

# 6 Human physiology

## 6.1 Digestion and absorption

### Starch digestion in the small intestine

- starch digestion illustrates catalysis, enzyme specificity, membrane permeability
- starch is a macromolecule composed of many  $\alpha$ -glucose monomers
- cannot pass through membranes and must be digested in the small intestine for absorption
- reactions in digestion of starch are exothermic but happen at very slow rates without a catalyst
- amylase begins the digestion of amylose and amylopectin; most occurs in the small intestine catalyzed by pancreatic amylase
- any 1,4 bond can be broken down by amylase, so amylose is broken down into maltose and maltotriose; 1,6 cannot be broken down by amylase
- fragments remaining of amylopectin are called dextrans
- digestion of starch is completed by three enzymes in membranes of microvilli: maltase, glucosidase, dextrinase digest maltose, maltotriose, dextrans to glucose
- glucose is absorbed into villus epithelium cells by co-transport with sodium ions, then moves by facilitated diffusion into fluid in interstitial spaces in the villus
- close capillaries in epithelium ensure that glucose only has to travel short distance
- capillary walls consist of a single layer of thin cells with pores between adjacent cells
- blood carrying glucose and other products of digestion flows through villus capillaries to venules in sub-mucosa of wall of small intestine; blood in venules is carried via hepatic portal vein to the liver
- excess glucose can be absorbed by liver cells and converted to glycogen for storage

### Modeling the small intestine

- to make a model of the small intestine, a dialysis tube is taken; suitable mixture is taken and knotted at both ends
- can be used to model the need for digestion or membrane permeability

## 6.2 The blood system

### William Harvey and the circulation of blood

- William Harvey is usually credited with the discovery of the circulation of blood
- toured Europe to show experiments and this makes it generally accepted
- demonstrates that flow is unidirectional with valves that prevent backflow, rate of flow would not allow blood to be digested and so must be recycled and return to the heart, heart pumps blood in arteries and it returns in veins, predicts presence of fine vessels linking arteries to veins
- blood capillaries are too small to be seen and the microscope was only invented after his death

### Atherosclerosis

- development of fatty tissue (atheroma) in the artery wall adjacent to the endothelium
- low density lipoproteins (LDL) containing fat and cholesterol accumulate which attracts phagocytes: these engulf them by endocytosis and grow very large
- artery wall bulges into the lumen, narrowing it and impeding blood flow
- in older people it can get advanced, goes unnoticed and blocks a major vessel and the tissues it supplies become comprised
- coronary occlusion is narrowing of arteries that supply blood containing oxygen and nutrients to the heart muscle; lack of oxygen (anoxia) causes pain and impairs ability to contract: heart beats faster to maintain blood circulation
- factors increasing risk: LDL, chronic high blood glucose concentrations, chronic high blood pressure (smoking), consumption of trans fats, infection of artery wall

### The cardiac cycle

- pressure changes in atrium, ventricle and aorta happen in following steps
- atria contract: rapid but small pressure increase, pumps blood from atria to ventricles through open atrioventricular valves; semilunar valves are closed so blood pressure in arteries drops

- ventricles contract with rapid pressure build up causing atrioventricular valves to be closed; semilunar valves remain closed
- pressure in ventricles rises above pressure in arteries and semilunar valves open and blood is pumped from ventricles to arteries; pressure in atria slowly rises
- semilunar valves close as pressure in ventricles drops below arterial pressure; atrioventricular valves remain closed
- pressure in ventricles drops below pressure in atria and atrioventricular valves open; blood from veins drains into atria and from there to ventricles causing slow pressure increase

## 6.3 Defense against infectious disease

### Coronary thrombosis

- blood clots form in coronary arteries in patients with coronary heart disease
- these arteries branch off from aorta close to semilunar valve; supply oxygen and nutrients to cardiac muscle fibers for cell respiration
- medical name for blood clot: thrombus
- coronary thrombosis: formation of blood clots in the coronary arteries
- if coronary arteries are blocked, part of heart is deprived of oxygen and nutrients: unable to produce sufficient ATP: contractions become irregular and uncoordinated
- heart starts making quivering movements called fibrillation
- atherosclerosis causes occlusion in the coronary arteries; where atheroma develops endothelium of arteries become roughened and artery wall is hardened by deposition of calcium salts; patches rupture causing lesion; all of these increase risk of coronary thrombosis
- risks: smoking, high blood cholesterol concentration, high blood pressure, diabetes, obesity

### Human immunodeficiency virus

- production of antibodies by immune system is complex and includes different lymphocytes
- HIV destroys helper T-cells: consequence is progressive loss to produce antibodies
- in early stages immune system makes HIV-antibodies; if these are found a person is said to be HIV-positive
- HIV is a retrovirus: has genes made of RNA and uses reverse transcriptase to make DNA copies of its genes once in a host cell
- antibody production eventually becomes ineffective
- accumulation of diseases or conditions existing together are called a syndrome
- when the syndrome of conditions is present: acquired immune deficiency syndrome (AIDS)
- AIDS is spread by HIV infection; virus only survives outside of a body for a short time
- infection normally occurs if there is blood to blood contact; sexual intercourse, transfusion of blood, sharing of hypodermic needles

### Testing penicillin

- Howard Florey and Ernst Chain investigate use of chemical substances to control bacterial infections; most promising is penicillin
- develop method for growing the fungus in conditions that stimulate it to secrete penicillin and also methods for producing reasonably pure samples
- penicillin kills bacteria on agar plates; test whether it can control bacteria in humans
- first test it on mice: works; for humans they need larger quantities
- test it on policeman: works but supplies run out and he dies
- proved highly effective against previously incurable infections

## 6.4 Gas exchange

### Antagonistic muscle action in ventilation

- ventilation involves two pairs of opposite movements that change the volume
- inspiration: diaphragm moves down and flattens, ribcage moves up and out
- expiration: diaphragm moves up into a dome, ribcage moves down and in
- antagonistic muscles are needed to cause these movements
- movement of diaphragm: diaphragm itself and abdomen wall muscles
- movement of ribcage: external (inhalation) and internal (exhalation) intercostal muscles

## Causes of lung cancer

- smoking causes 87% of cases; tobacco smoke contains mutagenic chemicals
- passive smoking causes 3% of cases
- air pollution causes 5% of cases; mostly vehicle exhausts and burning of organic matter
- on construction sites, solids in dust form can cause lung cancer
- in many cases it is discovered at a late stage; mortality rates are high; consequences are severe
- if a patient is cured, he will continue to have pain, breathing difficulties

## Emphysema

- healthy lung tissue: bronchioles lead to group of smaller thin-walled alveoli
- emphysema: alveoli are replaced with larger air sacs with a thicker wall: total surface area for gas exchange is considerably lower; lung is also less elastic so ventilation is more difficult
- phagocytes normally prevent infections by engulfing bacteria and produce elastase (protein-digesting enzyme) to kill them
- enzyme inhibitor called alpha 1-antitrypsin (A1AT) usually prevents elastase to digest lung tissue; in smokers the number of phagocytes increases and produce more elastase
- emphysema is a chronic disease and damage is irreversible; causes low oxygen saturation

## 6.5 Neurons and synapses

### Neonicotinoids

- synthetic compound similar to nicotine; bind to the acetylcholine receptor in cholinergic synapses in the central nervous system
- acetylcholinesterase does not break down neonicotinoids, so binding is irreversible: acetylcholine is unable to bind and synaptic transmission isn't prevented
- consequence in insects is paralysis and death: effective insecticides
- not highly toxic to humans: much greater proportion of synapses in mammals and they bind much less strongly to acetylcholine receptors
- mainly used on crops; concerns about beneficial insects (honeybees)

## 6.6 Hormones, homeostasis and reproduction

### Diabetes

- condition where a person has consistently elevated blood glucose levels; presence of glucose in urine; elevated glucose damages tissues, particularly their proteins; impairs water reabsorption from kidney resulting in large urine volume and dehydration
- two main types: type I diabetes and type II diabetes
- type I: early onset, inability to produce sufficient quantities of insulin; autoimmune disease: immune system destroys beta cells in islets of Langerhans
- type II: late onset, inability to process or respond to insulin due to deficiency of insulin receptors or glucose transporters on target cells; risk factors are sugary, fatty diets
- treatment of type I: testing blood for glucose regularly and injecting insulin if it is high or likely to become high (before meals); timing is important as insulin molecules do not last long
- treatment of type II: adjustment of diet; eat multiple times in small amounts rather than a couple of large meals; avoid foods with high sugar content; only eat starch if it is digested slowly

### Leptin and obesity

- attempts to treat obesity in humans by injecting leptin (as in mice experiments)
- volunteers were taken, some with leptin and some with placebo; double blind procedure was used, so neither patients nor doctors knew who had which treatment
- leptin injections caused skin irritation and swelling
- results varied with loss and gain of weight; body mass lost was usually gained rapidly after that
- humans have high blood leptin concentrations but target cells in hypothalamus may have become resistant and do not respond: appetite is therefore not inhibited
- leptin is a short-lived protein and has to be injected several times a day
- leptin was shown to affect development and functioning of reproductive systems

### Jet lag and melatonin

- symptoms are difficulty to remain awake during day and difficulty sleeping during night

- the suprachiasmatic nuclei (SCN in hypothalamus) and pineal gland are continuing to set a circadian rhythm to suit timing of the day and night at point of departure
- jet lag only last for a few days until ganglion cells in retina adjust the SCN to new rhythm
- melatonin is used to prevent jet lag; taken when sleep should begin
- most trials are effective and reduce jet lag

### In vitro fertilization

- natural method of fertilization is in vivo (in the body)
- fertilization can occur outside of the body in controlled laboratory conditions (in vitro)
- used to overcome fertility problems of either male or female parent
- first stage is down-regulation: woman takes a drug that stops pituitary gland to secrete FSH or LH: secretion of estrogen and progesterone stops: suspends normal menstrual cycle
- intramuscular injections of FSH and LH are given to stimulate follicle development; higher FSH concentrations are given so more follicles develop (super-ovulation)
- then follicles are stimulated to mature by injecting HCG and a micropipette is passed through uterus wall to wash eggs out of follicles
- each egg cells is mixed with 50'000 to 100'000 sperm in sterile conditions in a shallow dish
- if fertilization is successful, one or more embryos are placed into the uterus
- extra progesterone is given to maintain the uterus lining
- following pregnancy is no different than that by natural conception

### William Harvey and sexual reproduction

- known for discovery of blood circulation; also pioneered into sexual reproduction
- Harvey tests Aristotle's "seed and soil" (male produces seed, develops into egg and is then mixed with menstrual blood and develops into fetus in mother) using deer which are seasonal breeders and are only sexually active in autumn
- slaughters and dissects female deer during mating season; expects to find eggs in uterus immediately after mating but only finds signs of anything developing only after multiple months
- Harvey's conclusion that fetus does not result from events during coitus is also wrong