVOLVEDINHOLOZOICNUTRITION
1. ***Obtainingfood:***Mayinvolvemovementstocaptureorfindnewfoodsourcesfromtheenvironment.
2. ***Ingestion***:Theintakeoffoodintothebody(feedingmechanisms).
3. ***Digestion***:Chemicalbreakdown(byenzymes)andphysicalbreakdown(byteeth,gizzard,mandibles,radula)oflarge insolublemoleculesoffoodintosmallsolublemolecules.
4. ***Absorption***:Theuptakeof nutrientmoleculesintothecellsofthedigestivetractand,fromthere,intothebloodstream
5. ***Defecation(Egestion)***:eliminationofundigestedresidue.
6. ***Assimilation:***Theutilizationoftheabsorbedsolublefoodsubstancestoformenergyor materialswhichareincorporated intothebodytissues.

FEEDINGMECHANISMSOFANIMALS

Natureof food	***Mechanism***	***Organisms***	***Description***
Small particles	filter feeding/ microphagous feeding;	Whales,sharks,flamingo, herring;	Bodyappendages(gills/beaks/keratinousplates)filter planktons/bluegreenalgaesuspendedinwaterintobody cavity/mouththendigestionoccurs.
	Pseudopodial feeding	Amoeba	Pseudopodiaencloset hefoodparticletoform**food vacuoles**whichonassociatingwith**primarylysosomes** form**secondarylysosomes,**andafterdigestion,soluble productssimply/facilitativediffuse/activelymoveinto thecytoplasmwhile undigested wastesareegestedby **exocytosis**.
	Flagellatefeeding	Euglena,sponges	Flagellabeatingdirectsmicroscopicfoodparticlestothe regionofingestion,thenintracellulardigestionoccurs.
	Ciliaryfeeding	Paramecium,*Amphioxus*	Ciliabeatingdirectsmicroscopicfoodparticlestothe regionofingestion,thenintracellulardigestionoccurs.
	Tentacular feeding	Seacucumber	Mucusontentaclestraps foodparticles
	Setousfeeding	Waterflea(*Daphnia)*,culex mosquitolarvae	Setaeonappendagestrapand directsmallfoodparticles intothedigestivesystem.
	Mucoidfeeding	Somemolluscs	Mucuslayertrapsfoodparticles,laterswallowedandnew layerformed.
Fluidsor softtissues	Fluidfeeding;	Aphids,leeches,fleas,lice, mosquitoes,housefly, vampirebats/ Tapeworm,*Trypanosoma*;	Nutrient-richfluidfromthelivinghost;is suckedby modifiedmouthparts; Alreadydigestedfood isabsorbedacrosstheintegument;
Large particles	Substratefeeding /depositfeeding;	Insectlarvae/earthworms;	Non-selectiveswallowingof mud,silt,sand,etcafter burrowingtheirwaythroughthefood/organicmaterial;
	Bulkfeeding/ macrophagous feeding;	Landsnail,caterpillar, termites,snakes,birds, seals,squids,many mammals,spiders,blowfly larvae,crabs,dragonfly,etc.	Mayinvolvescrapingandboring(termites,snails)/ Capturingandswallowing(snakes,birds,dogfish,seals)/ Capturing,chewingandswallowing(squid,mammals)/ Capturing,digestingexternallyand ingesting(spider, starfish,blowfly);usingappendagesliketentacles/pincers, claws/poisonousfangsandjaws/mandibles;

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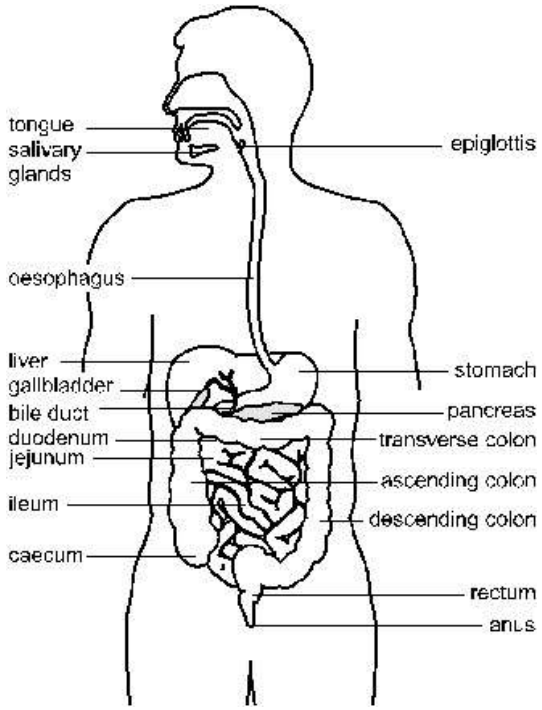
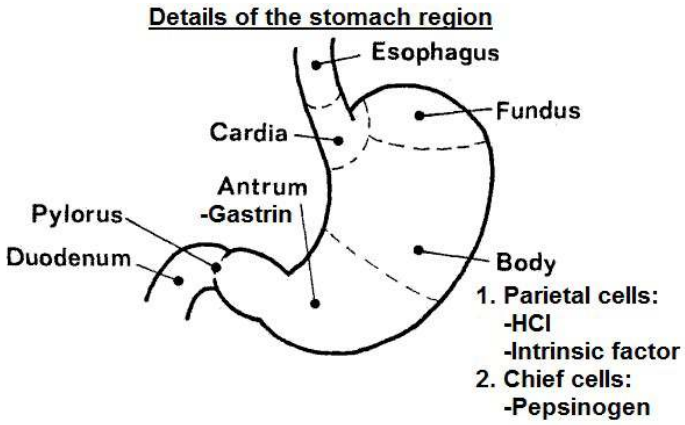
THEHUMANDIGESTIVESYSTEM

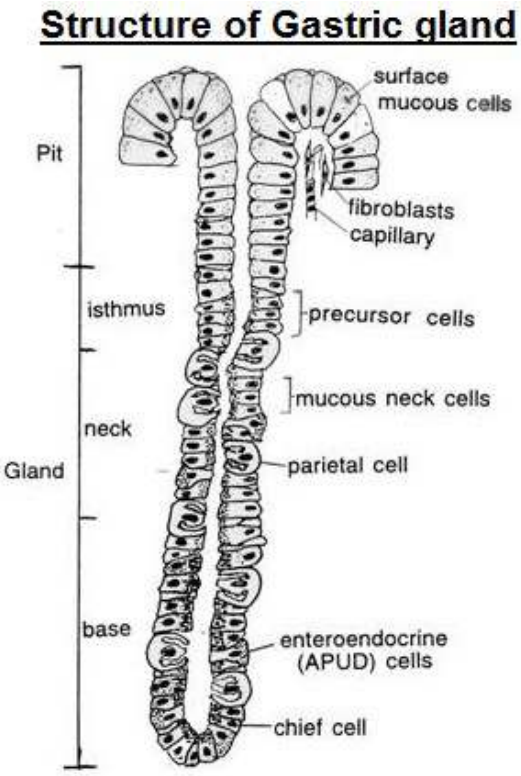
Thehumandigestivesystemconsistsof:

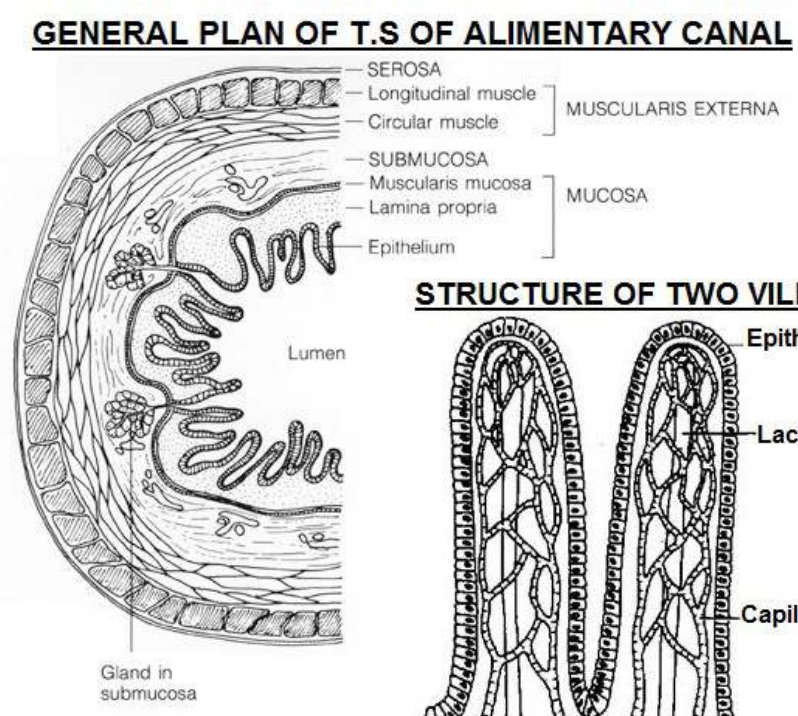
1. Alimentarycanal: Mouth,throat,oesophagus,stomach,smallintestine(duodenum,jejunumandileum),largeintestine (colon,caecumandappendix),rectumandanus.

2. Accessorystructures: Teeth,tongue,salivaryglands,liver,gallbalderandpancreas.Theseareorgans,glands,andtissues thatenabledigestiveprocesses,e.g.bysecretingfluids/chemicals,butthefooddoesnotactuallypassthroughthem.

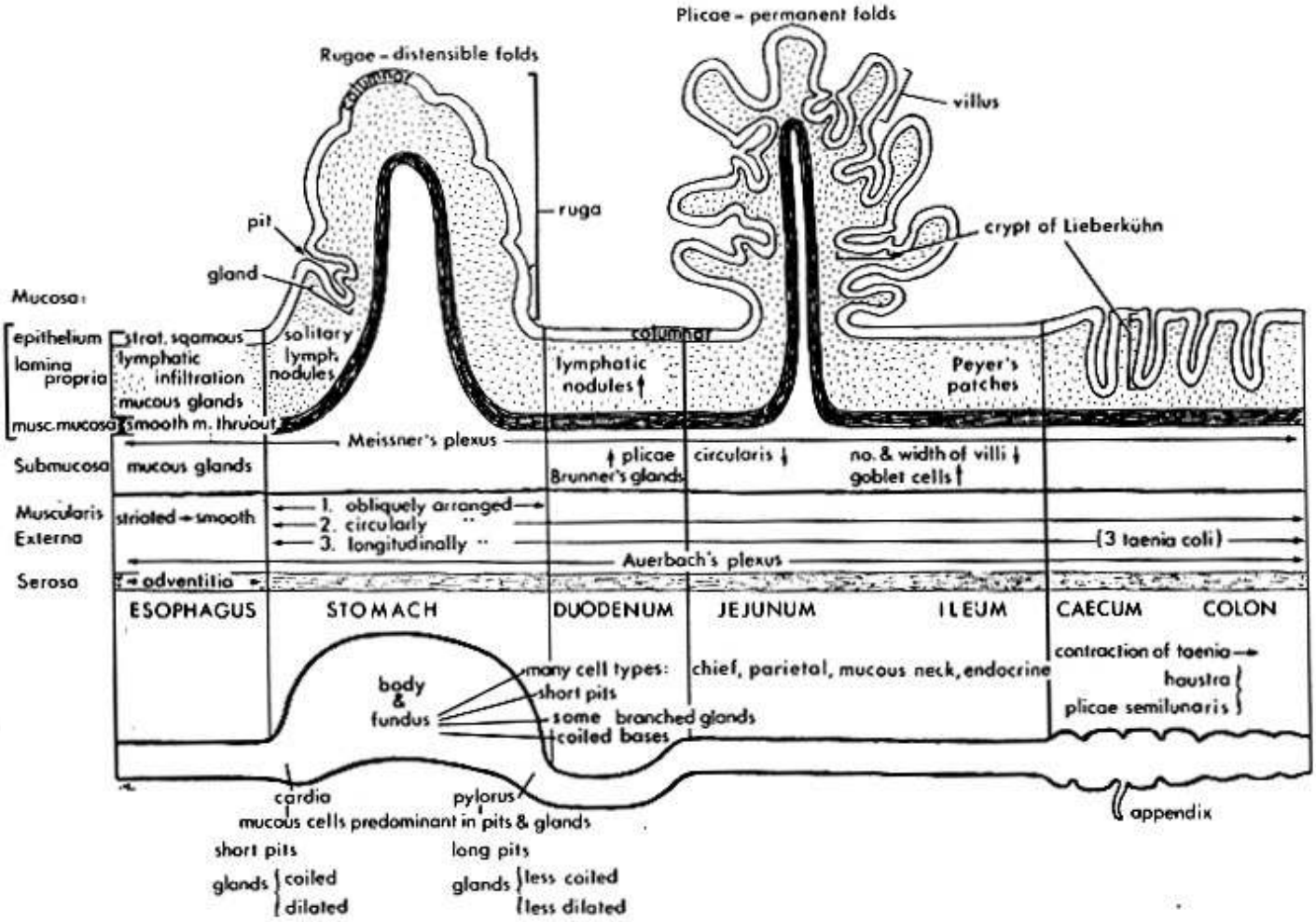








VERTICAL SECTION THROUGH THE ALIMENTARY CANAL



COMPARISONOFHISTOLOGYOF GASTROINTESTINAL TRACTREGIONS

WALL LAYER	STOMACH	DUODENUM	ILEUM	COLON
Serosa **(**Adventitia**)**	● Areolarconnective tissue,same compositionasmesenteries ● Itis called**serosa**whenthe outermost layerlies adjacenttotheperitonealcavity. ● Itis called**adventitia**whenthe outermost layerisattachedtosurroundingtissue.			
Muscularis externa	● Consistsofthree muscle layers: **(i)**innerobliquelayer**(ii)**middle circular layer **(iii)**outer longitudinallayer			
Auerbach'splexus **(**Myenteric plexus)	● Networkof**unmyelinated** nervefibers andganglia betweenMuscularis externa longitudinaland circularmuscles ● Bringsabout**peristalsis**whenstimulatedbypressure offoodinthe gut. ● Receivesimpulses fromthe**vagusnerve** ● Controlofnerve impulses is**involuntary** ● Promotessecretionofintestinaljuices ● Causessphincter muscles toopen,thus permittingfoodto passfromone part ofthedigestive systemtoanother			
Submucosa	● Consistsofloose connective tissue,collagen,large arteries andveins,lymphvessels and nerves			
	● **Brunner's glands** absent. ● No**goblet cells**	● **Brunner'sglands**present ● Brunner'sglands secrete alkaline mucus toneutralize acidic chymefromthe stomach ● Brunner'sglandsare compound,tubular,mucous ● **Gobletcells** present	● **Brunner's glands** absent. ● **Gobletcells** present	● **Brunner's glands** absent.
Meissner's plexus (Submucosal plexus)	● Nervenetworkofunmyelinated nerve fibres andassociatedganglia locatedwiththe submucosa ● Itis believedtowork against the myenteric plexus tocontrolthemuscular contractions more finely. ● Inintestines,itworkswithAuerbach'splexusin producingperistaltic waves andincreasingdigestive secretions.			

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WALL LAYER	STOMACH	DUODENUM	ILEUM	COLON
Mucosa	***1.Muscularismucosa:*** ● Thinlayerofsmoothmuscle at the boundarybetweenmucosa andsubmucosa. ● Containsbothcircular andlongitudinalmuscles ● Functionally,the***Muscularismucosa***presumablycauses stirring atmucosalsurfaceforincreasedsecretionand nutrientabsorption			
	2.Laminapropria: ● Formedbya verycell-richloose connective tissue (fibroblasts,lymphocytes, plasma cells,macrophages, eosinophilic leucocytes andmastcells). ● Laminapropriacontainsnumerous cells with**immunefunction**to provide aneffective**secondaryline of defense** e.g.**Peyer's patches**whichare lymphoidstructures locatedinthe ileum. ● Laminapropriaof **villi**includes **lacteals**(**lymphatic capillaries**). ● Laminapropriaof **intestinalvilli**mayinclude smoothmuscle fibers. ● In**oralcavity**and**oesophagus**,lamina propriaislocatedimmediatelybeneatha stratifiedsquamous epithelium			
	3.Surface epithelium: ● Mucosalepitheliumis highlydifferentiatedalongthe severalregionsofthe GItract. ● Atthe **upper** and**lower** endsofthe tract,the epitheliumis protective,***stratifiedsquamous***. ● Alongthe**liningofthe stomach,smallintestine,andcolon**,the epitheliumis***simplecolumnar*** ● Inthe stomach,surface epitheliumcontains mucous cells thatsecrete protective,alkaline mucus **(a)Plicae** ofthe smallintestine are permanentfolds inthe mucosasupportedbya core ofsubmucosa. Plicae increasethe absorptive surface area ofthe mucosa. **(b)Gastric pits**are shallowindentationsinsurface epitheliumofstomachmucosa intowhichgastric glands open. **(c)Intestinal crypts**(**crypts ofLieberkühn**)containsecretory**Paneth cells** atthe deepend,whichsecrete lysosomalenzymes thatcontribute toprotecting cellsinthe cryptlining. **(d)Villi**are verysmall,typicallydensely-packed,invaginationsofa mucosathatincreasethe surfacearea for absorption.Inthe**stomach**–novilli,**duodenum**–many,leaf-like villi,**ileum**–few,finger-like villi. **(e)Rugae**are distensible folds in the**gastric** mucosa.			

SECRETIONSFROMCELLSLOCATEDINTHEGASTRICWALL

Thesecretionsofthemucouscells,chiefcells,andparietalcellsare knowncollectivelyas***gastricjuice***,whosecomponents include:***mucus,pepsinogen,hydrochloricacid***and***intrinsicfactor***

TypeofCell	Secretion	Stimulusforsecretion	Function
MucousCells (i)Mucous surfacecells (ii)Mucousneckcells	Mucus	Tonicsecretion,with irritation ofmucosa	Physicalbarrier betweenlumenandstomachlining.
	Bicarbonate	Secreted withmucus	Buffersgastricacidto preventdamageto epithelium
Chief/ Peptic/ zymogeniccells	Pepsinogen	Acetylcholine, acid secretion.	Pepsin digestsprotein, including**collagen**
	Gastriclipase		Digests lipids
	Prochymosin (Prorennin)		RennincurdlessolubleCaseinogen(milkprotein)into insoluble caseinwhoseslow flow enablesdigestion
Parietal /oxynticcells	Hydrochloricacid	Acetylcholine,gastrin, histamine	(i)Activatespepsinogentopepsin,Prorennintorennin (ii) Killsbacteria. Only***Helicobacterpylori***,that cause ***gastritis*** and **gastric ulcers** surviveinthestomach
	Intrinsicfactor		● ComplexeswithvitaminB$_{12}$to enable absorption of VitaminB$_{12}$necessaryforred bloodcell formation ● VitaminB12isacofactor ofenzymeswhich synthesisetetrahydrofolicacid,which, inturn,is neededfor thesynthesisofDNA components ● Little***intrinsicfactor***causes**pernicious anemia**
Enteroendocrine cells (APUD-cells:amine precursoruptakeand decarboxylationcells)			
(a) G cells (Gastrin-producingcells)	Gastrin hormone	Acetylcholine, peptides, andaminoacids	(i)Stimulates secretion ofgastricjuice (ii)Increases contractionsofgastro-intestinaltract (iii)Relaxes thepyloricsphincter.
(b) D cells (Somatostatin-producingcells)	Somatostatin hormone	Acidinstomach	(i)**Inhibits** stomach secretionof**gastrin** and **HCl** (ii) **Inhibits** duodenalsecretion of**secretin** and **cholecystokinin** (iii)**Inhibits** pancreassecretionof**glucagon**
(c)VIP-producingcells(vasoactive intestinal peptide)	Vasoactive intestinal peptide	Distension of the stomach wall	(i)Induces smoothmusclerelaxation (ii) Inhibits gastricacidsecretion (iii)Stimulates pepsinogen secretionbychief cells
(d)Enterochromaffincells (Serotonin-containingcells)	Histamine	Acetylcholine,gastrin	Stimulatesgastric acidsecretion

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DIGESTION

Digestionistheprocessbywhichlargefoodmoleculesarebrokendownintosmallsolublemoleculeswhichcanbeabsorbed andassimilatedintothetissuesofthebody.
Digestionincludestwotypesofprocesses:
Mechanicalprocesses:whichincludethechewingandgrindingoffoodbytheteethandalsothechurningandmixingof thecontentsofthestomachtoexposemoresurfaceareatotheenzymesthat finishthedigestiveprocess.
Chemicalprocesses:whichincludehydrolysisactionofdigestiveenzymes,bile,acids.

DIGESTIONINTHEMOUTH

Itstarts withchewing(mastication),whichbreaksfoodintopiecessmallenoughtobeswallowedandalsoincreasesthe surfaceareaoffoodtodigestiveenzymes.
Thesight,taste,smellandthoughtoffoodinducessalivaryglandsto secretesaliva,awateryfluidwithPH of6.8to7.0.
Duringchewing,salivamixeswithfoodandthedifferentsalivacomponentsperformdifferentfunctions:
(i) **Salivaryamylase(ptyalin)**enzymecatalysesthebreakdownof**amylose**ofcooked**starch**into**maltose**. (ii) **Water**moistensfoodandbindingittogetherforswallowing
(iii)**Mucin**bindsandlubricatesfood;toenableswallowing.
(iv)**Chlorideions**activatesalivaryamylase
(v) **Lysozymes**killbacteriainthebuccalcavity.

NOTE:

- Amountof**amylase**secretedinsalivadependson**amountof starch**theanimalregularlyfeedson indiet.

1. Amylaseisusuallyabsentinthesalivaofcarnivoresbecauseofabsenceofcookedstarchinthediet.
2. Inseparatehumangroups,therelativeamountsofamylase(inarbitraryunits)producedinsalivawereas follows:

Tswana:248,Bushmen22,European:101.Whichhumangroup'sdietislargelymadeofflesh?

SWALLOWING

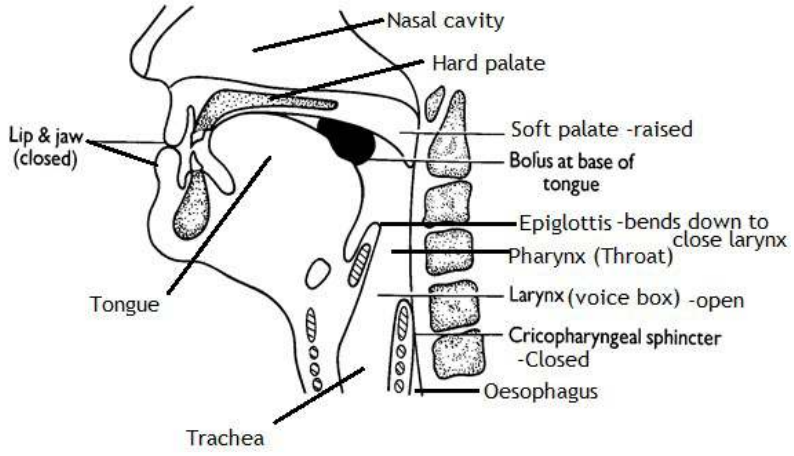
Thisisa reflexaction, whichlastslessthan10 seconds.

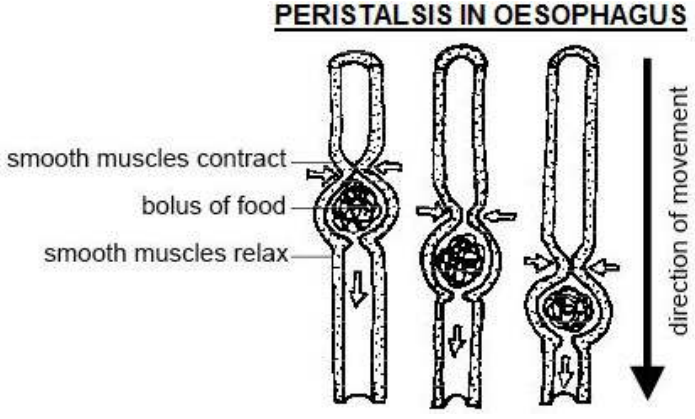
STAGESOFSWALLOWING

- **Tongue**contractsto pushthebolustowards thethroat,forcingthe**softpalate**upwardsto closethe **nasopharynx**
- **Larynx**and**hyoidbone**moveanteriorlyand upwards.
- **Epiglottis**bendsdownwardstoclose**larynx** (tracheaentrance)topreventfood fromentering thetrachea.

NB:*Anyfoodthatentersintotracheais expelledoutbycoughingreflex.*

- Breathingbrieflystopsdue toclosureof **glottis**.
- **Pharynx**shortens.
- **Upperoesophagealsphincter** (Cricopharyngealsphincter)relaxes,toallow thebolusenterinto**oesophagus**
- Inoesophagusthefoodbolus movesby **peristalsis**,a sequenceofwave-like contractionsthatsqueezefooddownthe oesophagus.
- **Loweroesophagealsphincter(cardiac sphincter)**relaxestoallowfoodinto stomach.





TYPICALEXAMINATIONQUESTION

(a)Describetheprocessofswallowingfoodinhumans.(10marks)
(b) Explaintheroleofgastricjuiceduring fooddigestionin adulthumans(10marks)

HETEROTROPHICNUTRITION

DIGESTIONINTHESTOMACH

● Arrivalof foodinthestomachstimulatessecretionof**gastrinhormone**from**G-cells**intothebloodstream,which stimulatesthe **gastricglands**to secrete**gastricjuice**,whosecomponentsinclude:***mucus*,*pepsinogen*,*hydrochloricacid*** **and*intrinsicfactor***.

● Thecomponentsofgastricjuiceare secretedbydifferentcellsandperformdifferentrolesasfollows:

TypeofCell	Secretion	Function
Mucouscells (i)Mucoussurfacecells (ii)Mucousneckcells	Mucus	Formsa barrieratthe stomachlining,topreventtissuedigestion.
	Bicarbonate	Buffersgastricacidtopreventdamagetoepithelium
Chief/Peptic/zymogenic cells	Pepsinogen	Pepsinogenonactivationtopepsindigestsproteintopolypeptides
	Gastriclipase	Digestslipidstofattyacidsandglycerol
	Prochymosin (Prorennin)	Rennincoagulatessolublemilkprotein**Caseinogen**intoinsoluble **casein**inbabies,whoseslowedflowenablesdigestionby**pepsin**.
	Gastriclipase	Gastriclipase**weakly**hydrolyses**fats**to **fattyacids**and**glycerol**
Parietal/oxynticcells	Hydrochloricacid	(i)Activatespepsinogentopepsin,Prorennintorennin (ii)Killsmostbacteriainthestomach. (iii)Providesoptimumacidic pH forpepsintohydrolyseproteins intopolypeptides. (v)Stopstheworkingofsalivaryamylaseenzyme
	Intrinsicfactor	● Formsacomplexwhichenablesabsorptionof vitamin B_{12} thatis necessaryinredbloodcellformation ● Little*intrinsicfactor*causes**perniciousanemia**

MECHANISMOFHYDROCHLORICACIDSECRETIONINPARIETALCELLS

● Hydrochloricacidisproducedby**parietal**cellsthrough a complexseriesofreactions.

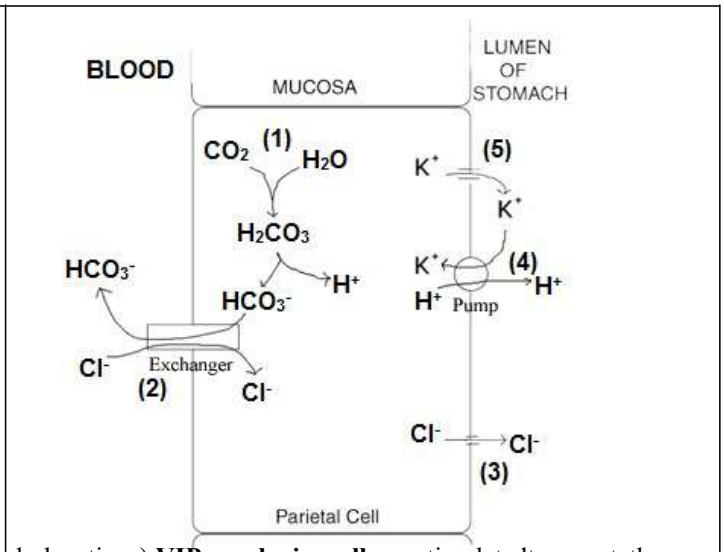
● Catalysedbytheenzyme**carbonicanhydrase**,**carbon dioxide**(whichdiffusedfromcapillaries)reactswith **water**toform**carbonicacid**,whichdissociatesinto **bicarbonateion**and**hydrogenion**.

● **Bicarbonateion**istransportedintothebloodstreamby an**ionexchangemolecule**inplasmamembrane which exchanges**bicarbonateions**exitingparietalcellsfor **chlorideions**entering.

● **Hydrogenions**are**activelypumped**intothe**duct**of **gastricgland**andthe**negativelychargedchlorideions diffuse**withthe**positivelychargedhydrogenions**.

● **Potassium ions**are**counterpumped**intotheparietal cellinexchangefor**hydrogenions**.

● Thenetresultisproductionofhydrochloricacidinthe **parietalcells**anditssecretionintothe**duct**of**gastric gland**.



● ~~Duetochurningbythe stomachwall(alternatecontractionsandrelaxations),**VIP-producingcells**are stimulatedto secretethe~~ hormonecalled**vasoactiveintestinalpeptide**,whichcausesrelaxationof**pyloricsphinctermuscle**toallowthe semisolid**chyme**flowfromthe stomachintotheduodenum,afteramaximumofabout**fourhours**.

DIGESTIONINTHEDUODENUM

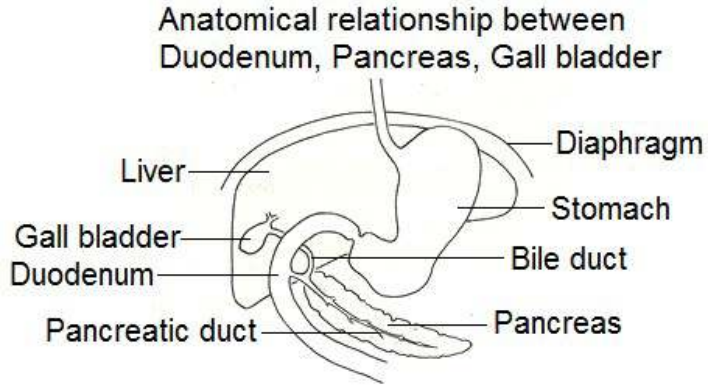
Arrivalof**partiallydigested,acidfood**mixtureintheduodenumstimulates**endocrinecells**induodenalwallstosecretethe hormones:**Secretin,Enterogastrone,Cholecystokinin(CCK)**formerly**Cholecystokinin-Pancreozymin(CCK-PZ), Villikinin**and**Enterocrinin**.Thesehormonescoordinateactivitiesofthe stomach,pancreas,gallbladderandileumas follows:

Hormone	Stimulusforsecretion	Effect
Secretinhormone	Acidchymein duodenum	● Stimulatesthe **liver**to secrete**bile**intothe**gallbladder**. ● Stimulatespancreaticsecretionof **non-enzymatic**substances(**hydrogen carbonateions)**from**acinarcells.** HCO_3^- neutralisetheacid fromthe stomachtoprovideanalkalinepHoptimumforpancreaticenzymes. ● InhibitssecretionofHClby**oxynticcells**aschymeleavesthe stomach.
Enterogastrone hormone	Acidandfat inthe duodenum	● Reducesstomachmotility ● Inhibitsoxynticcells fromsecretinghydrochloricacidinordertoprovide anoptimumpHforpancreaticenzymes. ● Signalsthestomachtoemptyslowlywhenfatispresent,allowingmuch timefordigestionoffatalreadyemptied. **NOTE**:Highfatdietsstimulateenterogastroneproduction,whichprolongs foodstayinthestomach,andisthereforeusefulintreatingduodenalulcer.
Cholecystokinin hormone (CCK)formerly called **Cholecystokinin**	Partiallydigested**fat** and**protein**inthe duodenum	● Stimulatescontractionof**gallbladder**to release**bile**into**duodenum**. **(i)**Bilesalts(sodiumglycocholate)emulsifyfatsi.e.fatsphysicallybreakinto dropletsduetoreducedsurfacetension,whichincreasestheirsurfacearea ● Stimulatesthepancreastosecrete**pancreaticenzymes**: (i)**Pancreaticamylase**whichcatalysesthe hydrolysisof **starch**into**maltose** (ii)**Enterokinase**,anon-digestiveenzyme whichactivates**Trypsinogen**to **Trypsin.** (iii)**Trypsinogen**,whichisactivatedby**enterokinase**to**Trypsin.** **Trypsin:** **(1)** Catalyseshydrolysisof**polypeptides**to**peptides.** **(2)** Activates**chymotrypsinogen**to**chymotrypsin**. (iii)**Chymotrypsinogen,**whichisactivatedto**chymotrypsin**by**Trypsin.** **Chymotrypsin**catalyseshydrolysisof**casein**/**polypeptides**into**peptides**.
Villikinin (Motilin)	**AlkalinepH**inthe duodenum	● Increasesperistalsisinthesmallintestineandileumvillimovements,in preparationforincomingfood.

NOTE:

1. Somesourcesindicatethat**enterogastrone**referstoanyofthehormonessecretedbythemucosaoftheduodenuminthe lowergastrointestinaltractinresponsetodietarylipidstoinhibitchurninge.g.**(i)**Secretin**(ii)**Cholecystokinin
2. All**proteolytic**(proteindigesting)enzymesalongthegutaresecretedin**inactive(precursor)**formtoprevent**autolysis** (self-digestion)of guttissues, whichareproteininnature.

Thechurningactionofduodenalwallsturnsthesemi-solid**Chyme**intoa thin, milky-lookingalkalinefluidcalled **Chyle**.



DIGESTIONINTHEILEUM

Distention ofthe small intestine by food / **tactile stimulus** / **irritatingstimulus**stimulatesthe secretion of**intestinal juice** (**Succusentericus**),which consists ofamixtureofsubstancesfrom **cryptsofLieberkühn**and **Brunner'sglands**.Someofthe componentsof**Succusentericus**includethefollowing enzymes:

● ***Peptidases*:**catalysehydrolysisof **peptides** into **amino acids**, therebycompletingthe digestion of proteins.

● ***Nucleotidases*:** catalysehydrolysis of **nucleotides** into **phosphoricacid,nitrogenousbases**and **pentosesugars**.

● **Maltase**:catalyseshydrolysisof**maltose**into**glucose**molecules, therebycompletingstarch digestion.

● ***Sucrase(invertase)***:catalyseshydrolysisof**sucrose**into**glucose** and **fructose**molecules.

● ***Lactase***: catalyseshydrolysis of **lactose** into **glucose** and **galactose**molecules.

● ***Intestinallipase***:catalyseshydrolysisof**lipids**into**fattyacids** and **glycerol**.

● ***Intestinalamylase***:catalyses hydrolysisof**starch** into **maltose**.

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FOODABSORPTION

Itistheprocessbywhich solublefoodsubstancesareabsorbedacrossthe**gutepithelium**into**bloodcirculatorysystem**or **lymphaticsystem**tobecarriedtoallbodycells.

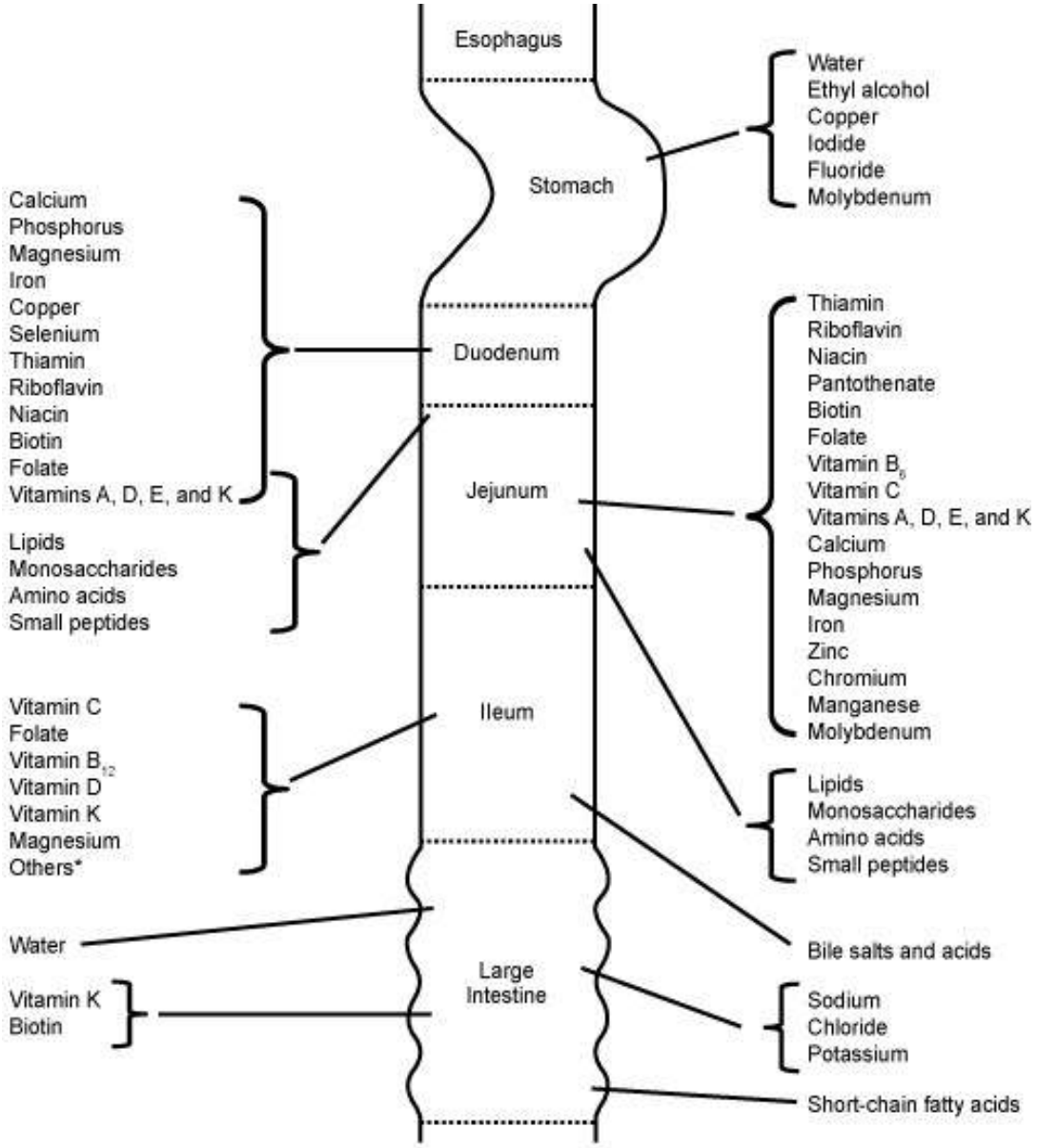
Duringabsorption,substancesmoveasfollows:

(i)From**intestinallumen**acrossthefreeend/**apical**end/ **mucosal**endoftheabsorbingcell.

(ii) Acrossthebase/ **basilar**end/ **serosal**endofabsorbingcellintothe**subcellularspace**,and finallyinto **blood circulatorysystem**or**lymphaticsystem**.

NOTE: Substancesenteringattheapicalsurfacemaybemetabolizedorwithinthecellor mayappearatthebasilarsurface whenchangedintoanother form.

MAINSITESOFNUTRIENTABSORPTION



*Many additional nutrients may be absorbed from the ileum depending on transit time.

HETEROTROPHICNUTRITION

PROCESSESINVOLVEDINABSORBINGDIGESTEDFOOD

(1) Simplediffusion**(2)** Facilitateddiffusion**(3)** Activetransport**:Direct**activetransportand**Secondary**activetransport

SECONDARYACTIVETRANSPORT

A formofactivetransportacrossa biologicalmembraneinwhicha transporterproteincouplesthemovementofanion (e.g. Na^+orH^+)**down**itselectrochemicalgradienttothe**uphill**movementofanothermoleculeorion **against**a concentration/electrochemicalgradient.Thus,energystoredintheelectrochemicalgradientofanionisusedtodrivethe transportofanothersoluteagainsta concentrationorelectrochemicalgradient.

TYPESOFSECONDARYACTIVETRANSPORT

1. Cotransport(alsoknownas**Symport**). **2. Exchange**(alsoknownas**Antiport**)

1. COTRANSPORT: Thedirectionof transportis thesamefor both thedrivingionanddrivenion/molecule.

Examples:

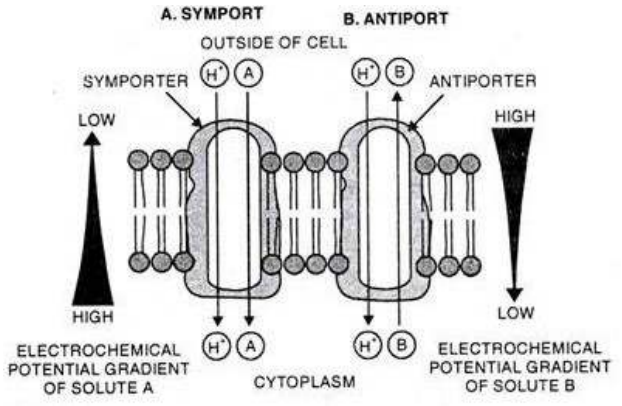
(i) TheNa^+/glucosecotransporterin**enterocytes**(smallintestine epithelialcell)andkidneyproximaltubuleepithelialcells simultaneouslytransports2 Na^+ionsand1 glucosemoleculeinto thecellacrosstheplasmamembrane.

(ii) TheH^+/dipeptideortripeptidecotransporterin epithelialcells ofsmallintestinecouplesthedownhillmovementof H^+across theplasmamembranetotheuphilltransportofdipeptidesand tripeptidesintothecellagainstaconcentrationgradient.

2. EXCHANGE: Thedrivingionanddrivenion/moleculemove in oppositedirections.

Example:

TheNa^+/Ca^{2+}exchangerin cardiacmusclecellstransports3Na^+ ions intothecellin exchangefor1 Ca^{2+}iontransportedoutof the cell.



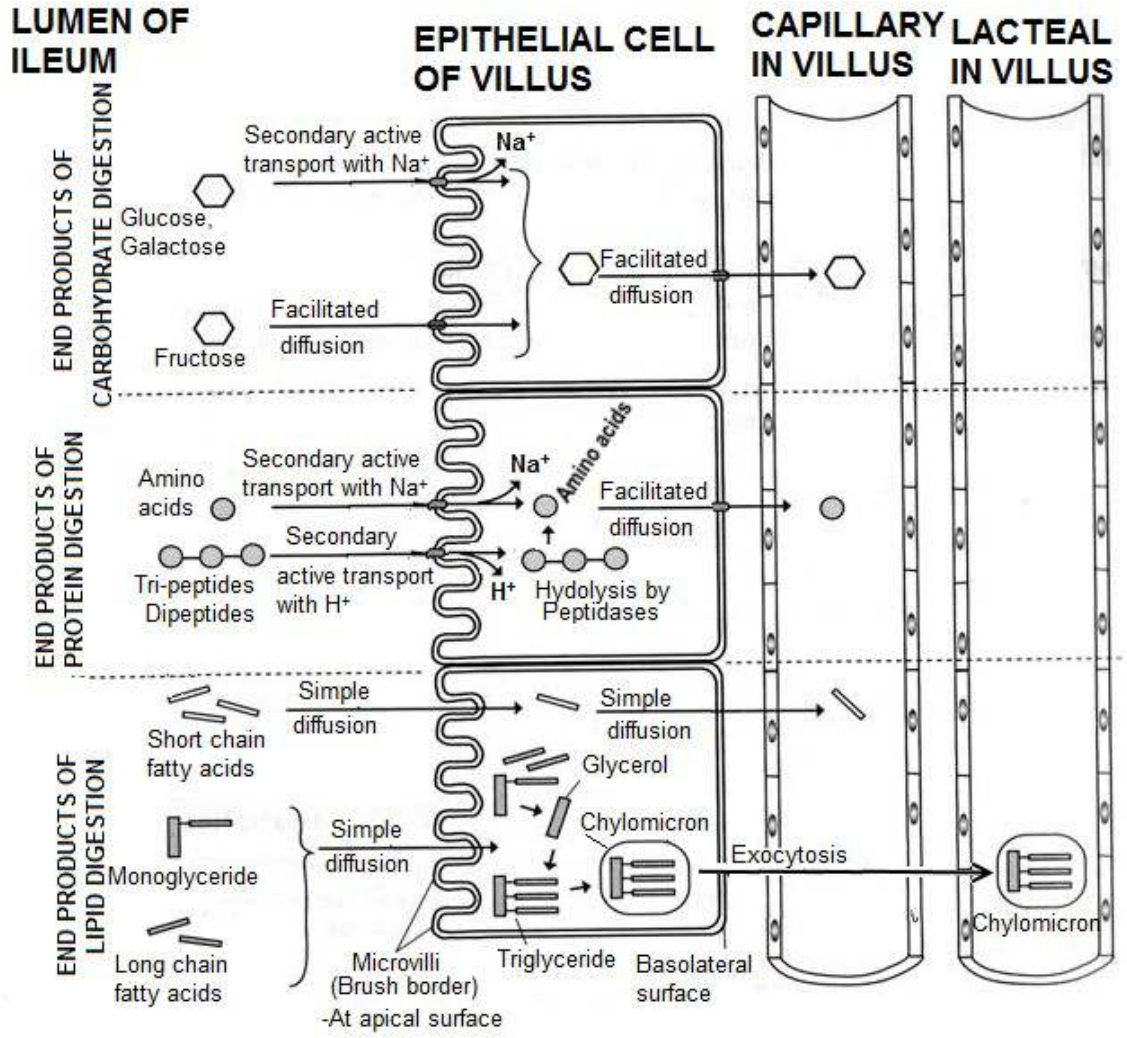
MECHANISMSOFABSORBINGDIGESTEDFOODINTHEILEUM

Digestedfood	Mechanism	Descriptionof the mechanism
Glucoseandgalactose	Secondary**active transport**withNa^+ (**CotransportwithNa$^+$**)	Glucoseandgalactosearе**cotransported**intoepithelialcellsof villiwith**Na$^+$**ions,thenexportedintobloodcapillariesby **facilitateddiffusion**.
Fructose	Facilitateddiffusion	Fructose movesintoepithelialcellsofvilliby**facilitated diffusion**,thenexportedintobloodcapillariesby **facilitated diffusion**.
Aminoacids	Secondary**active transport**withNa^+ (**CotransportwithNa$^+$**)	Aminoacidsare **cotransported**fromintestinallumenintosmall intestinalepithelialcells with**Na$^+$**ions,thenexportedto capillariesby**facilitateddiffusion**.
DipeptidesandTripeptides (Oligopeptides)	Secondary**active transport**withH^+ (**CotransportwithH$^+$**)	Oligopeptides(dipeptidesandtripeptides)are**cotransported** fromintestinallumenintovilliepithelialcellswith**protons(H+)** Oligopeptidesarethen**hydrolysedbycytoplasmicpeptidases** into**aminoacids**, whichareexportedfromthevilliepithelial cellsintobloodcapillariesby **facilitateddiffusion**.
Shortchainfattyacids	Simplediffusion	Shortchainfattyacidsmoveintoepithelialcellsof villiby **simplediffusion**,thenareexportedintobloodcapillariesby **simplediffusion**.
Monoglyceridesand Long chain fattyacids	Simplediffusion	Monoglyceridesand longchainfattyacids**diffuse**intocolumnar epitheliaof villi,**recombine**toform**lipids**,thencombinewith **proteins**toformwatersoluble**lipoproteins**called **chylomicrons**,whichareexportedby**exocytosis**tolacteals.

NOTE:

1. Absorptionof**wholeproteins**occursonlyina fewcircumstancese.g.**newborns**whensucklingabsorb**antibodies** (**immunoglobulins**)fromthemother'smilk(colostralmilk)to acquire**passiveimmunity**.

2. Inadults,absorptionofwholeproteincancause**allergicreaction**duetopresenceof**foreignprotein**inblood.



ILEUM–THEMAJORSITEFORABSORPTION

Adaptationsoftheileumtoabsorptionoffood

(i) Ileumis**long**and**highlyfolded**for **increasedsurfacearea**in**absorption**ofsolublefoodsubstances. (ii) Ileumhas**numerous**finger-likeprojectionscalled**villi**which**increase**the**surfacearea**for **absorption**ofsolublefood. (iii) Ileumepithelialcellshave**microvilli**whichfurther**increase**the**surfacearea**forefficientfoodabsorption. (iv) Ileum**epithelium**is**thin**to**reducediffusiondistance**for solublefoodsubstancestoallow**fastrate**of**diffusion**. (v) Ileum**epithelium**is**permeable**toallow**movement**ofsolublefoodsubstances**across**with**minimumresistance**. (vi) Ileumvillihave**densenetworkofbloodcapillaries**to**rapidlycarryawaydigestedfood**fromtheabsorptionarea which**maintains**a**steepdiffusiongradient**. (vii) Ileumvillihave**permeablelacteal**,a branchofthelymphaticsystemfor **carryingaway**fats (viii)Ileum**epithelialcells**have**numerousmitochondria**to generateATPenergyforactivetransportofsomeions. (ix) Ileum**innersurface**islined with**alot**of**mucus**to**preventautolysis(self-digestion)**by**proteolytic**enzymes.

TYPICALEXAMINATIONQUESTIONS

1. (a)Explainhowthestructureofvilliinthesmallintestineisrelatedtoabsorptionofdigestedfood.

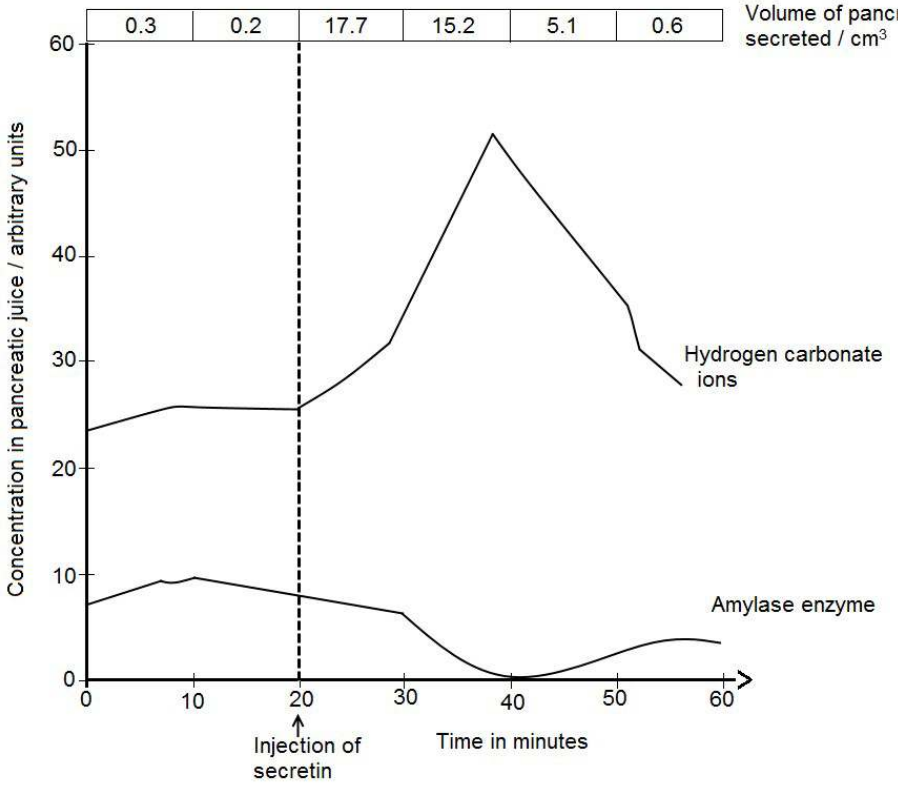
- Largesurfaceareabymicrovilli/protrusionofexposedpartsforfastuptakeofsolublesubstances.
- Epitheliumonlyonelayerthicktoreducediffusiondistance.
- Proteinchannelsallowfacilitateddiffusionandactivetransport.
- Numerousmitochondriaprovide much ATP foractiveuptakeof somenutrientslike glucoseandsalts.
- Bloodcapillariesclosetoepithelium/surfacetoreducediffusiondistanceduringabsorptionofglucose/aminoacids
- Lacteal/lymphaticvesselispermeable/haslargesurfaceareaatcentretoabsorbfattyacidsandglycerol.
- Tightjunctionsbetweenadjacentvillienablecontrollingabsorptionofsubstances

(b)The table belowshows experimentalresults ofthe rate of absorptionofhexosesugars (Glucose, galactoseandfructose), and pentose sugars (xylose andarabinose)bypieces oflivingintestine andbypieces ofintestine poisonedwith cyanide.The resultsare shown as relative tothe rate forglucose.

	Rateofabsorption	
	Byliving intestine	Bypoisoned intestine
Glucose	1.00	0.33
Galactose	1.10	0.53
Fructose	0.43	0.37
Xylose	0.31	0.31
Arabinose	0.29	0.29

(i)Explain theobserved rates ofsugar absorptionshownbythe twotissues.
● Therateofabsorptionofglucoseandgalactoseisfasterinlivingintestine;butmuch slowerinpoisonedintestine;**because**absorptionofthesesugarsis**activetransport** requiringATPwhoseformationdependsonenzymes;whichare**inhibited**byrespiratory inhibitor**cyanide;**Toa smallextent,the twosugars are absorbed**passively;**
● Rateofabsorptionoffructose,xyloseandarabinoseisthesameorrelativelythesame in livingintestineandinpoisonedintestine**; becauseabsorption**ofthesesugarsis **facilitateddiffusion**which**doesnot**requireATP;therefore,**notinhibited**byrespiratory poison**cyanide;**

2. Thegraphbelowshowshowaninjectionof secretinaffectsthesecretionofpancreaticjuicebythepancreas.



(a) Usethe graphtoexplaintheeffect ofsecretinonpancreaticsecretion.
(b)(i) Fromthegraph,commenton thecompositionofpancreaticjuice.
(ii) Stateanyotherdigestivesecretion stimulatedbysecretin.
(c) Certaintypesofulcersarethought oftobemadeworsebytheproduction oftoomuchacid fromthe stomach. Medicaldoctorshaveusedseveral methodstotreatsuchulcers. Suggesthoweachofthefollowing treatmentsmightreducetheamount ofacidsecretedbythe stomach:
(i) Cuttingthegastricvagusnerve.
(ii) Blockingtheactionof acetylcholinebygivingthepatient atrophine.

PROBABLESOLUTIONS

(a) ● Secretininjectioncausesarapidincreaseinthevolumeof**pancreaticjuice**from20minutesto30minutes;followedby gradualdecreaseto40 minutes; then arapid decreaseto60minutes;
● Secretininjectioncausesgradualincrease inthe concentrationofbicarbonate ionsfrom20minutesto30minutes;followedbyrapidincreasetoapeakat 40 minutes; thenrapid decrease until60 minutes;
● Secretin injectioncausesgradualdecreaseinconcentrationofamylasefrom20minutesto30minutes;followedbyrapiddecreasetoa minimumat40 minutes; then gradual increaseuntil55minutesandthereafter remainsconstant until 60minutes;
● Uponinjectionintoblood,secretinhormonecirculatestoreachthepancreasandliver,firstin**lowconcentration**from20m inutesto30minutes; gradually stimulatingpancreaticsecretionof**wateryhydrogencarbonateions**from**acinarcells**and**graduallystimulating**secreti onof**somatostatin hormone**which **gradually inhibits**secretionof pancreatic amylaseenzyme**.**
● From30minutesto40minutes,thereisnow**muchsecretinconcentration**inbloodcirculation;whichrapidlystimulates pancreaticacinarcellsto rapidly secrete**hydrogen**

carbonateionsand**also**greatlystimulatessecretionof**somatostatinhormone**which**rapidlyinhibits**secretionofpancreatic amylaseenzyme**;**

● From40minutesto60minutes,highPH(alkalinity)dueto**hydrogencarbonateions**inhibitstheworkingofsecretinhormone;causinglessstimulation of acinar cells hence rapiddecrease insecretionof hydrogencarbonate ions.**Somatostatinhormone**secretiondecreases hence decreasing the inhibitionof pancreaticexocrinecells causingincreasedamylaseenzymesecretion**;**

(b)(i) Pancreaticjuiceismainlycomposedof**substances**(likewater),**hydrogencarbonate ions,**andsmallamounts ofenzymes like **amylase**.

(ii) Secretionof **bile**inliver cells,storedinthe gallbladderwhichwhenreleasedintheduodenum emulsifies fatsintodroplets,whichisphysical digestion. **(c) (i)**Conditionedreflexes from vagalcentrein thebrainfailto stimulatesecretionof acetylcholine, no secretion ofgastrinhormone, no secretionof gastric juice (HCl) during thecephalicphase (beforefoodreaches thestomach)hencethestomachwallwillbe less irritated.

(ii) Blocking theactionof acetylcholineusingatrophine**inhibits**thesecretionof **gastrinhormone**;hence secretionof gastricjuice(HCl) isinhibited.

COLON

- Inthecolon,thereismainlyabsorptionof:

(i) Waterintothebloodcapillariesby**osmosis.**
(ii) VitaminsBiotin(B_7)andK,whichissynthesisedby*Escherichiacoli*bacteriathatliveinthe colon.
(iii)Na^+,Cl^-andK^+

NOTE: Thecolonwallcontainsmucussecretingcellsforlubricatingthemovementofundigestedfoodthroughthecolon.

APPENDIXANDCAECUM

- Inruminantslikecattleandinnon-ruminantslikerabbits,**mutualisticbacteria**secrete**cellulaseenzyme**whichdigests **cellulose**to **glucose,**whichislostalongwithfaeces.Intheprocessdescribedas**coprophagy(coprophagia)**,rabbitseat own faecalpellets whiledungbeetlesfeedoncowdungtoenableabsorptionofglucoseattheileum.
- Inhumans,appendixandcaecumhavenoobviousrole.

RECTUM

- Intherectum,foodisstoredtemporarilytoenableosmoticabsorptionofwaterintobloodcapillaries.

CONTROLOFDIGESTIONINHUMANS

Acombinationof**hormonal**and**nervousstimulations**and**inhibitions**ofthegutthat**regulate**the secretionofdigestive juicesinthegut.

IMPORTANCEOFCONTROLOFDIGESTION

(i) Secretionofdigestivejuicesdependsonrespiratoryenergy;therefore,unnecessarysecretionmustbepreventedtoavoid wastageofrespiratorysubstrates.
(ii) Secretionof**proteolyticenzymes**ininactiveformprevents**autolysis**(self-digestionoftissues).

MECHANISMSOFCONTROLLINGDIGESTIONIN HUMANS

- Involvesa combinationof**hormonal**and**nervous;stimulations**and**inhibitions**ofthegut;that**regulate**the secretionof digestivejuicesinthe gut;
- Thedigestivejuicessecretedinclude**saliva**inthebuccalcavity;**gastric**juiceinthestomach;**pancreatic**juiceand**bile**in theduodenum;**intestinal**juiceintheileum;

CONTROLINTHEMOUTH

- Sight/ smell/thoughtoffood**stimulate**conditionedreflexesinvolvingthe**cerebralcortex,hypothalamus**and**medulla oblongata;**which**stimulate**salivaryglandsto secretesaliva.
- Contactoffood withtonguetastereceptors**stimulates**nerveimpulsesviasensoryneuronstothe**hypothalamus**and **medullaoblongata;**relayedalongmotorneuronsto**stimulate**salivaryglandsto secretesaliva.

-Salivaryamylaseinsalivacauseshydrolysisofstarchtomaltose.

- Lossofappetite/ depression**inhibit**cerebralcortex**;**parasympatheticcentreis**not stimulated**,nosecretionofsaliva**;**

CONTROLINTHESTOMACH

Occursin3 phases:**cephalic;gastric;**and**intestinal**phases;

Cephalicphase/Nervousphase:

Itoccursbeforefoodentersthe stomach;

- Sight/ smell/thoughtoffood**stimulate**conditionedandunconditionedreflexes**;**involvingthe**cerebralcortex, hypothalamus**and**medullaoblongata;**which**stimulate**the**vagusnerve**causingthereleaseof**acetylcholine**;which **stimulates**the secretionofthe**hormonegastrin**;whoseeffectsare:

(i)Stimulatessecretionof gastricjuice.
(ii)Increasescontractionsofgastro-intestinaltract
(iii)Relaxesthepyloricsphinctertoletinbolusoffood fromthe gullet;

- Lossofappetite/depression**inhibit**cerebralcortex**;**parasympatheticcentreis**not stimulated**,no gastricsecretion**;**

NOTE:
Secretionofnervousphaselastsforaboutonehourduringwhichgastricjuicesecretionreachesamaximum,after whichthereisa rapiddecreasefrom1 hourto1.5hours.
Therefore,nervoussecretionis:**(i)** shortlastingand**(ii)**rapidascomparedtothe hormonalphase.

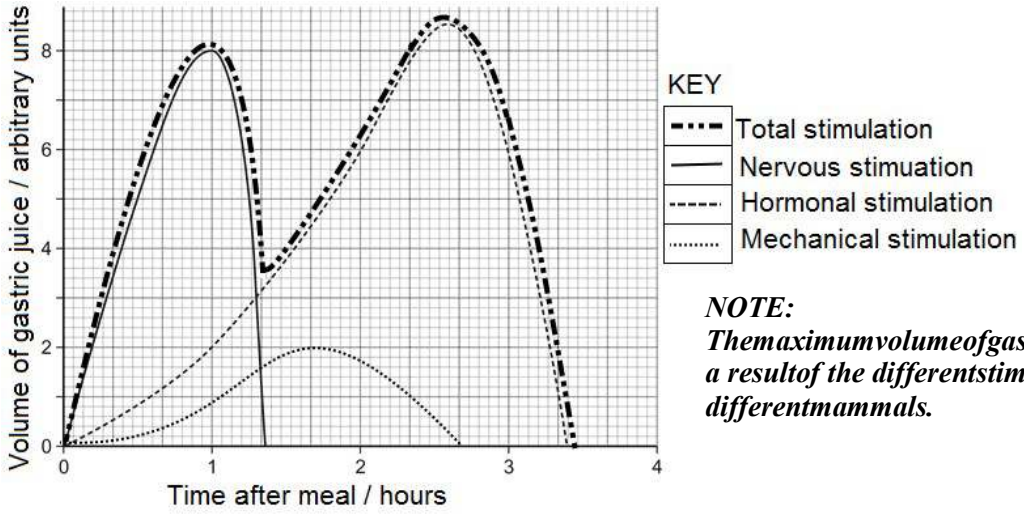
Gastricphase:
● Arrivaloffoodbolusdistends/stretchesthestomachwallwhichactivates**stretchreceptors**tofireimpulsestothe **Meissner'splexus**inthestomachwalltocausethefollowingeffects:
(i) Stimulatelocalsecretoryreflexesinthestomachwalltoactivategastricglandssecrete**pepsinogen**and**HCl**;
(ii)Stimulatereflexesinthe medulla,viathe**vagusnerve**toactivategastricglands wallto secrete**pepsinogen**and**HCl**;
(iii)Stimulate**enteroendocrine**cells/ G-cellsto secrete**gastrinhormone;**whichstimulatessecretionof**gastricjuice;**
(iv)Stimulate**enteroendocrine/enterochromaffin**cellstosecrete**histamine;**whichactivatessecretionof**gastricjuice;**
● Partiallydigestedproteinsespeciallypeptides/decreaseinpHactivates**chemoreceptors**,whichstimulateG-cellsto secrete**gastrinhormone;**whichstimulatessecretionof **gastricjuice;**
● Excessiveacidity(PHoflessthan2)**inhibitsG-cells**hence**gastricjuice**secretionreduces;
● Emotionalupsetactivates**sympatheticnervoussystem**whoseeffectsoverridethe**parasympatheticnervoussystem**;

NOTE:
Thegastricglandsarestimulatedbyhormonesto secretegastricjuiceforaboutfourhours.
Therefore,hormonalsecretionis:**(i)**longerlastingand **(ii)**gradualascomparedtothecephalicphase.

Intestinalphase:
● Distensionofduodenum/presenceofacidchyme/partiallydigestedfoodstimulatesthesecretionof**intestinal**(**enteric**) **gastrinhormone**;whichstimulatessecretionof **gastricjuice**inthestomach**;**
● Distensionofduodenum/presenceofacidchyme/fattyacids/irritants/intheduodenumstimulatesthesecretionof Intestinalhormones:
(i) **Secretin**;whichstimulatesthereleaseof **bile**fromtheliverand**hydrogenbicarbonateions**inpancreaticjuice; (ii) **Cholecystokinin**;whichstimulatesthepancreasto secreteitsenzymes;
(iii)**Enterogastrone**;whichinhibits/suppressesgastricactivity(anyfurthersecretionofacidbythe stomach);
(iv)**Vasoactiveintestinalpeptide**inhibitsgastricacidsecretion.
● Distensionofduodenum/presenceofacidchyme/fattyacids/irritants/intheduodenuminitiatesgastric-inhibitory impulsesintheenterogastricreflexcausingsuppressionofgastricactivity;andemptyingofstomach;

CONTROLINTHEILEUM
Contactoffood withintestinallliningstimulatestheintestinalglands;to secreteintestinaljuicecomposedofenzymes responsibleforcompletionofdigestionoffoodsubstrates;

Variations involume of gastricjuiceproducedbynervous, hormonalandmechanicalstimulationswithtimeafter eatingfood



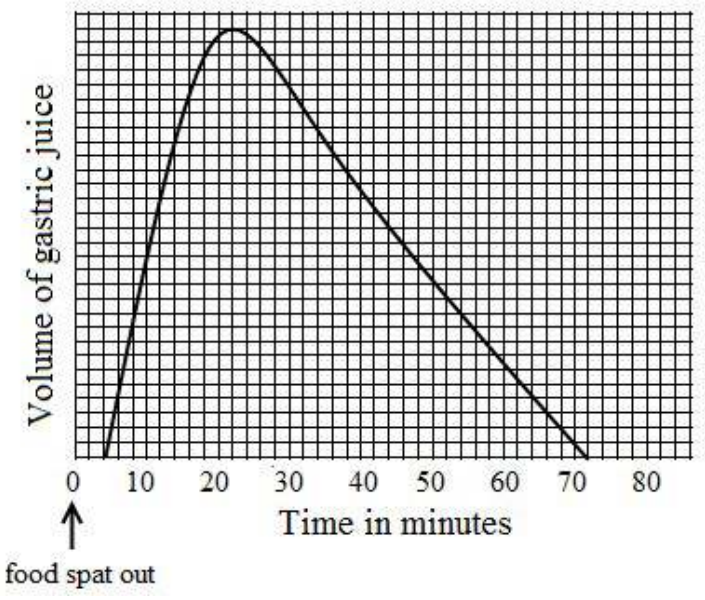
NOTE:
Themaximumvolumeofgastricjuiceproduced as a resultof the differentstimulationsvariesin differentmammals.

OBSERVATIONS/DESCRIPTION
1.Volumeofgastricjuiceproducedduringnervousstimulationincreasesrapidlyfrom0hourtoamaximumat1hour,thendecreases rapidlyandceases at 1.5hours.Nervous secretionis:(i)shorterlasting (ii)instantlyrapidas comparedtohormonalandmechanicalphases.
2.Volumeofgastricjuiceproducedduringhormonalstimulationincreasesgraduallyfrom0hourto1hour,thenincreasesrapidlytoa maximumatabout2.5hours,then decreases rapidlyandceases atabout3.3hours.
Therefore, hormonalsecretionis:**(i)**longerlasting and**(ii)**initiallygradualas comparedtothe cephalic phase.
3.Volume ofgastric juiceproduced during**mechanicalstimulation (foodstretchingstomachandduodenalwall)**increases gradually from0 hourto0.7 hour,thenincreases rapidlytoamaximum atabout1.6hours,then decreases rapidlyandceases atabout2.6 hours

HETEROTROPHICNUTRITION

TYPICALEXAMINATIONQUESTION

Thegraphbelowshowstheamountof gastricjuiceproducedbythe stomachofanindividualwhohadjustchewedsome food.**Thefoodwasspatoutafterbeingchewed,andnonewasswallowed.**



(a)Nametwoconstituentsof gastricjuice
(b)Assumingthatnotracesoffoodgotdowninto the stomach,explainhowthesecretionof gastric juicewasbroughtabout.
(c)(i)Howmuchtimeelapsedbetweenthemoment thefood wasspatoutandthemomentgastricjuice startedtobeproduced?
(ii)Accountforthedelayin(c)(i)above.
(d)Ifthe stomachofanadultpersonissurgically removedthroughanoperation,suggestwithreasons, themoresuitabledietforsucha personafter recoveryfromtheoperation.

ASSIMLIATIONOFFOOD

Assimilation:Theprocessbywhichsimplesolublefoodsubstancesareabsorbedand usedbybodycellsinthe variousways. Theproductsofdigestionarebroughtdirectlythroughthe hepaticportalvein toliver,whichcontrolstheamountofnutrients releasedintothemainstreambloodcirculatorysystem.
Assimilationsupportsgrowth,development,bodyrenewal,and storingupofreservesusedasa sourceofenergy.
Metabolism: Chemicalprocesseswithincellsofanorganism.
Itinvolves:
(i)Catabolism: Breakdownofcomplexmoleculesintosimplermolecules,withreleaseofenergy**. (ii) Anabolism:**Assembly/buildingupofcomplexmoleculesfromsimple moleculesusingenergy.

FOOD	HOWABSORBEDFOODISUSEDINTHEBODY	HOWBODYDEALSWITHEXCESS
Glucose	● ATPsynthesisinrespiration ● Formation ofglycoproteinsinvolvedincelltocell recognitionmechanisms. ● Forproductionof mucus ● Excesscarbohydratesare storedintheformof glycogenin theliverandmuscles.	● Storedintheliveras glycogen. ● Excesscarbohydratesmaybeconverted into fatsfor storage.
Aminoacids	● Formation ofprotoplasmofcellsduringgrowth ● Production ofenzymesandantibodies ● Formation ofbodystructuressuchas hairs,nails, hooves, cellmembranes ● OxidisedtoreleaseATPenergyduringseverestarvationi.e. intheabsenceof glucoseandfats. ● Formation ofhormonese.g. insulin ● Formation ofplasmamembranecomponentse.g. glycoproteins,channelproteins	● Deaminatedinthelivertoformurea, whichisexpelledbykidneys. ● Someaminoacidsare**transaminated** toproducea differentaminoacid
Fattyacids andglycerol	● Thelongchainfattyacidsaredesaturatedintheliverand arethenbrokendowntocarbondioxideandwaterby successiveoxidations. ● Someofitcanbeconvertedintoglucose ● Someusedtoformvariousstructureswhicharecomponents ofcellse.g.phospholipids	● Storedasfatundertheskin

TYPICALEAMINATIONQUESTION

(a) Whatrolesdotheliverandpancreasplayin:(i)fooddigestion (ii)metabolismofabsorbedproducts

(b)Howcanthedietofraw liverpreventthediseaseperniciousanaemia?

	Digestion	**Metabolismofabsorbedproducts**
Pancreas	Onstimulationby**cholecystokininhormone**,the pancreassecretesenzymeswhoseeffectsareas follows: (i)Amylasecatalyseshydrolysisof starchinto maltose (ii)EnterokinaseenzymewhichactivatesTrypsinogen toTrypsin. (iii)Trypsin: (1)Catalyseshydrolysisofpolypeptidestopeptides. (2)Activateschymotrypsinogentochymotrypsin. (iii)Chymotrypsincatalyseshydrolysisofcasein/ polypeptidesintopeptides. (iv) Lipasehydrolysesfatstofattyacidsandglycerol (v) Nucleasehydrolysesnucleicacidsto nucleotides (vi)Polypeptidasehydrolysespolypeptidestoamino acids. Onstimulationbysecretinhormone,thepancreas secreteshydrogencarbonateionsfromacinarcells, whichneutralisetheacid chymefromthestomachto provideanalkalinepHoptimumforpancreatic enzymes.	(i)Ifinexcess(above90mg/100cm^3),thepancreasis stimulatedto secreteinsulinhormonewhichcauses conversionofglucosetoglycogenfor storage,fator metabolizingittoenergyandCO_2. (ii)Iflittle(below90mg/100cm^3),thepancreasis stimulatedto secreteglucagonhormonewhichcauses conversionofglucagontoglucosehenceincreasingthe bloodglucoselevel.
Liver	Onstimulationbysecretinhormone,theliversecretes **bile**intothe**gallbladder**. OnstimulationbyCCK hormone,**gallbladder** contractstoreleasebilesalts whichemulsifyfatsi.e. fatsphysicallybreakintodropletsduetoreduced surfacetension,whichincreasestheirsurfacearea	**1. TheLiverregulatesbloodglucose:** (i)Ifinexcess(above90mg/100cm^3),glucoseis convertedinto glycogenfor storage. (ii)Iflittle(below90mg/100cm^3),glycogenis convertedinto glucosefor use. **2. Theliverregulatesaminoacidsinthebody:** Excessaminoacidsare notstoredinthebody,but undergodeaminationprocess.i.e.theaminogroup(-NH_2)fromtheaminoacidisremovedtoform ammonia,whichlaterformsureathatiscarriedin bloodto kidneysforexcretion. **3. Theliverregulateslipids(fats)inthebody:** Itsynthesizesanddegradesphospholipidsand cholesterol. 4.Theliverformsredbloodcellsinfoetusandbreaks downwornoutredbloodcellsinadults. 5.Theliverformsplasmaproteinsfromaminoacids 6.TheliverstoresfatsolublevitaminsA,D,E,Kand watersolublevitaminsB$_{12}$andC 7.Theliverstoresmineralslikelron,potassium, copper,zincandtraceelements. 8.Theliverdetoxifiespoisonoussubstancesi.e.toxic substancesareturnedharmlessbythelivercellse.g. alcohol,cholesterolandhydrogenperoxide.

(b) RawliverisrichinvitaminB$_{12}$whichisessentialforformationofredbloodcells(erythrocytes),whoseabsencecauses perniciousanaemiacharacterisedbypaleness, slownessanddeath.

HETEROTROPHICNUTRITION

FOODANDDIETINHUMANS

Food:Anysubstancetakeninto nourishthebodyandsustainlife.Foodprovidesenergyandnutrients.
Nutrient:isa substancewhichisneededfor**growth**,**repair**and**metabolism**.
Thethreemainnutrientsare: **(1)** carbohydrates **(2)** proteins **(3)** lipids(fatsandoils)

MEASURINGFOODENERGYCONTENT

Theenergycontentina foodsamplecanbemeasuredby**simplecalorimetry.**
Calorimetry:Measuringtheamountof heatgivenoutortakeninbya process,suchasthecombustionofa fuel.

PROCEDUREOFCALORIMETRY

(i)Pourcoldwaterintoa boilingtube/smallbeaker/metalcan
(ii) Recordthe startingtemperatureofthewater
(iii)Measureaccuratelythemassofthefoodsampleina crucible
(iv)Heatthefooduntilitcatchesfire.
(v)Heatthewaterusingtheflamefromtheburningfood
(vi)Recordthefinaltemperatureofthewater andcalculatethe temperaturedifference.

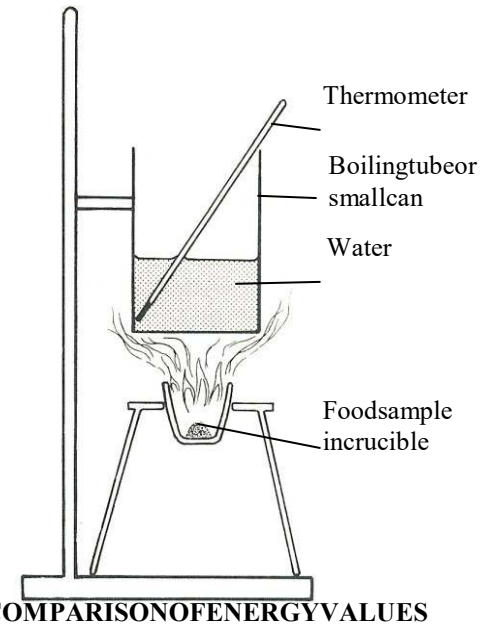
NB:Theexperimentabovecanbedonemoreaccuratelyusinga **foodcalorimeter,**thoughitcostsmoremoneytopurchase.

Calculations
Workouttheenergytransferredtothewaterinjoulesorincalories
Energytransferred(J)=
Massofwater(g)× 4.2(J/g°C)× temperatureincrease(°C)

Note:4.2kJ(1cal.)ofenergyarerequiredtoraisethe temperatureof1 kgofwaterthrough1^{0}C

Workedexample
When0.5goffoodisburned,10cm^{3}ofwater warmsupby20°C.
Whatistheenergycontentofthefoodin J/g?

Solution
1 cm^{3}ofwaterhasamassof1g
Energytransferredtowater=10× 4.2× 20= 840J
Energycontentoffood= 840÷ 0.5=1680J/g
Tofindtheenergyvalueof sugar,1gofsugarisburntina crucible, theflameproducedisusedto heat100g waterinametalcanand the riseintemperatureofthewater measured.



COMPARISONOFENERGYVALUES
Carbohydrate: 1 gramcontains17 kJ
Fat: 1gramcontains39 kJ
Protein: 1 gramcontains18Kj

ENERGYUNITS
Energyunitsarejoules,nolongercalories
4.18joules= 1 calorie
1000calories= 1 kilocalorie(kcal.)= 1 Cal
1000joule=1 kJ (kilojoule)= 1joule
1000kJ= MJ(megajoule)

PRECAUTIONS

Whencomparingdifferentfoods,itisimportanttocarryoutafairtestbykeepingother variablesconstant:
(1) Startingtemperatureofwater **(2)** temperatureincrease **(3)** distanceoftheflamefromtheboilingtube
● Morereliableresultscanbe obtainedbyrepeatingtheexperiment.

SOURCESOFERRORINCALORIMETRY

(a)Inaccurate weighingofsugar
(b) Incompletecombustionofthesugar
(c)Inabilitytomeasurethetemperaturedifferenceaccuratelyenough
(d)Heatfromtheburningsugarescapingwithoutheatingthewater.

HETEROTROPHICNUTRITION

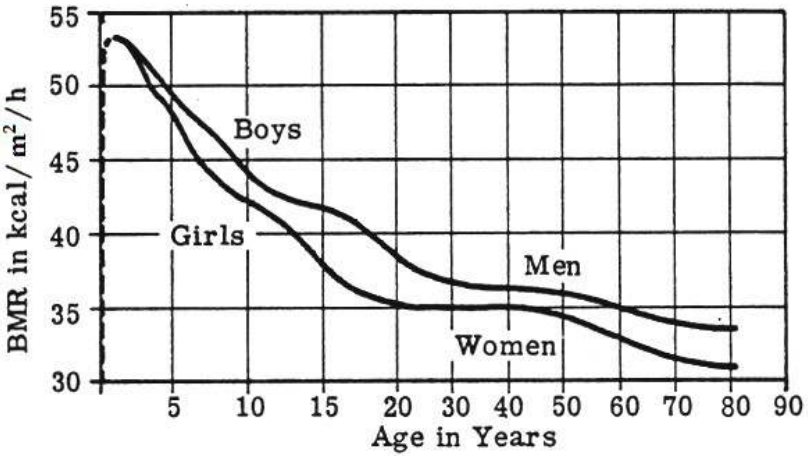
ENERGY-FOODINTAKEANDCONSUMPTION

Thebodyneedsenergyfor **three main**reasons:
(i) Maintainthe**basalmetabolicrate** (**BMR**)–minimumenergyabodyrequiresatresttoperformvitalfunctionslike beatingoftheheart,breathing,peristalsis,impulsetransmission,synthesisofbiologicalmoleculeslikeproteins,etc.
(ii) Sustainbodyactivitieslikemusclecontractionduringmovement,locomotion,etc.
(iii) Generationof heattomaintainbodytemperatureatabout37^{0}C

NOTE:BMRaccountsforabout65%oftheenergyusedinthebodyeachday.

FACTORSWHICHDETERMINEBASALMETABOLICRATE

Age,Sex,Bodymass,Natureofphysicalactivityengagedin,Musclemass,Diet,Drugs,Environmentalfactorse.g. temperature,Hormonalfactorse.g.duringpregnancyandlactation,Genetics.



(a)(i)Factorsshowninthegraph,which affectBMR: Ageandsex

(ii)Otherfactorsnotshowninthegraph, whichaffectBMR:
Musclemass,Bodysize,levelofphysical activity,andPregnancyandlactation,Diet, Drugs,Environmentalfactorse.g.temperature, Hormonalfactorse.g.duringpregnancyand lactation,Genetics

Explanation of variationinBMRwiththe factors in(a)(i) above.
VariationinBMR withsex
● Atabout2.5years and below,BMR inmales is equivalenttoBMR infemales**because** infants have basicallyidenticalcomposition of carbohydrates,fatsand protein.
● Fromabout2.5years throughoutlife,BMR is slightlyhigherin males thaninfemales**because**males usuallyhavemore bodymuscle thanfemaleswhile females usuallyhavemore fatthanmalesper unitbodymass andsurface area.The moremuscle tissue inthe body,the more energythe bodyneeds just tofunctione.g.toconductimpulses andbiosynthesis comparedtofatcellsthatlargelystorefat,withlittle biosynthesis.

VariationinBMR withage
● Infantsandchildren have relativelyhighBMR thanold-agedadults**because** atinfancyandchildhoodmuch ofthe energyconsumedis usedinbiosynthesis ofcellular components requiredforgrowth.Atadulthood, biosynthesis isgreatlyreducedsince growthhas stopped.
● Fromthe age BMR was**first**determinedtoabout20years ofage,BMR decreases rapidly,thenremains constantupto about50years of age andthereafter decreases slowly.
● Frominfancytomaturityat 20years ofage, biosynthesis ofcellular components requiredforgrowthdecreases rapidly,thenremains constantbymiddleage until50 years ofageandthereafter decreases slowly,partlybecauseoflossofmuscle tissue,andalsobecauseof hormonalandneurologicalchanges.Onlyrepairandreplacementofworn outcells occurs atslowrate byadulthood.
.
Explanation of variationinBMRwiththe factors in(a)(ii) above.
● **Musclemass** (amount ofmuscle tissue in thebody). Muscle requires more energytofunctionthanfat.Themore muscle tissueinthe body,the more energythe bodyneeds just toexist.
● **Bodysize:**Larger bodies tendto have ahigherBMRbecausetheyusuallyhave largerinternal organsandfluidvolume tomaintain. Taller people have a largerskinsurface,therefore have highermetabolismtomaintaina constanttemperature.
● **Genetics:**Genotypesandgenetic disorders determine the rate ofBMR.
● **Physicalactivity:**Regular exercise increasesmusclemass andcauses thebodytoburnkilojoulesata fasterrate,evenwhenatrest.
● **Hormonalfactors(e.g.duringpregnancy andlactation):**Hormonalimbalances caused bycertainconditions,includinghypo-and hyperthyroidism,canaffectthemetabolism.Expectantandlactatingmothers require more energytosupportfoetalandbabygrowth respectively.
● **Environmentalfactors(e.g.temperature):**Weathercanalsohave an effect on bodymetabolism;ifitis verycoldorveryhot,thebody works hardertomaintainits normaltemperature andthatincreases the metabolic rate.
● **Drugcontentinthe body:**Caffeine and nicotine canincreaseyourmetabolic rate,while medications includingsome antidepressants andanabolic steroids cancontribute toweightgainregardless ofwhatyoueat.
● **Diet:**Certainaspects ofone'sdiet canalsoaffectmetabolisme.g.inadequate intake ofiodine foroptimalthyroidfunctioncanslow downbodymetabolism.

HETEROTROPHICNUTRITION

BALANCEDDIET

Balanceddietisone whichcontainsthecorrectproportionsandquantityofprotein,carbohydrate,lipids,vitamins, mineral salts,wateranddietaryfibre/roughagerequiredtomaintainhealth.

- Mainly,carbohydratesandlipidsareforenergyproduction,proteinsarefor growthandrepair,vitaminsandmineralsalts areforprotectionofgoodhealth, waterisa solventwhileroughagestimulatesperistalsistopreventconstipation.
- Anunbalanceddietcanleadto**deficiencydiseases**.

EFFECTSOFUNDERFEEDINGANDOVERFEEDING

- Ifenergyoutputexceedsenergyinput,carbohydratereserves(glycogen)andfatreserves(adiposetissue)arerespiredand theperson'sbodymassdecreases.Whencarbohydrateandfatreservesexhaust,tissueproteinisrespiredandthebodywastes away.
- Ifenergyintakeexceedsenergyusageovera periodoftime, carbohydrateisturnedinto fatandtheperson'sbodymass increasesleadingto**obesity**(overweight).

Disadvantagesofobesity:(1)theextra masscausesa personto gettiredquickly**(2)** increaseschancesofstroke/heartattack.
Howanobesepersoncanloseweight:(1) Eatinglessenergyfood **(2)**Takingmoreexercisestoincreaseenergyoutput

BODYMASSINDEX(BMI)

Thisisoneofthewaysofdeterminingwhethera personis**underweight**or**overweight**.
BMIcanbecalculatedusingtheformula:

$$\text{BMI} = \frac{\text{Mass in kg}}{(\text{Height in m})^2}$$

Qn. CalculatetheBMIofa femaleof mass69 kgandheightof1.67m
Anotherwayofdeterminingwhethera personisunderweightoroverweightistousea graphshowingtherelationship betweenheightandbodymass.

CHANGESINBODYENERGYRESERVESDURINGSTARVATION

- **Starvation**results fromthe inadequate intake ofnutrientsorthe inabilitytometabolize orabsorbnutrients.

CAUSESOF STARVATION
Prolongedfasting,anorexia, deprivation,or disease

SYMPTOMSOF STARVATION
Weightloss, dehydration,apathy,listlessness,withdrawal,increased susceptibilitytoinfectious disease,discolouredhaircolor,flakyskin,and massiveedema inabdomenandlowerlimbscausingthe abdomento appear bloated.

ADVERSE EFFECTSOF STARVATION
(i)Marasmus:occurs onaccountofextreme energydeficiency,typically frominadequate amounts ofproteinandcalories.
(ii)Kwashiorkor:isrelatedtomarasmus, affectschildrenwhoare protein-energydeficient,andcanresultin edema (fluidic inflammation) andanenlargedfattyliver—resultinginthe counterintuitive distendingof bellies,givingthe illusoryimpressionthatstarving childrenare wellfed.

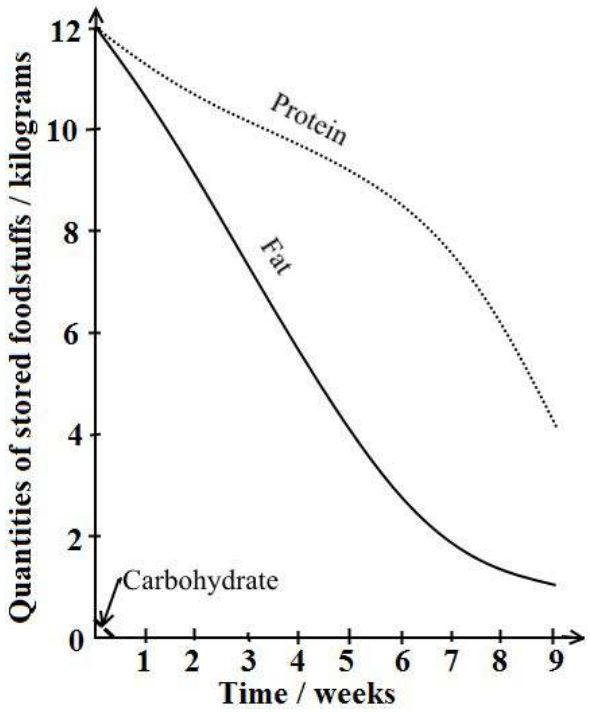
INTERVENTIONSAGAINST STARVATION

- Rehydrationandfeedingthe starvingperson low-bulkfoodwithmuch proteins,muchenergyandfortifiedwithvitamins andminerals.Avoid foods highin bulkbutlowinproteincontent

DESCRIPTION OF CHANGESIN ENERGYRESERVES

- Glycogen,proteins,andfatsare allmetabolizedduringstarvation.
- Exhaustionofbloodglucosestimulates**glucagon**secretionand**insulin** secretionisinhibited.
- Withinthe first 24hours,the verylow glycogenamountstoredinthe liverandmuscles decreases rapidlyto depletion**because**glycogenis brokendownintoglucoseforoxidationtorelease energy,while the amountsof fats and proteinremain high.

Anaerobic breakdown of glycogeninskeletalmuscle is alsostimulated.



HETEROTROPHICNUTRITION

Withinweek1, a fewhoursafterdepletionofcarbohydrate/glycogen,theamountoffatsdecreasesrapidlywhiletheamount ofproteindecreasesgraduallyuntilabout6weeksofstarvation.

- Thisisbecausefatsarehydrolysedrapidlyintofattyacidsandglycerolwhile oxidationofaminoacidsreleasesenergy.
- Theliver metabolizesfattyacidsinto**ketonebodies**that aredegradedtoreleaseenergy.Accumulationof ketonescauses **ketosis,**byconditioncharacterisedbyblood becoming**acidic**
- Fattyacidsin skeletalmusclesarebrokendowntoreleaseenergy,thusdecreasingtheuseofglucosebytissuesotherthan thebrain.
- Glycerolisconvertedinto smallamountof glucose,but mostoftheglucoseisformedfromtheaminoacidsofproteins.
- Thebrainbeginstouseketonebodies,as wellsasglucose,forenergy.
- Dependencyonfatsforenergyreleasedecreasesthedemandfor glucose,proteinbreakdownreducesbutdoesnotstop.
- Theliverdegrades**non-essentialproteins**intoglucoseforthebrainina processcalled**gluconeogenesis,**whichinvolves convertingcarbonskeletonsintopyruvateorKrebs'cycleintermediatesandexcretingaminogroupsfromthebodyasurea.

From6weeksto8weeks,amountoffatdecreasesslowlytoverylowlevels, whileamountofproteindecreasesrapidly.

- Thisisbecauseas fatreserves/storesare gettingdepleted,metabolismoffatstoreleaseenergyoccursgraduallyandthe bodybeginstorapidlybreakdown**essentialproteins**,leadingtolossofliverandheart functionastheseorgansarebroken downforfuelmetabolizingproteinsasthemajorenergysource.
- Muscles,thelargestsourceofproteininthebody,arerapidlydepleted.

TYPICAL EXAMINATION QUESTIONS

Agroup ofrats were encouragedtoovereat byfeedingthem with unlimitedsuppliesofprocessedfoodssuchas chocolate andcakes overa three weekperiod.Theserats were called**cafetarian rats**.Overthe same period,anothergroup ofcontrolrats fed onunlimitedsupplies of their naturalfood.

	AVERAGE OVER 21DAYS	
	Cafetarian rats	**Control rats**
Energycontentof foodeaten(kj)	11670	6480
Gaininthe body mass(g)	131	103
Gaininbodyfat(g)	66	40
Energyused(kj)	9440	4690

(i)Whatwas the effectoffeedingthe rats onfoodother thantheir naturalfood?(1½marks)
Theygainedmore bodymass,fatandenergy

(ii)Determine the average gaininmassofthe cafetarian ratsover the controlratsduringthe 21days Average gaininmass= gaininbodymassofcafeterian– gainin bodymassofcontrolrats =131 –103=28g

(iii) State three features ofthe twogroupsofrats whichshouldbekeptthe same: Age,sex,species **(1½marks)**
(iv)Which chemicaloflife inthe rats wouldhavebeenresponsible formostofthe gaininmass?Bodyfat **(½ marks)**
(c)Explainthe observationthatsomepeople eat enormousamounts offoods withoutputtingonweightwhere as others become over-weightonquite smallfoodintake: Weightgaindoes notonlydependonfoodintake,butonotherfactors likegeneticmakeup.
(d)Usingevidence fromthedata,explainwhycafetarianrats were able togainmore weightthancontrol rats. (2marks)
The difference betweenthe energy contentof foodand energyusedis higherincafetarianrats;sounusedfoodhadto be convertedtofat
(e)Whywere controlrats necessaryinthis experiment?Forcomparison ofresults **(1mark)**

FEEDINGEXPERIMENTSILLUSTRATINGTHEIMPORTANCEOFVITAMINSINNORMALDIETARIES

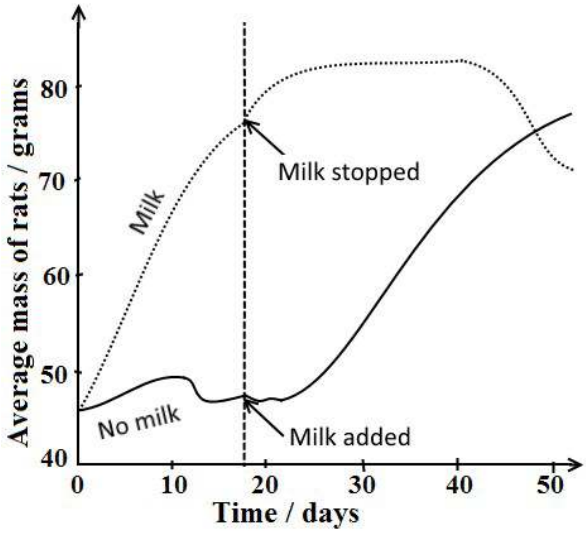
Inhisinvestigationsexploringtherelationshipbetweendiet and growthinrats,**FrederickGowlandHopkins**foundthata diet consistingofprotein,salts,fats,andcarbohydrates**couldnotalone** supportgrowth.

EXPERIMENT

Twogroupsofyoungratswereused.
GroupAwerefedona dietofpurifiedcasein,starch,glucose,lard, mineralsandwateronlyforthefirst18days.
GroupBwerefedona dietofpurifiedcasein,starch,glucose,lard, mineralsandwater**plus**anextraof3cm^{3}of milkdailyforthefirst 18days.
After18daysmilkwasgivento groupAratsandremovedfrom groupB'sdiet.

OBSERVATIONS

GroupA ratsincreasedin massgraduallyfrom0 dayto10days, massdecreasedgraduallyuntilabout12days,massremained relativelyconstantupto22days,then massincreasedrapidlyfrom about22daysto50days



HETEROTROPHICNUTRITION

GroupB ratsincreasedrapidlyinmassfrom0 dayto18days,then graduallyincreasedinmassfrom18daystoabout23 days,stoppedgrowingfromabout23daysto40daysandgraduallydecreasedin mass/lostweightthereafter.

CONCLUSION: Hopkins'sexperimentsrevealedthat,to grow,animalsneededsmallamountsofothersubstanceshecalled **"accessoryfoodfactors"**-nowknownas**vitamins**.

EXPLANATION
GroupAratsresumedgrowthandincreasedin weightafter18dayswhile**groupB** ratsstoppedgrowingandlostweightafter18 days.Whilethe3$cm^3$of milkhadaninsignificantfoodvalueintermsof carbohydrate,fat,proteinandminerals,the milkcontains anextranutrientwhichtheratsneededtobeable to growanddevelop.

Whyitwasnecessaryto transfermilkfromgroupBto groupA halfwaythroughtheexperiment?
Toensurethatallgroupsof ratsaresubjectedtoidenticalconditionse.g.feedingthemonidenticalfood soastoestablishthe effect of milkon growthwhileeliminatingthepossibilityof otherfactorsbeingresponsibletheobserveddifferencesin resultse.g.choice of rats in onegroup(groupA)mayhavebeenmoresicklythanthosein groupB etc.

Whyfeedingratsononetypeof protein(casein),nota variety is ruledoutasa possiblecauseofgrowthstoppageandweight loss?
Althoughproteinsareessentialforgrowthandtherearedifferenttypes, proteinsarehydrolysedin thebodyinto differentamino acids,andthebodyis ableto makesomeaminoacids foritself.Thereforeeventhough theratswereonlygettingcaseinthiswas enoughto nothavean effectongrowth.

Whywhilea dietof proteinaloneis sufficientforyounganimals,itis inadequateforadults?
Muchas milkcontainsall thenutritionalrequirementslikeprotein,carbohydrates(lactose),lipids,mineralsalts,vitaminsand water,someamountsmaybe nutritionallyinsufficientto meetthemetabolicdemandsofadults.
Somepeoplewhoarelactoseintolerantcan'tdigestthe mainsugar(lactose)in milk.Innormalhumans,productionoflactase enzymethatdigestslactosestopsbetweenagesoftwoandfive years,whichwouldresultin insufficientATPproduction.

NUTRITIONINCARNIVORESANDHERBIVORES
(a)Carnivorousanimals:areeither**predators**or**scavengers**whosedietconsistsof mainlyfleshobtainedfrom**preys**.
(i)Predator:Ananimalthathuntsandkills animalsforfood.
(ii)Prey:Ananimalthatis huntedandkilledforfood.
(iii)Scavenger:Ananimalthateatsdeadanimals,butdoesn'tkill them.
(b) Herbivore:An animalwhosedietis mainlyvegetation
(i)Grazers:Mainlyfeedon grass
(ii)Browsers:Mainlyfeedonleavesof shrubsandtrees

	Carnivore	**Herbivore**
Adaptationsfor finding and capturing prey (**carnivores**) or grazing/ browsing (**herbivores**)	● Well-developedsense ofsmellforlocating prey ● Fastmovingtooutpace andcapture prey ● Well-builtbodytomanipulateandcapture prey. ● Verysharpclawsforgripping andkillingprey. ● Keeneye sightforlocating preyfroma distance ● Footpads enable stealthmovementtoambushprey. ● Long,stickytongue forreachingdistantpreye.g.toads. ● Elongatedcanines for diggingtuppreye.g.walrus	● Upperjawlacks incisors to provide a hardpadagainst whichlowerincisors press andcutgrass. ● Tongueis highlymuscularformanipulatingfood during chewing.
Adaptationsfor ingestingthe food	● Sharppointed canines fortearingthe fresh of prey ● Flatmolars tocrushprey ● Incisorspointedfor nipping and biting. ● Carnassialteethpresentforshearingflesh. ● Upperjaw widerthanlowerjawtofacilitate shearing. ● Up-and-downjawactiononly prevents lateral movement hence reducingthedanger ofdislocation ● Powerfuljaw muscles provide muchforceforchewing	● Molarsandpremolars areridgedformaximum grindingofhardcellulosematerials. ● Molarsandpremolars have large surface areafor maximumgrindingofthe hard cellulosematerials. ● Articulationoflowerjawpermits lateralmovementto enable maximumgrindingof food. ● Well-developedjaw muscles provide muchgrinding powerforcrushing cellulosematerials. ● Betweenthe frontandcheekteeth,there's a gap called diastemaforseparatingcrushedgrassfrom uncrushedgrassforeffective chewing.
Adaptationsfor digestingthe food	● Nocellulose indiet hence less developedcaecumand appendix toreduce onbody weighttoenable fast running. ● Relativelyshortalimentary canalreduces weight,since diet is entirelyprotein.	● Ruminantstomachs arefourchamberedtoderive maximumnourishmentfrom grass. ● Mutualisticbacteria incaecumandappendix enable chemical digestion ofcelluloseintoglucose. ● Relativelylong alimentary canalto digestvegetation

HETEROTROPHICNUTRITION

DIFFERENCESBETWEENCARNIVORESANDHERBIVORESRELATEDTO NUTRITION

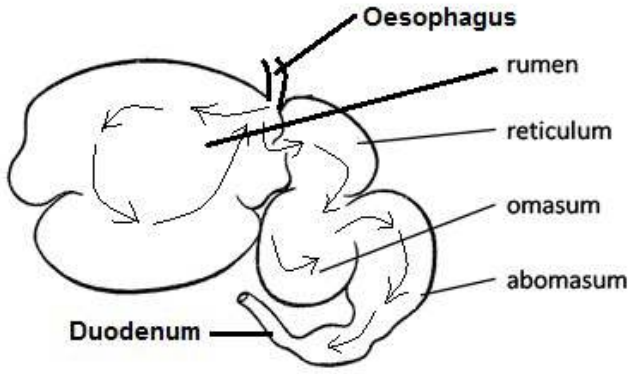
Carnivores	Herbivores
● Closedpulpcavityinteeth	● Openpulpcavityinteeth
● Upperjawincisorspresent	● Upperjawincisorsabsentinmostherbivores
● Caninespresentandwelldeveloped	● Caninessmallorabsenttocreatea diastema
● Carnassialteethpresent	● Carnassialteethabsent
● Cheekteethpointed	● Cheekteethflattenedwithenamelridgesand dentinegrooves
● Articulationoflowerjawpreventslateralmovement	● Articulationoflowerjawpermitslateralmovement
● Relativelyshortalimentarycanal	● Relativelylongalimentarycanal
● Nocellulosedigestion	● Cellulosedigestionoccursincaecum

EXAMPLESOFSYMBIOTICASSOCIATIONSINANIMALS

● **Symbiosis:**Ecologicalrelationshipbetweentwoormoreorganismslivingtogetherwithsomeformoffeedingrelationship.
● **Mutualism:**Closerelationshipwheretwoorganismsof differentspeciesdependoneachother forreciprocalbenefit,without anyharme.g.pollinationflowersbyinsects,**Trichonympha**and**termites,**cellulaseproducingbacteriaandherbivores,etc.
● **Commensalism:**Looserelationshipinwhichtwoorganismsofdifferentspecieslivetogether,onlyoneorganismbenefitswhile theotherremainsunharmede.g.seaanemoneandclownfish.
● **Parasitism:**Closerelationshipbetweenorganismsof differentspeciesin whichoneorganismcalled**parasite**obtainsnutrients fromandharmsalargerlivingorganismcalledhost.

DIGESTIONINRUMINANTMAMMALS

Ruminants:arethemammals,whichhavea 4-chamberedstomachforthedigestionofplantbasedfood.
Ruminationinvolvesregurgitationoffermentedgrassknownascud,chewingandre-chewingitagaintofurtherbreakdown plantmatterandstimulatedigestion.
Ruminatingmammalsincludecattle,goats,sheep,giraffes,deer,camels,antelope,etc.
Four-chamberedstomachshowingfoodmovementduringfeeding



1. Rumen(Paunch): Bacteriaandprotozoain therumen secrete**cellulaseenzyme**whichbreaksdowncelluloseinto glucosewhichundergoesfermentationtoform **organic acids**,**carbondioxide**and**ethane**.Thefermentationprocess producesheatthat keepsruminantswarm.

2. Reticulum(Honeycombbag): Hereanyforeignobjects that mayhavebeenaccidentallyswallowedwithfoodsettle outinthe**honeycomb**structureof thereticulum'swalls. Reticulumis sometimescalled**"hardwarestomach".**

3. Omasum(Psalterium/Manyplies): Absorbswaterfrom foodandalsoabsorbsmorenutrientscalledvolatilefatty acidsthat supplyruminantswithenergy.

4. Abomasum(Reed/ Truestomach): Here,thefoodparticlesaredigestedbyhydrochloricacidinthesamewayitoccurs inhumanstomachs.Theremainingparticlesarethenpassedontothesmallintestinewheremostofthenutrientsare absorbedbythebodyandmadeavailabletotheruminant.

CELLULOSEDIGESTIONINTERMITES

Gutsofwood-eatingtermitescontainamicro-organismcalled**Trichonympha,**whichsecretes**cellulaseenzyme**todigest celluloseinwood.Thetermiteabsorbssomeoftheproductsofdigestion(**glucose**),while **Trichonympha**getssheltered.

CELLULOSEDIGESTIONINRABBITS(NONRUMINANTS)

Thecaecumandappendixofarabbitcontainbacteriathat secrete**cellulaseenzyme**fordigesting**cellulose**into**glucose**.The herbivoregains**glucose**whilethebacteriaget**shelter**.
Intheprocessdescribedas**coprophagy(coprophagia)**,rabbitseatownfaecalpelletswhiledungbeetlesfeedoncowdung toenableabsorptionofglucoseattheileum.

PARASITISM

Closerelationshipbetweenorganismsofdifferentspeciesinwhichoneorganismcalled**parasite**obtainsnutrientsfromand harmsa largerlivingorganismcalledhost.

Challenges/Dangersfacedbyectoparasites	Challenges/Dangersfacedbyendoparasites
● Failureto clingonthehosttoavoidbeingdislodged. ● Failuretoobtainnutritivemoleculesfromthe host. ● Failuretofindtherighthostfordispersaltotheirfinalhost	● Failuretopenetratethe host ● Failuretoobtainnutritivemoleculesfromthe host. ● Destructionbythedigestiveenzymesandimmune responsesofthe hosts. ● Completeeliminationorextinction. ● Fluctuatingenvironmente.g.lowoxygentensions,excess heat,soluteconcentration,darknessetc. ● Failuretofindtherighthostfordispersaltotheirfinalhost

GENERALADAPTATIONSOFPARASITES

Structuraladaptations	Physiologicaladaptations	Reproductiveadaptations
● Possessionofpenetrative devices for host entrye.g.fungalhaustoria,cuttingteethin hookworms*Ancylostomaduodenale*) ● Possessionof nutrientsuckers e.g.leech ● Developmentofdigestive-resistantouter covering toavoid host's enzymeattacke.g. *Ascaris*and*Taenia*etc. ● Camouflagingmorphologytoincrease survivalchances e.g. brownticks onbrown cattle. ● Possessionofspecialisedmouthpartsin some ecto-parasites tosuck hostse.g.sharp stylets inaphids andtsetse flies. ● Possessionofspecialisedhaustorial structuresinCuscuta (Dodder plants)for obtaining nutrients fromthe host ● Degenerationofnon-essentialorgans e.g. nofeedingorgans,nolocomotoryorgans, noalimentary canaltoreducebodysize and fitinintestines /bloodvesselsandfor reducing energyexpenditureonsuch organs forexample*Fasciolahepatica* (liverfluke), tape worm, hookwormetc.	● Productionofenzymestodigest the host's tissuesduring penetrationinto the host e.g.fungiandplasmodium ● Productionofanticoagulantsby blood feedingparasitic animals suchas mosquitoes andtickstoavoidbloodclotting duringfeeding. ● Highlytoleranttofluctuating environmente.g.anaerobic respirationin areas oflowoxygentensions, high temperatures, darkness and pH changes in places where theylivee.g.most endoparasites. ● Rapidmeans ofescapewhichincreases theirchances ofsurvivale.g.fleasand mosquitoes. ● Productionofmuchmucusforresisting digestion byhost's enzymes. ● Someendoparasitesproduce chemicals to protectthemselves against the immune responseofthehost.	● Someare hermaphrodites withthe ability tocarryoutselffertilisationtoincreasethe rate ofreproduction e.g.*Fasciola*,*Taenia*. ● Someasexuallyreproduce forhighrate ofreproductiontoavoidextinction. ● Releaseofsexuallymature forms ofthe parasites as free livingorganismse.g.in some parasitic animals suchas the horse hairworms ● Productionoflarge number ofinfective agents suchas eggs,cysts,andspores which increase survivalchances toavoid extinctione.g.tape worms. ● Developmentofreproductive bodies that are highlyresistantwhen outof the hostto survive adverseconditions e.g.cysts in amoeba,fungalspores,etc. ● Useofintermediate host (vector)fortheir transfertoprimaryhost e.g. plasmodiumin female anophelesmosquitotoman. ● Someparasiteslocalisethe strategic pointsfor propagationtothenext host e.g. HIVwhichcauses AIDSislocalisedinthe sexorgans. ● Someusehereditarytransmissionfor increasedspreading i.e.some parasites infectthe ovaryof primaryhostwhichlays parasite infectedeggs.

COMMONPARASITES

Definitivehost(finalhost/primaryhost):a hostinwhichaparasiteattainssexualmaturity.

Intermediatehost(secondaryhost):a hostin whicha parasitepassesoneormoreofitsasexualstages;usuallydesignated firstandsecond,ifthereismorethanone.

Phylum/division	Parasite	Host		Effectonprimaryhost
		Primary	Secondary	
Platyhelminthes	*Fasciolahepatica*(liverFluke)	Sheep,cattle	Pondsnails	Liverrot
	Schistosomamansoni(bloodfluke)	Humans	Pigs	*Schistosomiasis*(Bilharzia)
	Taeniasolium(Porktapeworm)	Humans	Pigs	**Taeniasis;**Anaemia,Weightloss Abdominal(intestinal)pain
	Taeniasaginata(Cattletapeworm)	Humans	Cattle	
Nematoda	*Ascarislumbricoides(*roundworm*)*	Humans	None	*Ascariasis,*Intestinalobstruction
Spermatophyta (Seedplants)	Dodderplant(Cuscuta)	Nettle,clover, tomato,potato	None	Damagestissuescausing secondaryinfections
Spermatophyta (Seedplants)	*Striga*sp.(witchweeds)	Maize,millet, groundnut,etc.	None	Stuntedgrowth,wilting,and chlorosis
Heterokontophyta	*Phytophthorainfestans*	Tomatoleaves	None	Lateblightofpotatoandtomato (Blackleafspots,tuberrot)
Arthropoda	*Plasmodiun*	Female Anopheles	Humans	Malariafever

HETEROTROPHICNUTRITION

LIFECYCLESOFSELECTEDPARASITES

Lifecycleof*Ascarislumbricoides*(roundworm)	**Adaptationsof *Ascaris*toparasiticlife**
● Adultfemaleinlumenofileumlaysabout200,000eggsdaily, whicharepassedoutinfaeces. ● Fertileeggs**embryonate**andbecomeinfectiveafter about**three** weeks,(***optimumconditions:***moist, warm,shadedsoil). ● Onbeingswallowedbyhumans,eggshatchintolarvae,which invadeintestinalwall,andarecarriedviatheportal,thensystemic circulationto lungs. ● Larvaematurefurtherinlungs(10to14days),penetrate alveolar walls,ascendthebronchitothethroat,andareswallowedintogut. ● Uponreachingtheileum,theydevelopintoadult worms. ● Between2 and3monthsarerequiredfromingestionoftheinfective eggsto **oviposition**bytheadultfemale. ● Adultwormscanlive1 to2years.	● Degenerationof structuresreducesspace occupied. ● Possession ofdigestive-resistantcuticleresists destructionbythehost'senzymes. ● Abilitytopositionitselfina habitat whereit gainsmaximumnourishment. ● Eggshaveprotective/resistantshellwhichis theirmaininеffectiveandresistantstage. ● Toleranceto oxygendeficientenvironment ● Abilitytocopulatewithintheintestinesfollowed bythelayingof verymanyeggsincreasessurvival chances.

Lifecycleof*Taeniasp.(*Tapeworm)	**Adaptationsof*Taenia*toparasitism**
● Humansarethe definitivehostsfor*T.saginata*and*T.solium*. ● Eggsor **gravidproglottids**arepassedoutinfaeces; ● Cattle(*T.saginata*)andpigs(*T.solium*)becomeinfectedbyingestingvegetation contaminatedwitheggsor gravidproglottids. ● Intheanimal'sintestine,the**oncospheres**hatch,invadetheintestinalwall,and migratetostriatedmuscles,wheretheydevelopinto **cysticerci**.Acysticercuscan survivefor severalyearsintheanimal. ● Humansbecomeinfectedbyingesting rawor undercookedinfectedmeat. ● Inthe humanintestine,thecysticercusdevelopsover2 monthsintoanadult tapeworm,whichcansurviveforyears. ● Adulttapewormsattachandstayin smallintestinebytheirscolex. ● Theadultsproduceproglottidswhich mature,becomegravid,detachfromthe tapeworm,andmigratetotheanusorarepassedinthe stool(approx6perday). ● Theeggscontainedinthegravidproglottidsarereleasedaftertheproglottidsare passedwiththefeces.	● Hashooksandsuckersforholding tightlyontoileumwall. ● Flattenedbodyincreasessurface area forabsorbingitshost'sdigested food ● Degenerationof structuresreduces onspaceoccupied. ● Laysmanyeggstoincrease survival chances. ● Hooksforboringthroughthe gutof the host ● Eggshavea thickshellforresisting enzymedestruction. ● Beinghermaphroditeincreases reproductiverate

Hygienicpracticesforcontrollingendoparasites

● Avoideatinginfectedundercooked meat
● Throughproperdisposalofsewagewhichpreventsthesewormsfromspreading
● Throughcookingmeatthoroughlyforexampleprolongedheatingdestroysthetapewormbladders
● Regulardewormingtoflush thewormoutofthewalloftheintestinesinfaeces.
● Throughregularmeatinspectionbeforeitisconsumedbyman.
● Byprohibitionofthedischargeofrawsewageintoinlandwatersandseas.

PLASMODIUM–THEMALARIACAUSINGPARASITE

Thereareapproximately156namedspeciesof*Plasmodium*whichinfectvariousspeciesofvertebrates.Fourspeciesare consideredtrueparasitesof humans,astheyutilizehumansalmostexclusivelyasa naturalintermediatehost:*P.falciparum, P.vivax,P.ovale*and*P.malariae*.

LIFECYCLEOF*PLASMODIUM*

● Malariaparasitelifecycleinvolves**humans**as**intermediate**hostandadultfemale**anopheles**mosquitoas **definitive**host.
● Duringa bloodmeal,amalaria-infectedfemale***Anopheles***mosquitoreleases**sporozoites**intohumanblood.
● Onreachingtheliver,**sporozoites**infectlivercellsandmatureinto**schizonts**,whichruptureandrelease **merozoites**.
● Afterthisinitialreplicationintheliver(**exo-erythrocyticschizogony**),theparasitesundergoasexualmultiplicationinthe erythrocytes(**erythrocyticschizogony**).
● **Merozoites**infectredbloodcells,theringstage**trophozoites**matureinto**schizonts**,whichrupturereleasing**merozoites**.
● Someparasitesdifferentiateintosexual**erythrocytic**stages(**gametocytes**).
● Bloodstageparasitesareresponsiblefortheclinical manifestationsofthedisease.
● Thegametocytes,male(**microgametocytes**)and female(**macrogametocytes**),areingestedbyan *Anopheles*mosquito duringa blood meal.
● Theparasites'multiplicationinthemosquitois knownas the**sporogoniccycle**.

HETEROTROPHICNUTRITION

- Whileinthemosquito'sstomach,the**microgametes**penetratethe**macrogametes-generatingzygotes**.
- **Zygotes**becomemotileandelongated(ookinetes),invadethemidgutwallofthemosquitotodevelopinto **oocysts**.
- **Oocysts**grow,rupture,andrelease**sporozoites**,whichenterthemosquito'ssalivaryglands.
- Inoculationofthe **sporozoites**intoa newhumanhostperpetuatesthemalarialifecycle.

LIFECYCLEOF*PHYTOPHTHORAINFESTANS*

- *Phytophthora*producetwokindsof sporei.e.diploid**oospores**,formedsexuallyfromfusionof haploid**antheridia**and **oogonia,**and**chlamydospores**formedasexually.Bothtypesofspore havethickcellwallsfor survivingharshconditions.
- Undercoolwetconditions,*Phytophthora*spores(**oospores**or**chlamydospores**)germinatetoformhyphaeordirectly producesporangia.
- Sporangiareleasefreeswimming**biflagellatedzoospores,**whichtravelinmoistureatthesurfaceofleaves,andinsoil.
- Onreachingplantrootorleafsurfacea zoosporeformsacyst.
- Theencystedzoosporethengerminatestoformhyphaeonthe host surface,whichpenetratesplantleaforroottissuesto absorbnutrients.
- After*Phytophthora*infectstheplant,it produces**sporangia**and**zoospores**whichfurtherinfectothertissuesofthesame plantor nearbyplants.
- Sexualreproductionoccurswhenpositiveandnegativematingtypesarepresent.
- **Haploidnuclei**of**antheridium**and**oogonium**fusetogetherwhenthe**antheridium**entersthe **oogonium**toforma **diploidoospore**,whichdevelopsintoa**sporangium**andthecyclewillcontinueasiswouldasexually.

TYPICALEXAMINATIONQUESTION

1.Thebloodfluke,*Schistosomamansoni*isanimportanthelminthparasitethatresideswithinthemesentericveinsofits definitehost.Experimentsweredoneandthe graphsinfigures1, 2 and3belowshowtheeffectoftemperature,lightand salinityonthehatchingoftheeggsof*Schistosomamansoni.*At hourlyintervals,thenumberofeggshatchingwas determinedandexpressedasapercentageoftotalhatch.

Figure1showstheeffectoftemperatureonhatching.After4hoursoftreatmentatthetemperaturesshown,thesamples wereincubatedfora furthertwohoursat28^{0}Catconstantlightandsalinity.

Figure2showstheeffectoflightonhatching.One samplewas keptinlightfor6hourswhileasecondsamplewasfirst kept inthedarkfor3 hours,thentransferredtolight for3 hoursatconstanttemperatureandsalinity.

Figure3showstheeffectofsalinityon hatchingaftertreatmentfor6 hoursatconstanttemperatureandlight(percentageof totalhatchisexpressedasa % ofnumberofeggshatchingin0%saline).

Figure1

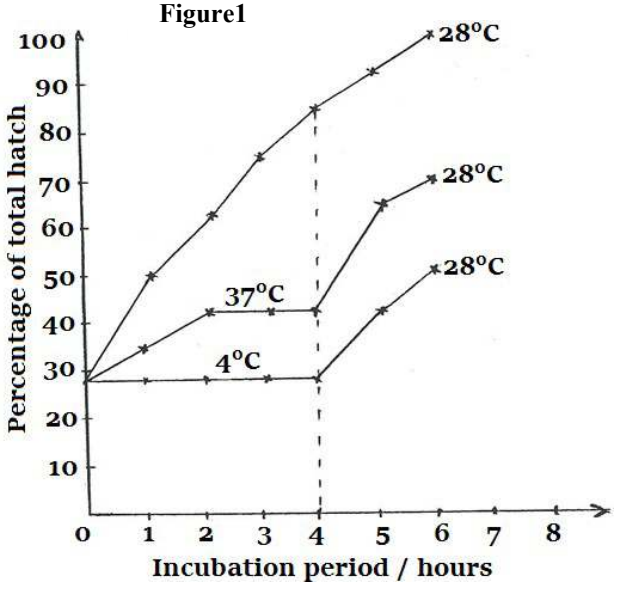
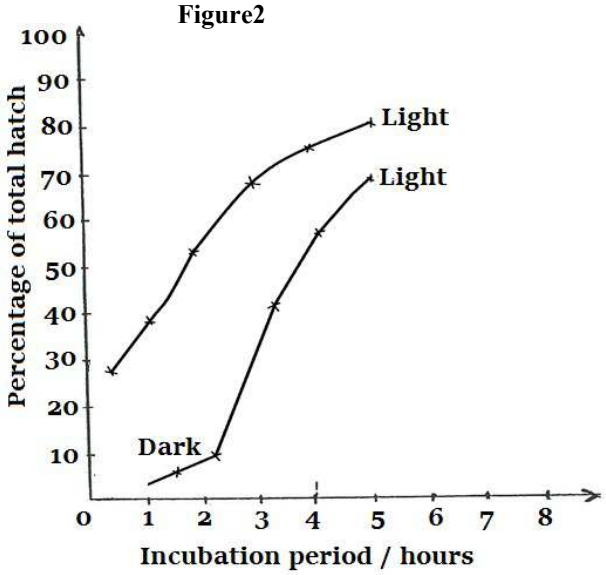


Figure2



HETEROTROPHICNUTRITION

Theeggskeptin0.8%salinefor6 hoursasinfigure3 abovewereremoved,dividedequallyinto fourlotsandplacedina rangeof salinesolutionsfora further6 hours.Theresultsareasshownin**table1**below:

Figure3

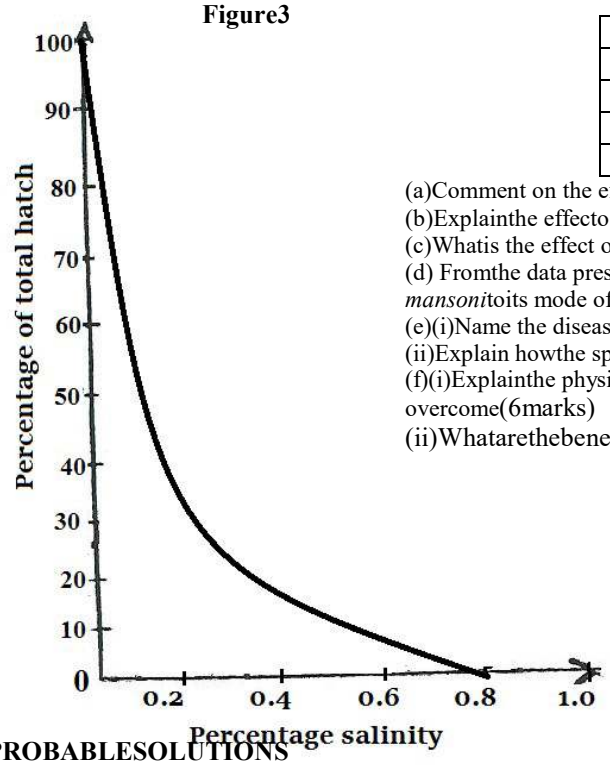


Table1

Salinity(%)	Totalhatchafter6 hours(%)
0.0	100
0.2	40
0.4	20
0.6	8

(a)Comment on the effect oftemperature on hatchingof*Schistosomamansoni*eggs.(7marks)
(b)Explainthe effectoflight onpercentage hatch ofeggs.(6marks)
(c)Whatis the effect ofsalinityonpercentage hatchofthe eggs? (4marks)
(d) Fromthe data presentedandrestrictingyourselftoeggstage only, discuss adaptationsof*S. mansoni*toits mode oflife.(10 marks)
(e)(i)Name the disease causedbythis bloodfluke toman(1mark)
(ii)Explain howthe spread of disease can be controlled (4marks)
(f)(i)Explainthe physiologicalchallenges facinghumanendo-parasites andhowtheyare overcome(6marks)
(ii)Whatarethebenefitsofparasiticnutritiontoorganismsthatexhibitit? (2marks)

PROBABLESOLUTIONS

(a)Commentontheeffectoftemperatureonthehatchingoftheeggsof*Schistosomamansoni.*(7marks)

- Atconstantlight,salinityandtemperatureof28^{0}C;✓eggshatchedrapidly;✓tocompletion;✓
- At highertemperatureof37^{0}Candlowertemperatureof4^{0}C;✓hatchingisjustslightlystimulated(greatlyinhibited);✓
- Restoringtemperaturefrom37^{0}Cand4^{0}Cto28^{0}C;✓stimulatesrapidhatching;✓

(b) Explaintheeffectoflightonthepercentageofthetotalhatchoftheeggs. (6marks)

- Thelotofeggsexposedtolighthatchrapidlytocompletion;✓becauselightstimulates/activatesa hatching substance/enzyme;✓whichdigests/breaksdowntheeggmembranestoenableemergenceoflarvae;✓
- Darknessgenerallyinhibitshatching;✓becausethe hatchingsubstanceisinactive;✓howeverinthiscasea littlehatching occurredinthedarkprobablyduetoexperimentalerrorswhichresultedinsomeilluminationofeggs;✓

(c)Whatistheeffectof salinityonthepercentageoftotalhatchoftheeggs? (4marks)

- Infreshwater(at0%salinity) alleggshatched;✓at0.8%salinitynoeggshatched(hatchingwasinhibited);✓increase insalinity;✓causesa rapiddecreaseinhatching;✓

(d)Fromthedatapresentedandrestrictingyourselftotheeggstageonly,discussthe adaptationof*S.mansoni*
(Formoreinformation,seeMBVRoberts;functionalapproach,pg.552-553)

- Inthemesentericveinsofthe mainhostof*Schistosomamansoni*;✓thereistotaldarknessandtemperatureisabout37^{0}C; ✓bothofwhichpreventhatchingofeggsinto miracidia(larvae)in man;✓becausetheywoulddie; ✓
- Whenfaeceswitheggsreachfreshwaterbodies;✓wherethereismuchillumination(light),lowertemperatureandvery lowsalinity;✓allofwhichfavourrapidhatchingofeggs;✓manylarvae(miracidia)areformed;✓whichinfectwater snails;✓(intermediatehost)and formmorelarvae(cercariae)thatinfectman;✓

(e)(i)Namethediseasecausedbythisbloodfluketoman (1mark)

Bilharzia(Schistosomiasis);✓

(ii) Explainhowthespreadofthediseasecanbecontrolled(methodanditspurpose=01markx4)

- Disposaloffaecesinlatrines/toiletstoavoidtheircontactwithfreshwaterbodies;✓
- Dewormingto killadult wormsin humans; ✓
- Wearinggear(boots/shoes)thatshield/protectfeetfromlarvae(cercaria)infection;✓
- Usemolluscidesto killlarvae's(miracidia)intermediatehosts(adultsnails)inwater;✓
- Biologicalcontrolin whichsomefishandducksareintroducedinwatertofeedonlarvae/snails;✓

HETEROTROPHICNUTRITION

(f)(i) Explainthephysiologicalchallengesfacinghumanendo-parasitesandhowtheyareovercome
(Any3, @challenge–1 mark,howovercome–1mark= 06marks)

Challenge	Howit isovercome
◦ Digestionbythe host'senzymes;✓	◦ Developmentofthickcuticle/secretionofinhibitorysubstances/mucus✓
◦ Osmoticchangesinthe habitat;✓	◦ Increasedchemosensitivityinorder toequilibratewithhost✓
◦ Inhibitorychemicalenvironment;✓	◦ Secretionofanti-inhibitorysubstances;✓
◦ Anaerobicconditions;✓	◦ Abilitytorespireanaerobically;✓
◦ Attackbyhost'simmunesystem;✓	◦ Developmentofprotectivestructuresagainstthehost'simmuneattack✓

(ii)Importanceofparasiticnutrition(2marks)
◦ A varietyofnutrientsrequiredfor growth,developmentandbodymaintenancemaybeobtainedfromone meal
Lessdevelopmentofdigestivesystemsince mostnutrientsobtainedarefully/partiallydigested.

SAPROTROPHISM(SAPROTROPHICNUTRITION)
Theprocessofobtainingsolubleorganicsubstancesfromextracellulardigestionofdeadordecayedorganicmatter.
Saprotroph:Anorganismthatabsorbssolublenutrientsfromextracellulardigestionofdead/decayingorganicmatter.

EXAMPLESOFSAPROTROPHS
(i) Saprobes:fungilike mushrooms,yeastsandmoulds
(ii) Saprophytes:**saprotrophicplants**e.g.sugarstick, gnomeplant,Indian-pipeand**putrefyingbacteria**whichconvert complexorganicsubstancesintosimplercompoundse.g.**Zygomonas**bacteriumferments**glucose**producing**alcohol,lactic acidandcarbondioxide**,**Clostridiumaceto-butylicum**forms**butylalcohol**from**carbohydrates**,**Lactobacillus**converts **sugars**into**lacticacid**.
(iii)Saprophages:Animalscavengers,suchasdungbeetlesandvultures

DESCRIPTIONOFSAPROTROPHISMINFUNGALMOULDLIKEMUCOR/RHIZOPUS
● Undersuitableconditions(moisture/water,oxygen,neutral/mildlyacidicpH,temperatureofabout25 °C)the saprotroph secretesdifferentenzymesintothe deadanimal/plantbody;proteases,lipases,carbohydrasese.g.amylasewhichbreakdown insolublecomplexorganicsubstancesintosimplesolublesubstancesas follows:
-**Proteases**breakdown**proteins**into**aminoacids**
-**Lipases**breakdown**lipids**into**fattyacids**and**glycerol**
-**Carbohydrases**e.g.**Amylases**breakdown**starch**into**maltose**/**simpledisaccharides**
● Theendproductsofextra-cellulardigestionsuchas**fattyacids**and**glycerol,glucose,aminoacids**plusothernutrients like**vitamins**e.g.**thiamine**and**ions**e.g.**potassium,phosphorus,andmagnesium**are re-absorbedintothehyphathrough thecellwallby**endocytosis/simplediffusion/facilitateddiffusion/activetransport**andpassedonthroughoutthe myceliumcomplextoenablegrowthand repair.

COMPARISONOFSAPROPHYTESWITHPARASITES
Similarities
Both:**(1)** are heterotrophs**(2)**absorbsolublefood **(3)** havesimpledigestivesystems**(4)** havesexualandasexualphasesin theirreproduction**(5)** producelargenumbersofoffspring.

Differences

Parasites	Saprophytes
● Energyderivedfromliving organisms	● Energyderivedfromdead organisms
● Manystagesinlifecycle	● Usuallyasingleadultstage,with sporesinclusive
● Veryspecifictotheir host	● Usea varietyoffoodsources
● Nutritionallyhighlyadapted	● Simplemethodsofnutrition
● Mostplantandanimalgroups haverepresentatives	● Almosttotallyfungiandbacteria
● Mostareaerobic	● Anaerobicandaerobic

IMPORTANCEOFSAPROPHYTES
● Recyclingof materialse.g. carbon, nitrogen,phosphorus
● Brewingandbakinge.g. yeast (S*accharomyces*)
● Makingantibioticse.g.Penicillin
● Decompositionofwastese.g.sewage
● Production ofyoghurtandcheese
● Foodsourcee.g. mushrooms
● Industrialapplicationse.g.leather tanning,productionofvitamins,etc.