(a) To explain the cardiovascular & respiratory changes during pregnancy, their causes, and their consequences.

Cardiovascular changes

- progressive increase in cardiovascular stress as woman heads towards full term
- cause of changes = a new being forming in uterus requiring O2 supply, CO2 removal and all the nutrients to grow and develop normally.

See diagram - Cardiovascular changes in pregnancy (summary)

*By 3rd trimester*

- blood volume increased by 40%
- red cell volume increase by 30%
- plasma volume increases by 50%

-> relative anaemia

- concentration of protein, gamma globulins decrease
- increase in platelets, clotting factors, decreased plasminogen activator and fibrinolytic activity (hypercoaguable)
- oxy-Hb dissociation curve shifts to right from increase in 2,3-DPG
- decrease in TPR c/o placenta acting like a AV shunt + vasodilation in kidney, GIT, heart, breasts & skin.

- Q still increased 33% but in supine position decreased secondary to hypotension from obstruction of IVC & aorta -> fetal asphyxia & distress (aorto-caval compression)
- uterine blood flow goes from 80 to 800ml/min over pregnancy

*Labour*

- pain & apprehension increase Q & SV 45% over pre-labour values
- each uterine contraction increases BP, central blood volume & Q by 20% (auto-transfusion)
- normal blood loss (1) NVD - 500mL (2) C/S - 1L

*Post-partum*

- central blood volume & SV increases owing to emptying of uterus -> relieving obstruction of IVC & aorta.

*Consequences*

- prevent aorto-caval compression: (1) manually displace to left, (2) position patient on left side, (3) tilt delivery or operating pregnancy, (4) use a pillow to elevate patients right buttock and back 15cm.
- drugs causing hypotension (iso, thiopentone, epidural anaesthesia) may aggravate uterine and fetal blood supply.
- epidural venous engorgement -> decreased dose of spinal
- hypercoaguable -> minimises blood loss

**Respiratory changes**

See diagram - Respiratory changes in pregnancy (summary)

- causes of changes: abdominal mass, progesterone action on respiratory center

**Anatomical changes**

Upper airway

- capillary engorgement of mucosa -> swelling of nasopharynx, oropharynx, larynx & trachea

Lower airway

- TV increases 40%
- RR increases 15%
- -> increase in MV by 50%
- decrease in AWR by 35%

(1) **Hyperventilation**

- RR increases by 15%
- hypoxic ventilatory response doubles + increase in slope of PCO2 ventilatory response curve.
- PaCO2 decreases to 30mmHg
- this helps gradient of CO2 clearance by fetus

(2) **Vital capacity**

- increases
- cephalad migration of diaphragm + increase in AP & transverse diameter of chest wall.

(2) **Deadspace**

- alveolar deadspace declines nothing c/o increased Q

(3) **RV & FRC**
- RV decreases by 20%
- ERV decreases (700mL)
- FRC decreases by 500mL
- FRC is below closing capacity in 50% of patients
- pregnant uterus & abdomen sustain diaphragm up against lung base at end of expiration.

(4) O2 consumption

- negligible increase up to 20wks
- increased by 16% at full term
- thus 30% increase in Q is the most important factor in O2 flux in third trimester.
- oxy-Hb dissociation curves -> right c/o increased 2, 3 DPG production

(5) TV & MV

- increase in parallel up to 40% above normal at term.
- no reduction in ventilatory capacity
- closing capacity is inside TV breath

(6) ABG

- PaCO2 32mmHg
- PaO2 105mmHg
- HCO3- decreases

Consequences

- decreased FRC -> decreased apnoic oxygen supply -> desaturate quicker
- increased MV -> need to ventilate at a higher rate
- in supine position: 1/3 of airway close during TV -> atelectasis & V/Q mismatch increases
- airway manipulation harder
- intubation difficult
- increased speed of induction and emergence from inhaled agents

(b) To explain the consequences of the supine posture during pregnancy.

- dynamic airways closure (1/3 of patients) -> increased V/Q inequality
- FRC decreases by 500mL -> decreased apnoic O2 supply
- aorto-caval compression -> hypotension of lower limbs and bubs
- blood shunted from vena cava -> epidural-azygous system -> reduces the size of the epidural & subarachnoid space -> greater systemic engorgement of LA & decreased volume needed (only 2/3rds needed).
(c) To describe the functions of the placenta.

Transport
Immunological
Metabolic
Endocrine

(TIM) -> its like the liver, kidney & the lungs all in one!

Transport
- gas exchange (O2 & CO2)
- delivery of nutrients (glucose, aa, lipids)
- removal of wastes (urea, bilirubin)
- transport of other substances (drugs)
- heat transfer

substances cross the placenta:

(1) diffusion - (most important) -> according to Ficks Law of Diffusion
(2) facilitated diffusion (glucose)
(3) active transport (aa, Ca2+, Fe, iodine & water soluble vitamins)
(4) pinocytosis - large, non-lipid soluble and do not have carrier (globulins, phospholipids & IgG antibodies)

Immunological
- protection of foetus from infection
- protection of foetus from rejection by mother (immunological barrier function) - trophoblast cells do display Class I or II MHC (major histocompatibility complex) proteins thus they cannot present antigen to lymphocytes and cannot be recognised by activated cytotoxic T lymphocytes.

Metabolic
- synthesis of glycogen, cholesterol, FFA's and enzymes

Endocrine
- synthesis of 4 main hormones:

(1) human chorionic gonadotrophin - maintain corpus luteum during early pregnancy
(2) human placental lactogen - regulates glucose availability for the foetus (insulin antagonist)
(3) oestriol
(4) progesterone.

Dr Jeremy Fernando (2006)
- synthesis of various other hormones & growth factors:

(1) placental corticotrophin
(2) human chorionic somatostatin
(3) human chorionic thyrotropin
(4) epidermal growth factor
(5) somatomedin

(d) To describe the transfer of gases between mother & foetus including the double Bohr & Haldane effects.

- total surface area of placenta = 16m² (60m² in lung)
- minimum diffusion difference = 3.5mm (0.5mm in lung)
- lower gas permeability

- the foetus requires and increasing O₂ supply as it grows which are met by:

(1) increased maternal blood supply to placenta (80 -> 800mL/min)
(2) increased foetal blood supply to placenta
(3) presence of foetal Hb which as a higher O₂ affinity than maternal Hb
(4) higher Hb concentration in the foetus (40%)
(5) foetal Hb has a higher SpO₂ at a given PO₂ (p50 = 19mmHg) -> OxyHb dissociation curve shifted to left c/o low levels of 2, 3 DPG.

(5) the Double Bohr effect

- operates in both foetal & maternal circulations.
- an increase in PCO₂ (from foetus) in the maternal intervillous sinuses assist O₂ unloading
- this decrease in PCO₂ on the foetal side assists O₂ loading

-> the Bohr effect facilitates the reciprocal exchange of O₂ for CO₂
-> the oxyHb dissociation curves for maternal HbA & foetal HbF move apart (in opposite directions)

- foetal CO₂ elimination met by:

(1) maternal hyperventilation -> PaCO₂ of 32mmHg -> provides a gradient for foetal CO₂ to move down.
(2) double Haldane effect

- fully oxygenated Hb is able to carry less CO₂ -> the imidazole groups in the globin chains are more dissociated (ie. stronger acid) and thus cannot accept CO₂.
- as foetal blood is oxygenated -> foetal Hb is more able to loose its CO₂ -> and be mopped by maternal Hb.

(e) To describe the endocrine changes that occur during pregnancy and their consequences.

1. Chorionic gonadotrophin
2. Chorionic somatomamotrophin (placental lactogen)
3. Progesterone
4. Oestrogen
5. Gastrin

**Chorionic gonadotrophin (hCG)**
- MW 38,000
- secreted by trophoblastic cells of placenta during first trimester
- maintains corpus luteum during early pregnancy

**Chorionic somatomamotrophin (placental lactogen)**
- MW 18,500
- secreted by trophoblastic cells
- similar to human growth hormone
- counter regulation to insulin
- promotes FFA mobilization
- inhibits maternal glucose uptake
- promotes mammary development for lactation

**Progesterone**
- peaks at 3 weeks after fertilisation then declines.
- maintains endometrium & suppresses spontaneous contraction of the myometrium
- stimulates development of mammary glands
- increases TV & RR -> MV
- induces hepatic enzymes

**Oestrogen**
- oestriol is the main oestrogen secreted by placenta.
- levels increase x50 during pregnancy
- assist uterine development
- help mammary gland formation
- inhibits hepatic enzymes

**Gastrin**
- levels increase
- increase in acidity & volume of gastric contents

**Motilin**
- levels decrease
- gastric emptying slowed
Effects on Systems

GI tract

- anatomical displacement of stomach
- reduced motility
- reduced LOS tone
- delayed gastric emptying
- 70% of term patients have GORD

-> regurgitation & aspiration

CNS

- increased sensitivity to anaesthetic agents
- epidural & CSF pressures are increased
- epidural space pressure becomes positive

Liver

- increased cholesterol -> gall stones

GU

- bladder is hyperaemic
- increased lumber lordosis make bladder at increased risk of trauma.

(f) To describe the haematological changes during pregnancy.

Blood Volume

- plasma volume increases from 40 to 70mL/kg
- red cell volume increases from 25 to 30mL/kg
-> relative anaemia of pregnancy

Platelets

- increase

Clotting factors

- increase in II, VII, VIII, IX, X and plasma fibrinogen.
- decrease in plasminogen & fibrinolytic activity.
-> hypercoaguable state
-> protects from excess maternal blood loss.

**Oxy Hb dissociation curve**

- decreased 2, 3 DPG levels in fetal Hb
- greater O2 unloading at tissues at a higher PO2
- shifts to the right (increased O2 unloading)

**Albumin**

- decreased c/o dilution
- 40 to 25 g/L