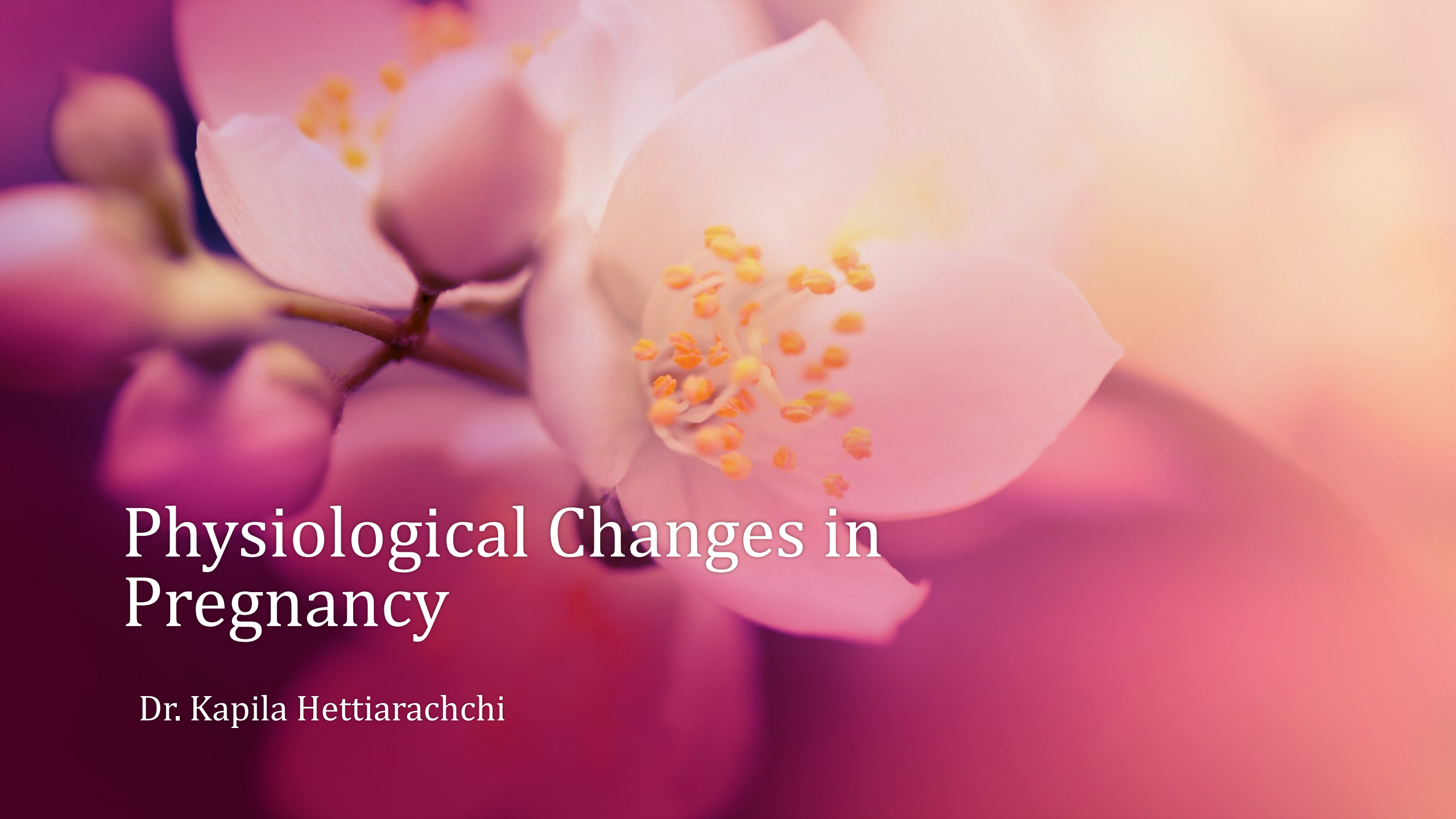


Physiological Changes in Pregnancy

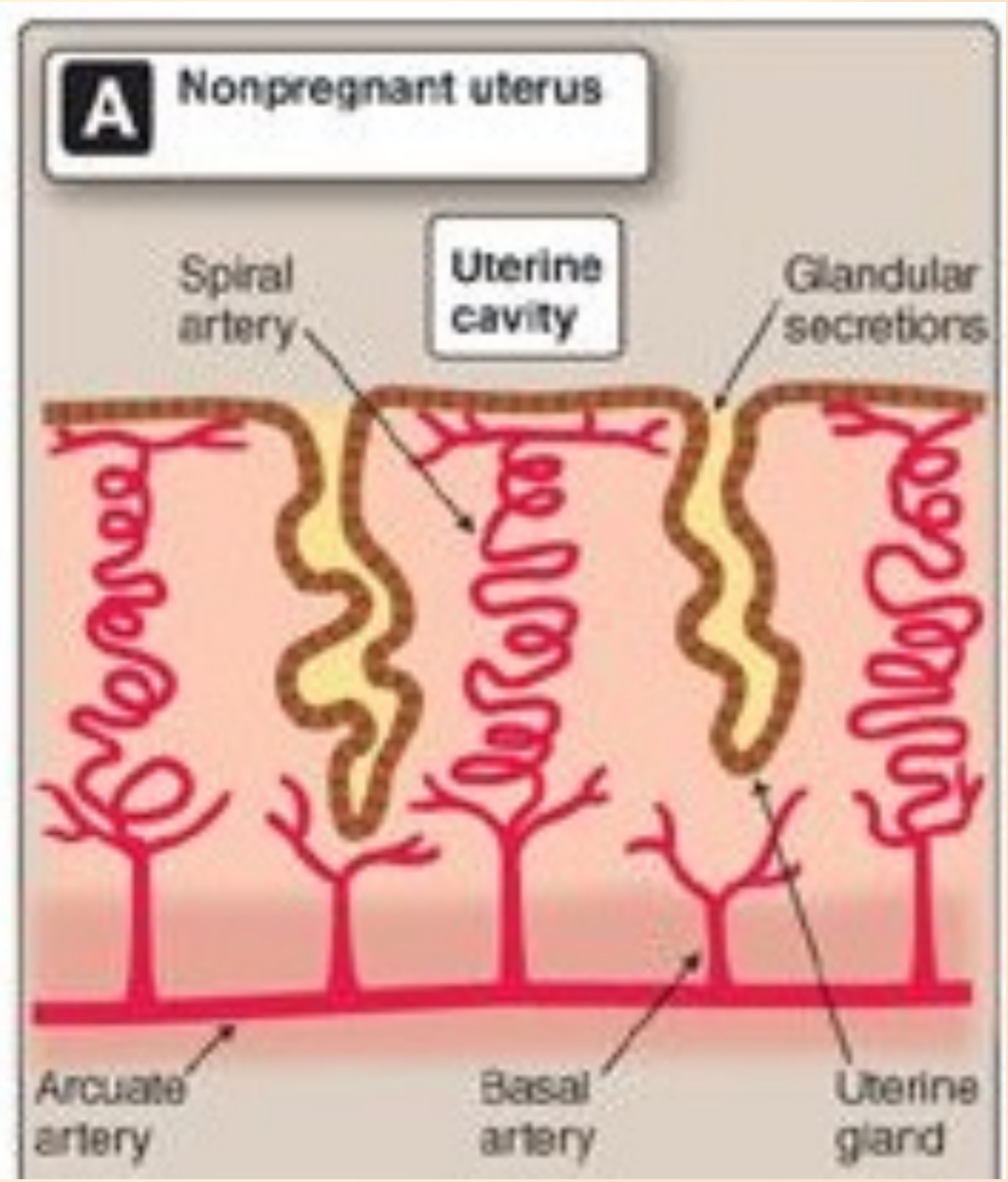
Dr. Kapila Hettiarachchi

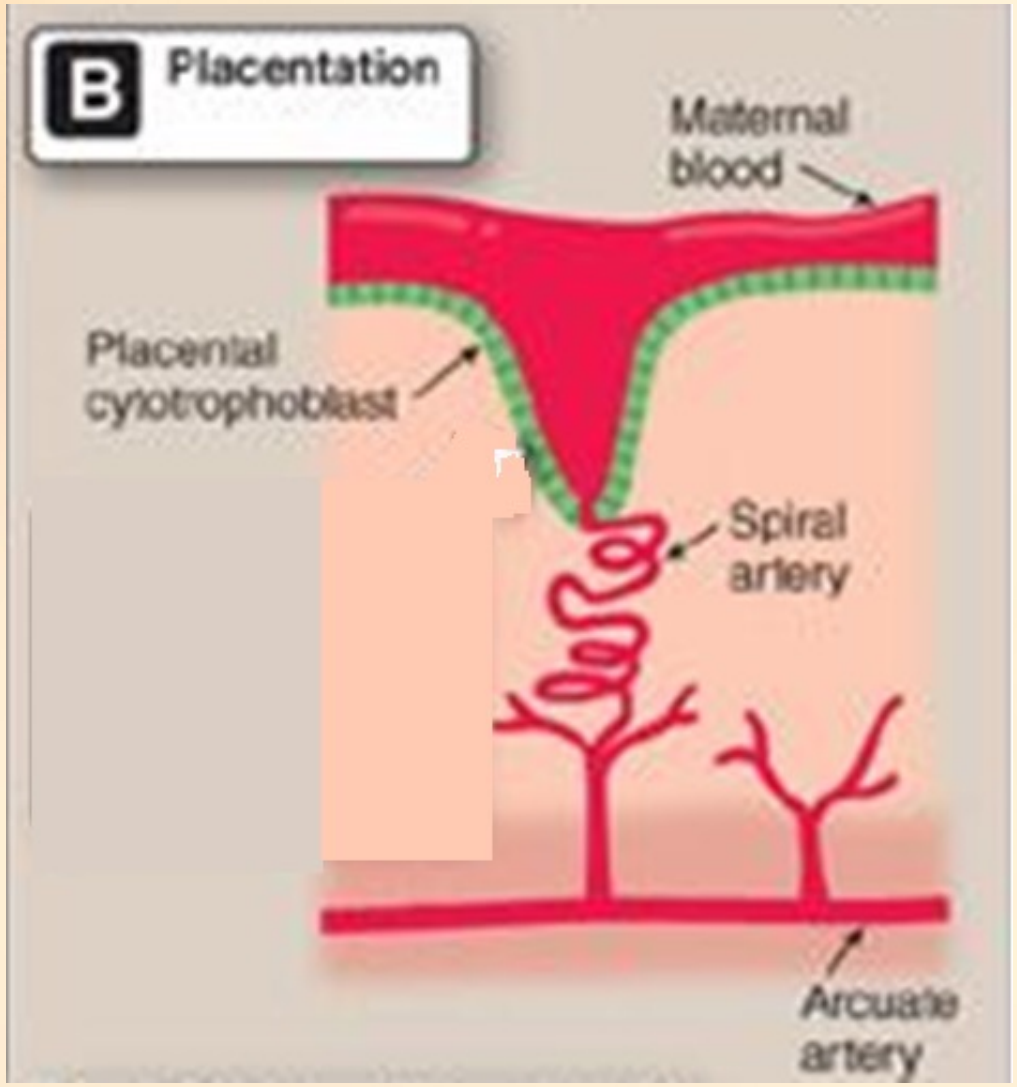
Is uterine blood flow auto-regulated ?

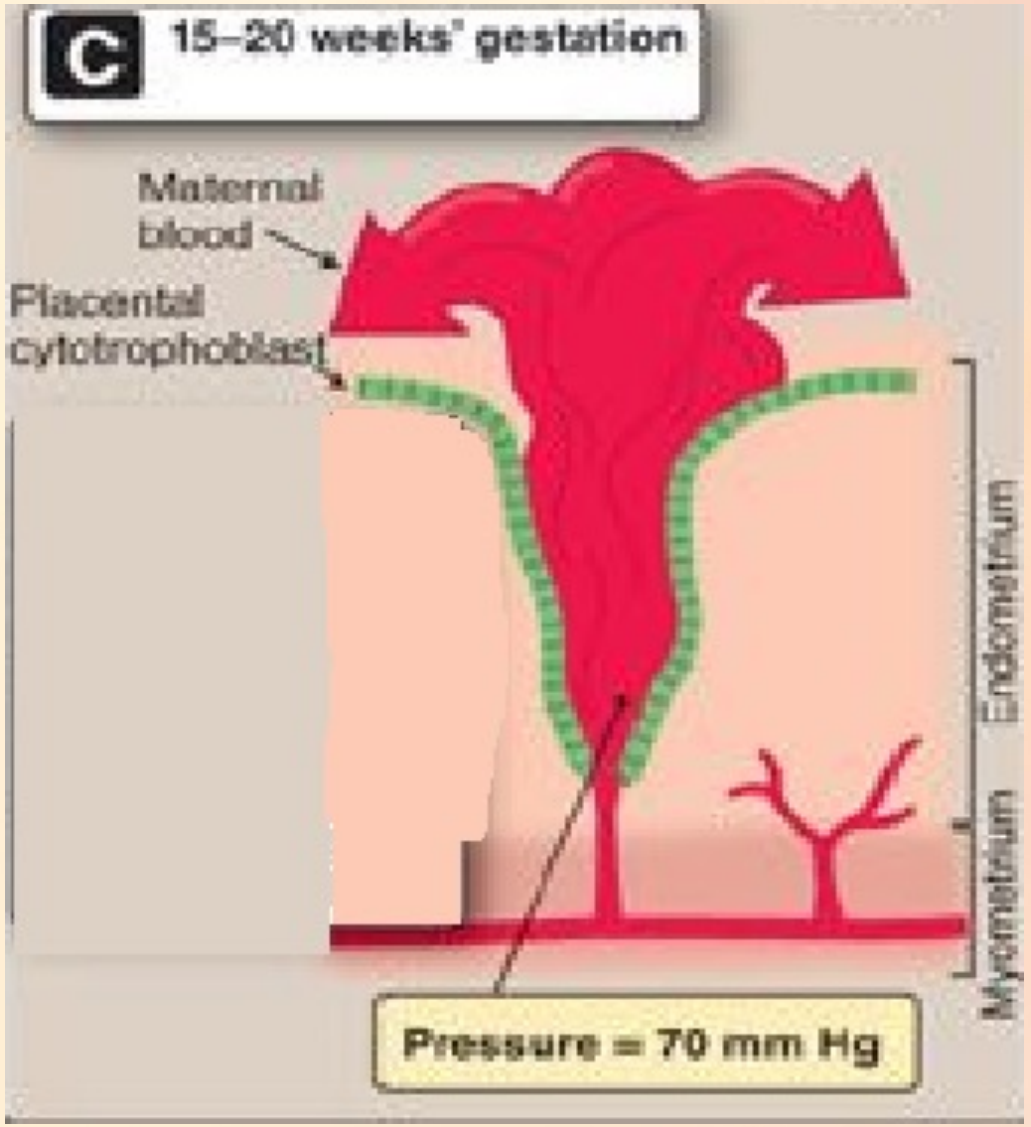
HIGHLY

MUSCULAR

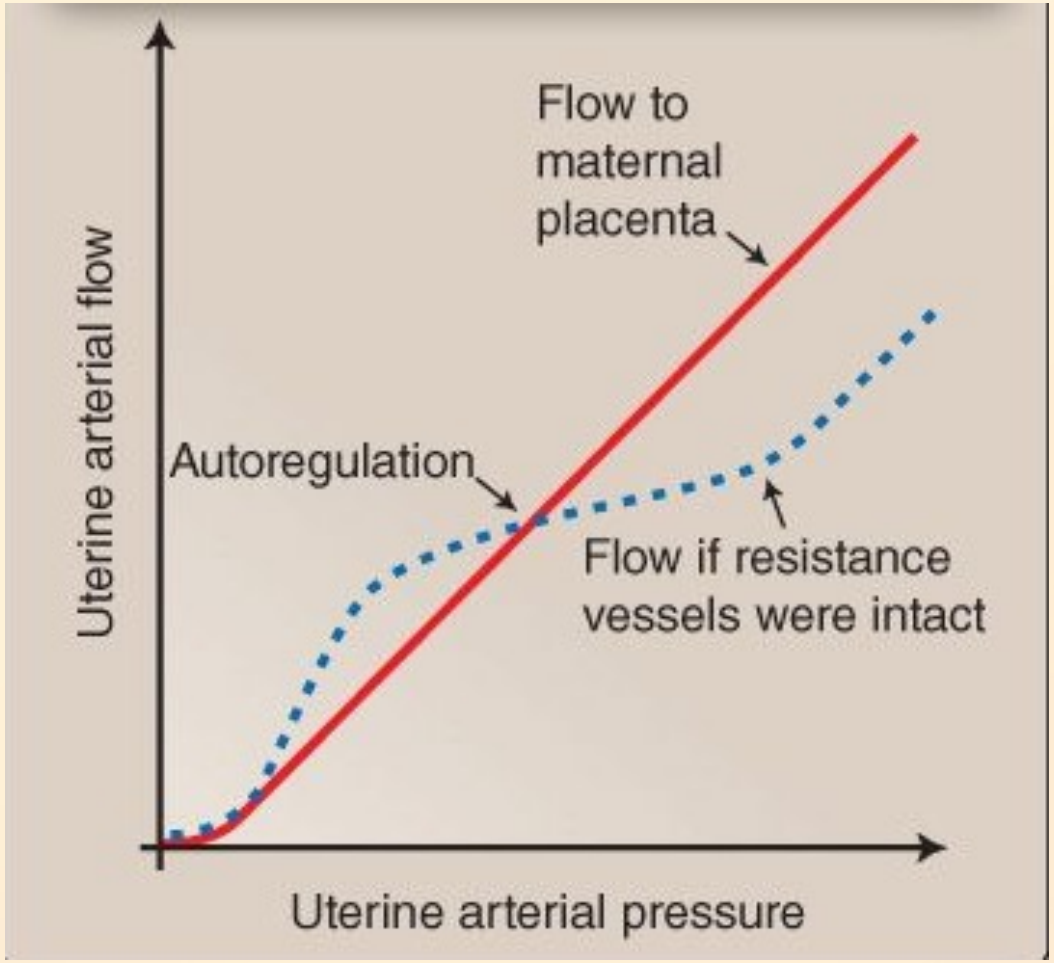
spiral arteries



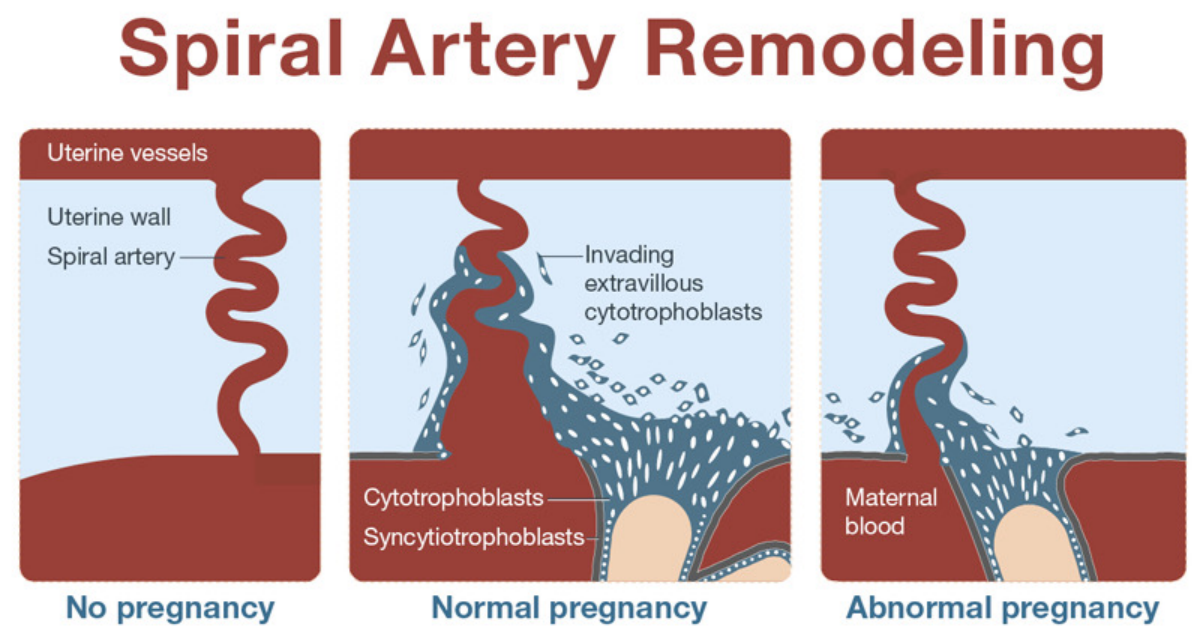




Fetoplacental endometrium filled with 500ml maternal blood


Flow to
maternal
placenta
Autoregulation
Flow if resistance
vessels were intact
Uterine arterial flow
Uterine arterial pressure

In pre-eclampsia – maternal placental vessels are narrowed so increased resistance.



Flow increasing from ~50 mL/min at 10 weeks' gestation

to **>500 mL/min** at term

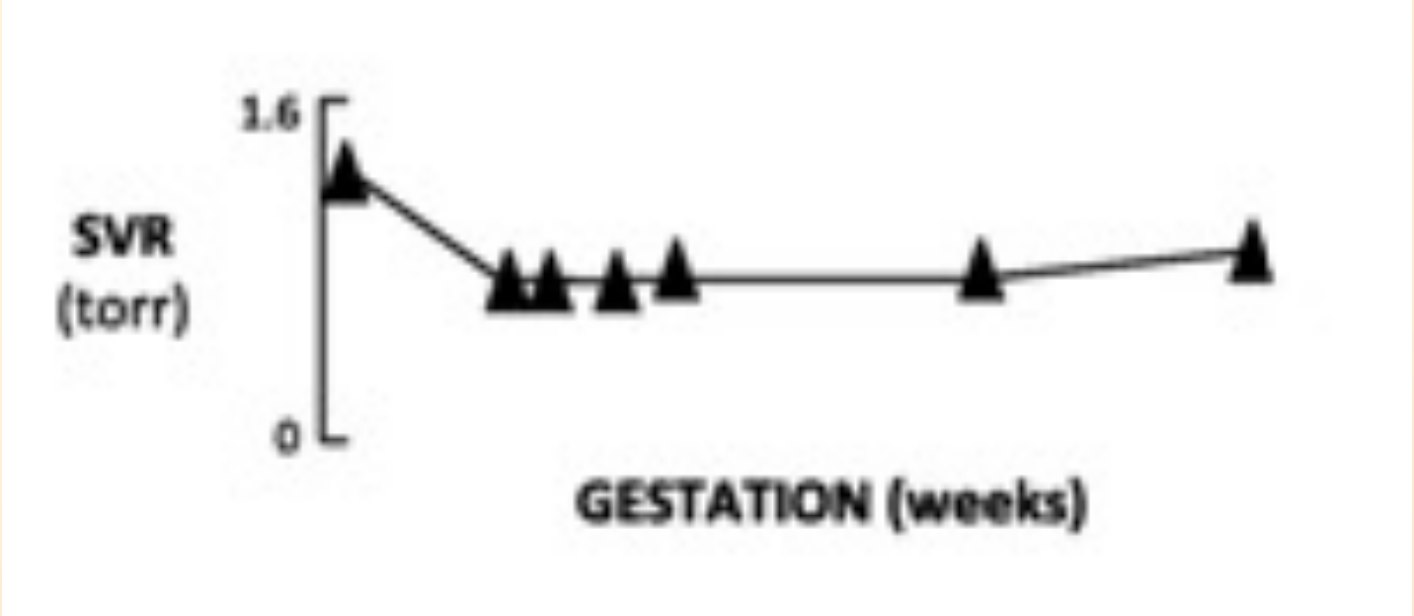
Implications

- **Removal of placenta at delivery** leaves a large raw surface and many open vascular spaces;
- **Good contraction of uterine muscle** only can stop bleeding.
- Pregnant lady has a risk of bleeding to death within a very short time;
- PPH management should be done promptly and accurately.

Hemodynamic Changes

Systemic Vascular Resistance

Falls steadily over the first 20 weeks



Primary cause

Erosion of maternal resistance vessels by the fetal placenta

Progesterone

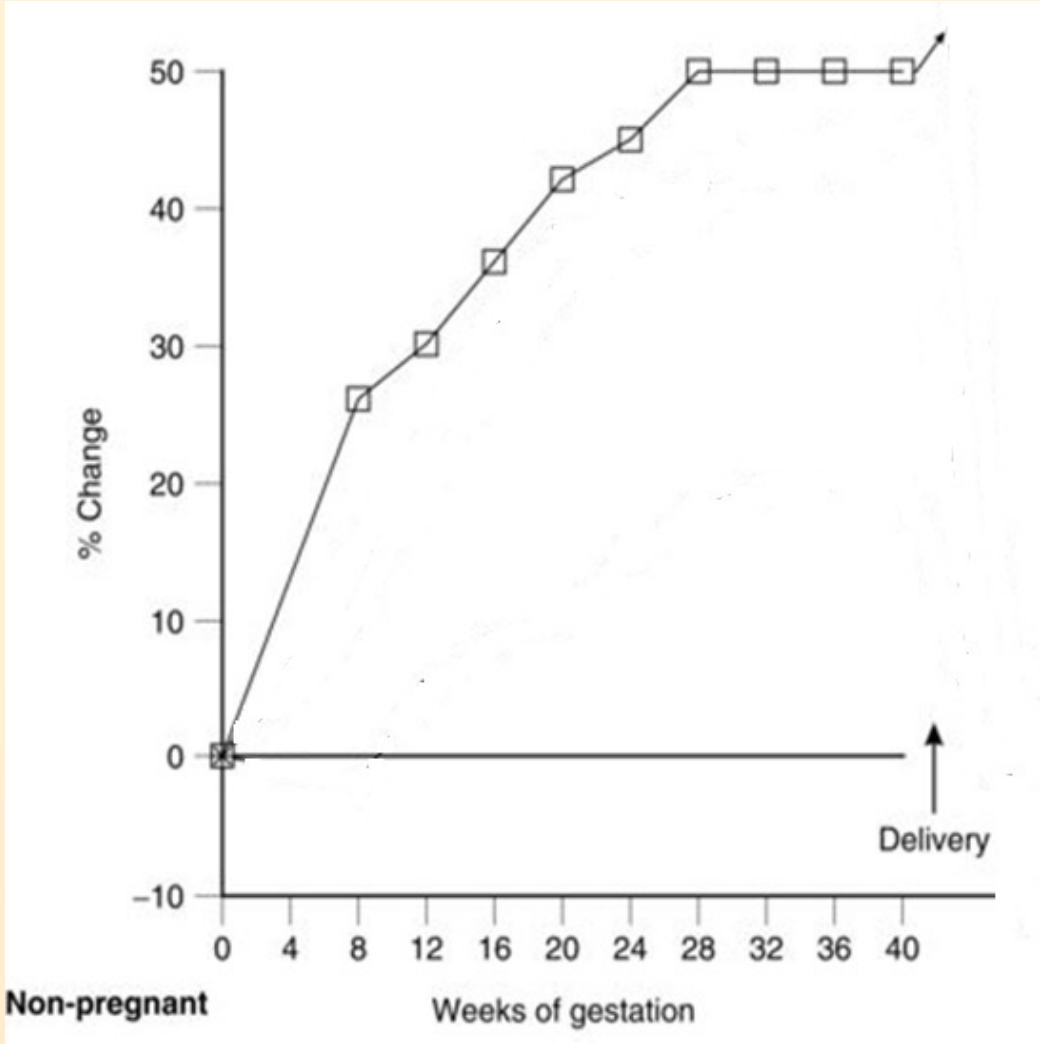
Dilate

cutaneous and renal vascular beds

Easy venous access

- Venodilatation making venous access easy

Cardiac Output



Cardiac Output increase by 40-50%

Stroke Volume - 20-30%

Heart rate - 10-15%

Cardiac output

Stroke Volume

begins to rise very early in pregnancy, mediated by an increase in

preload and contractility

Preload

1. Na^+ and water retention

2. Placental hormones potentiate

Renin– angiotensin–aldosterone system and thirst

Contractility

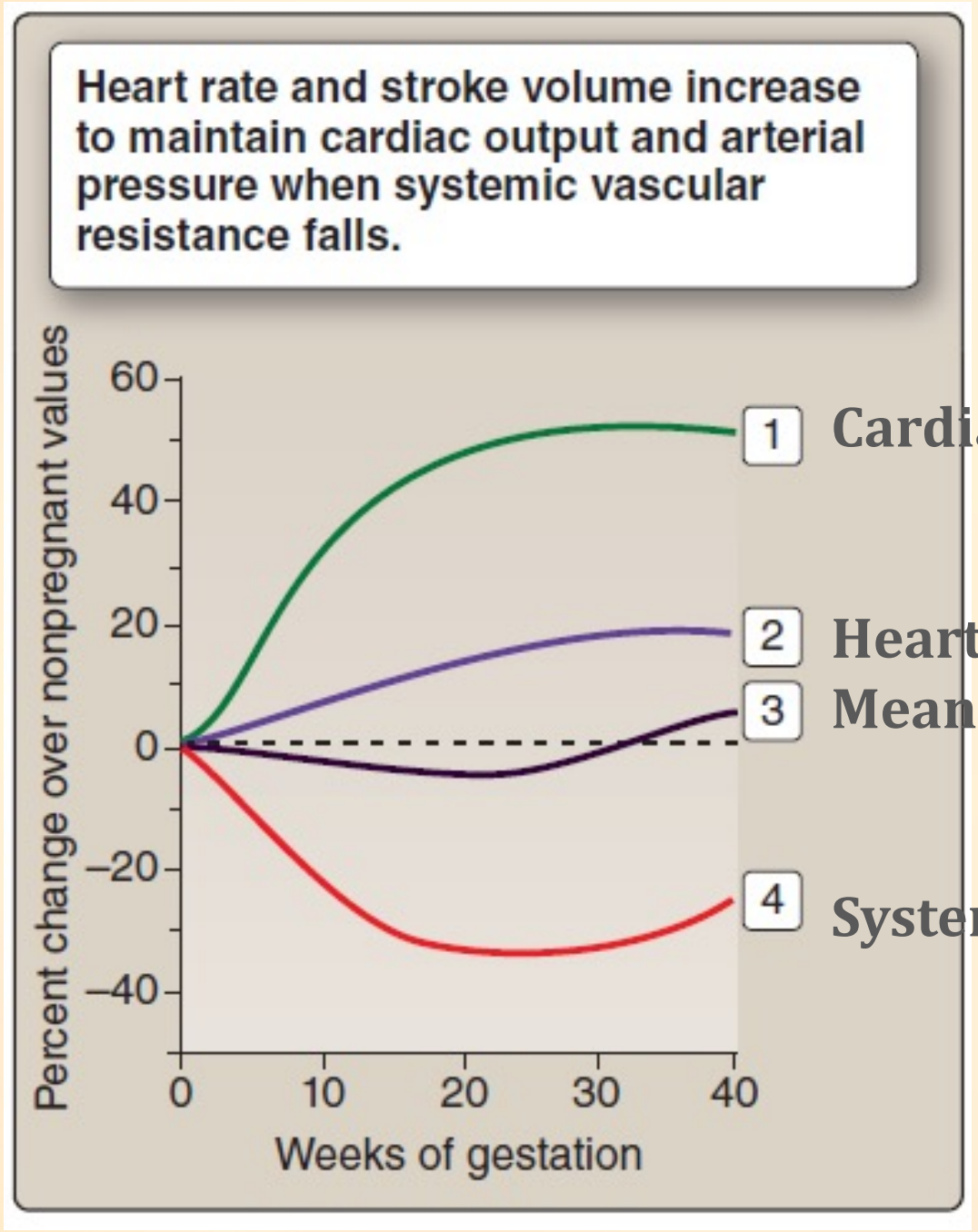
Sustained increases in cardiac output stimulates ventricular hypertrophy

ECG changes - Cardiac axis shifts to left; ST depressions and T inversions may be seen in LIII

Mean Arterial Pressure

Diastolic Blood Pressure falls

Pulse pressure widens



Cardiac output

Heart rate

Mean arterial pressure

Systemic Vascular Resistace

Increased diastolic runoff

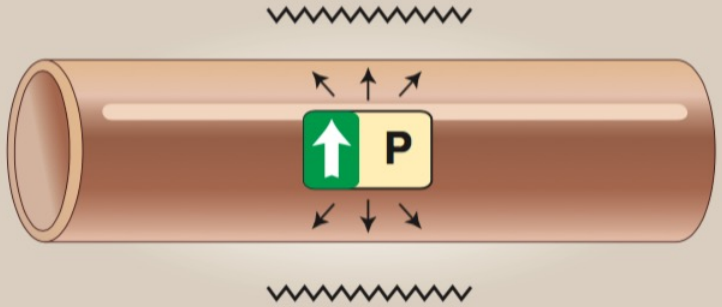
Blood escapes the arterial system

more easily during diastole

Noncompliant

Rigid tubes resist expansion when internal pressure rises.

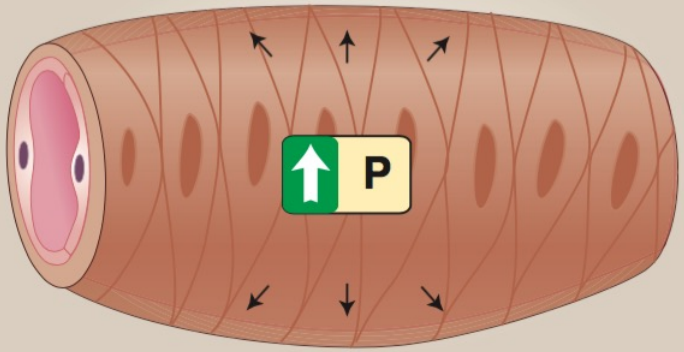
Examples: **Capillaries, arterioles, copper pipe.**

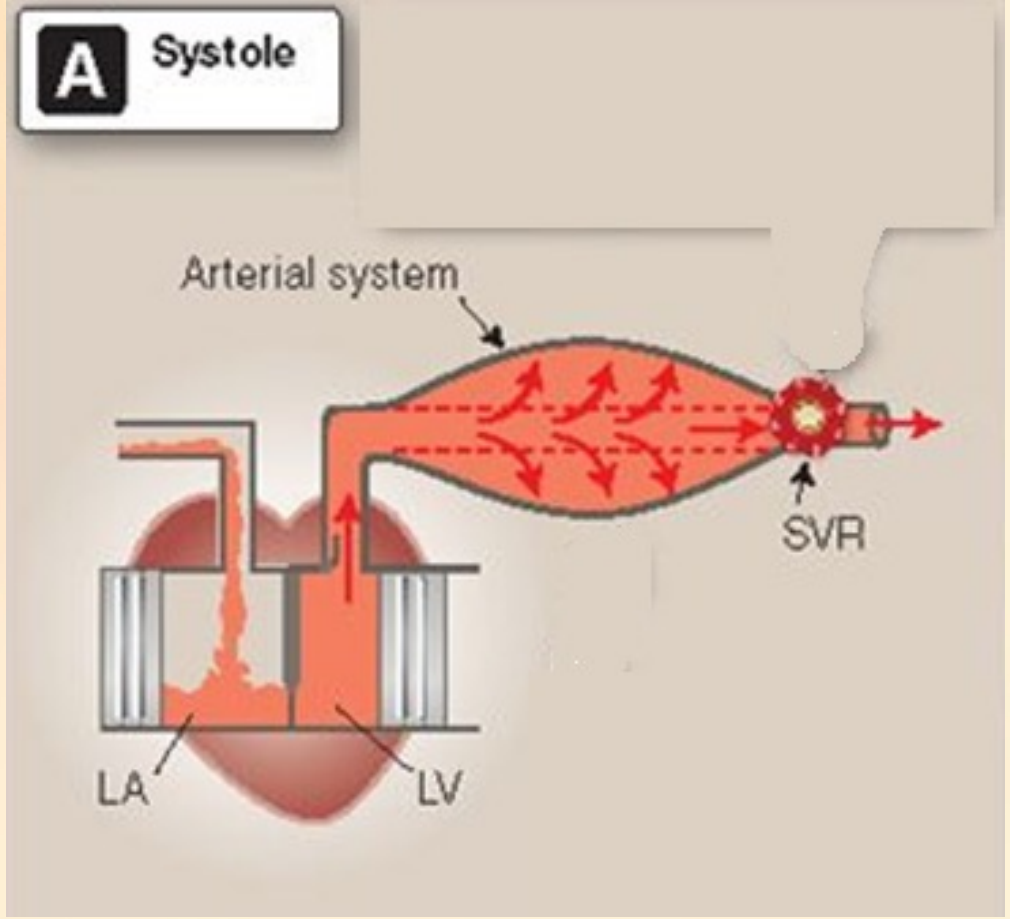


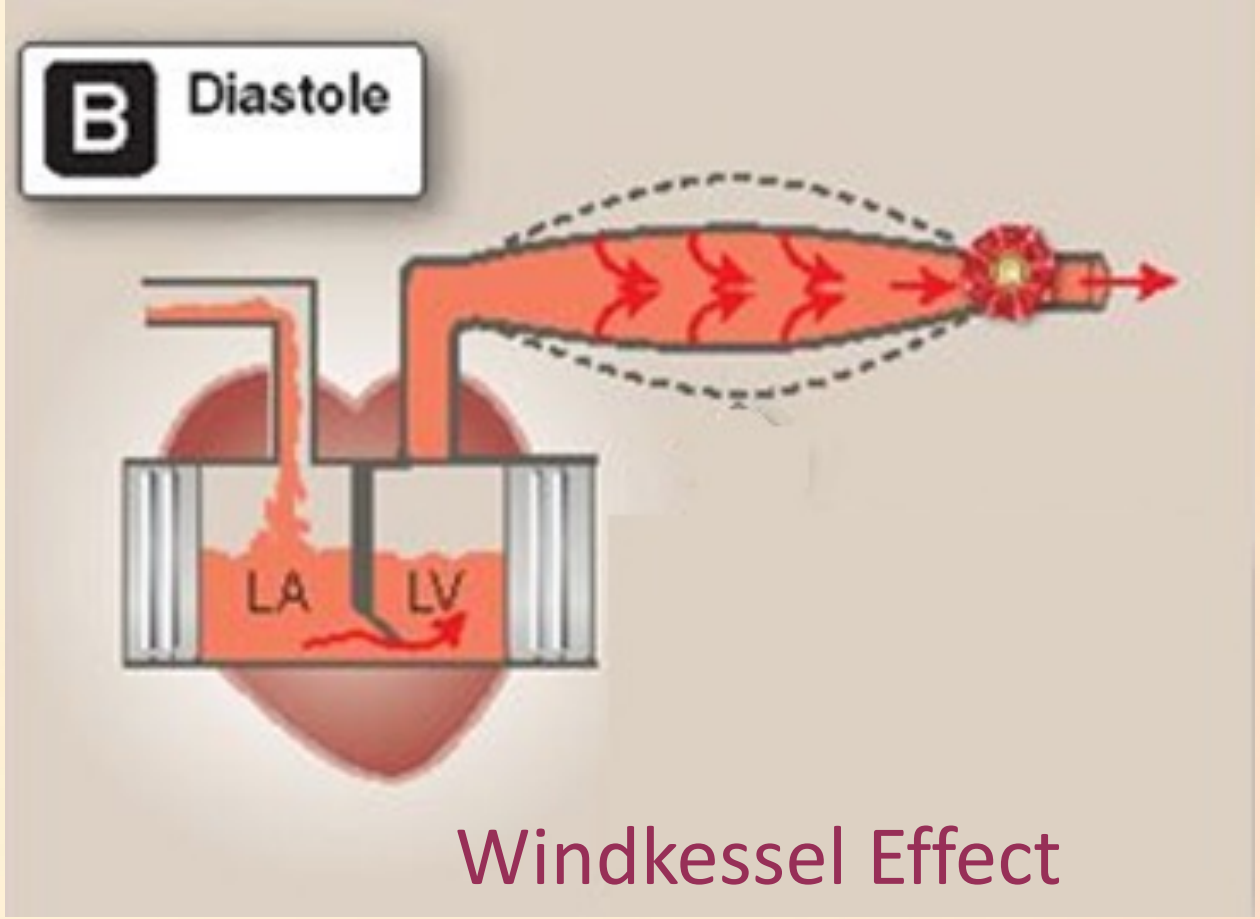
Compliant

Tubes with elastic walls swell when internal pressure rises.

Examples: **Arteries, veins, rubber tire inner tubes.**







Windkessel Effect

Evens out pressure and flow through the vasculature over time

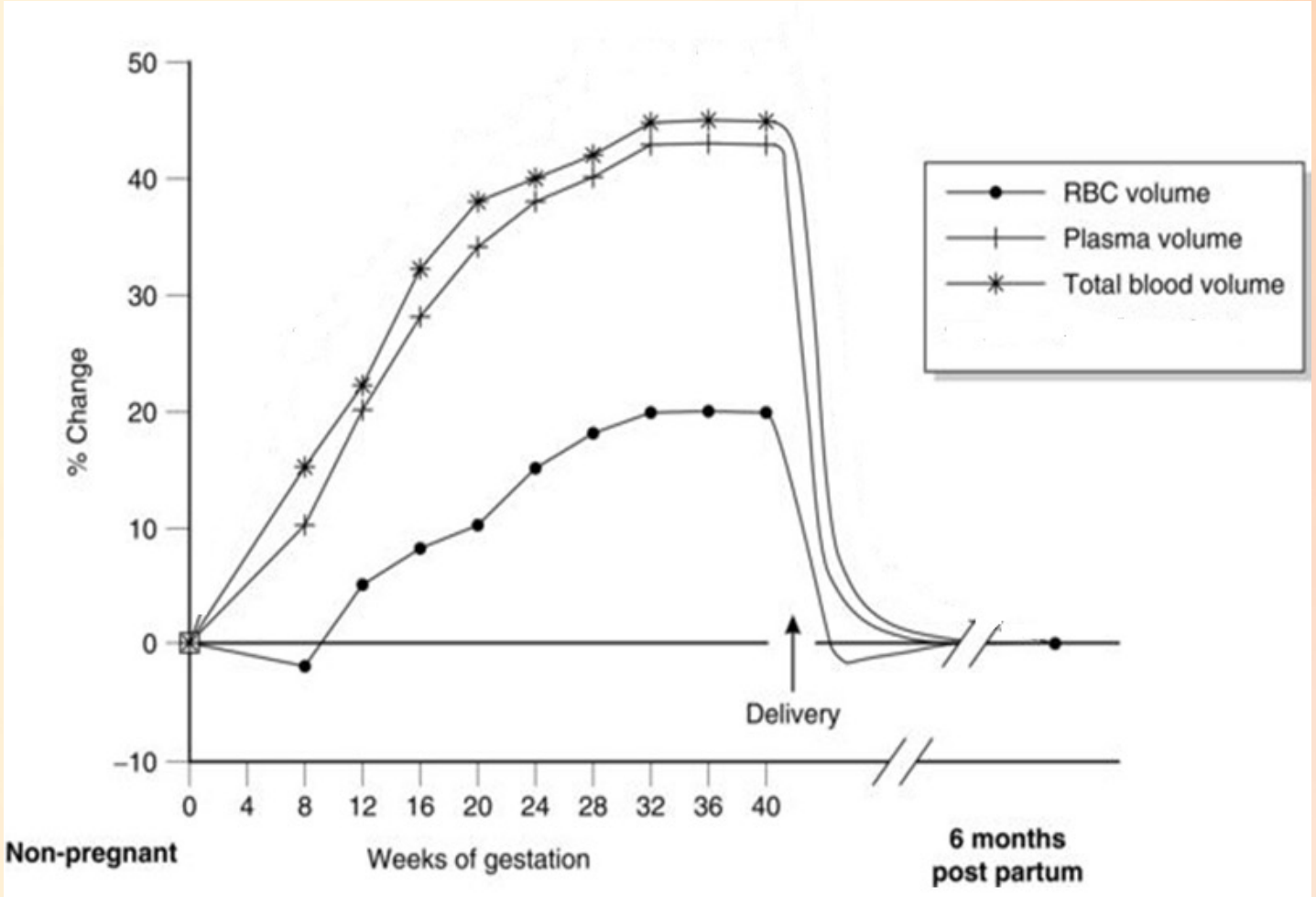
C. Physiologic anaemia

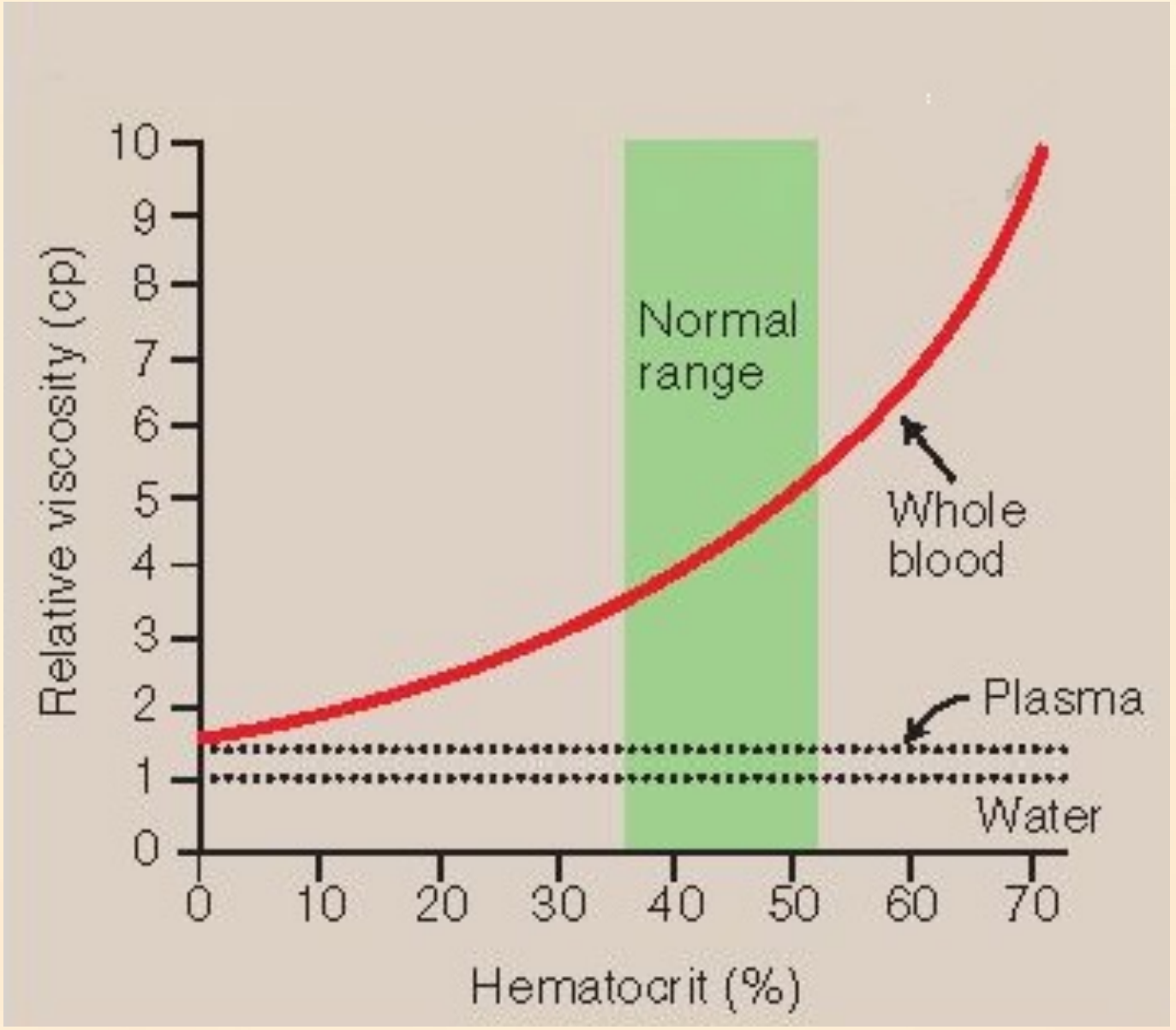
Plasma volume increase by

40%–50%.

Red blood cell increase by

25%–35%.




Relative viscosity (cp)
10
9
8
7
6
5
4
3
2
1
0
Normal range
Whole blood
Plasma
Water
0
10
20
30
40
50
60
70
Hematocrit (%)

Physiologic benefit

Reduces blood viscosity So, reduces shear stress.

Then less likely to damage vascular endothelium

Murmurs

Functional murmurs

Venous hum

Reynolds equation

The likelihood of turbulence can be predicted

N_R is Reynolds number,

v is mean blood velocity,

d is vessel diameter,

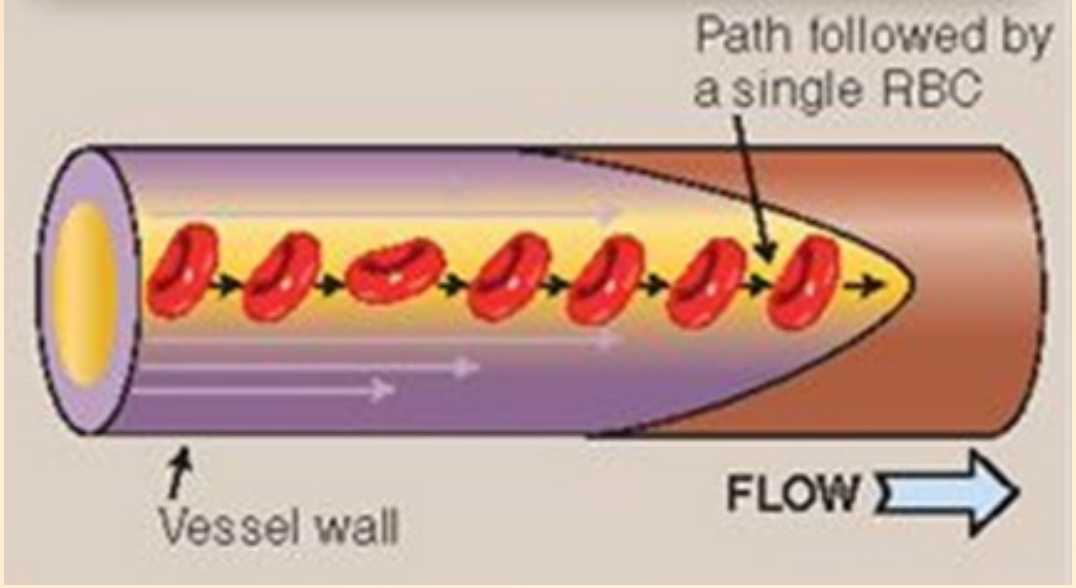
ρ (rho) is blood density,

η is blood viscosity.

$$N_R = \frac{v \times d \times \rho}{\eta}$$

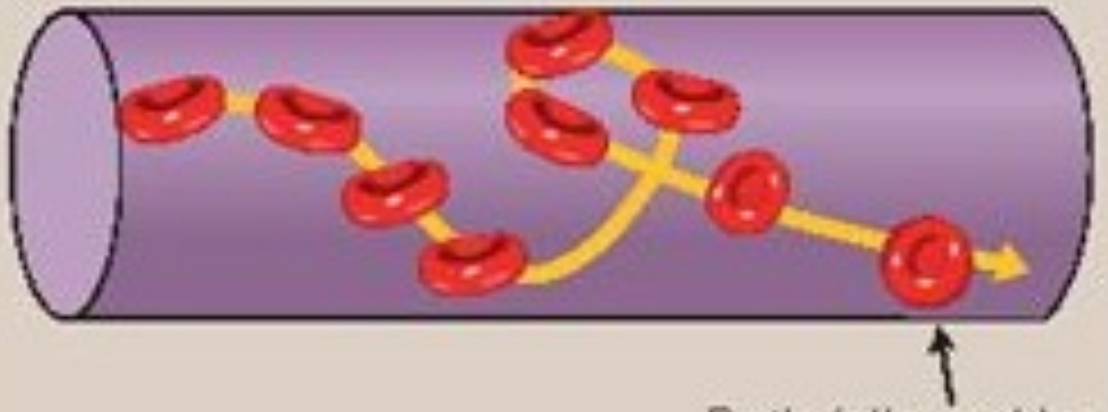
Streamline flow

- Normal pattern of flow in vasculature
- Highly efficient
- Follows the Poiseulle law



Turbulent flow

- Occurs in regions where flow velocity is high
- Inefficient, energy is wasted in chaotic movement
- Cannot apply the Poiseuille law



Aortocaval Compression

Compensation occurs through sympathetic stimulation and

collateral venous return via vertebral plexus and azygous veins

Aortocaval Compression

- Two important implications for us in anaesthesia.

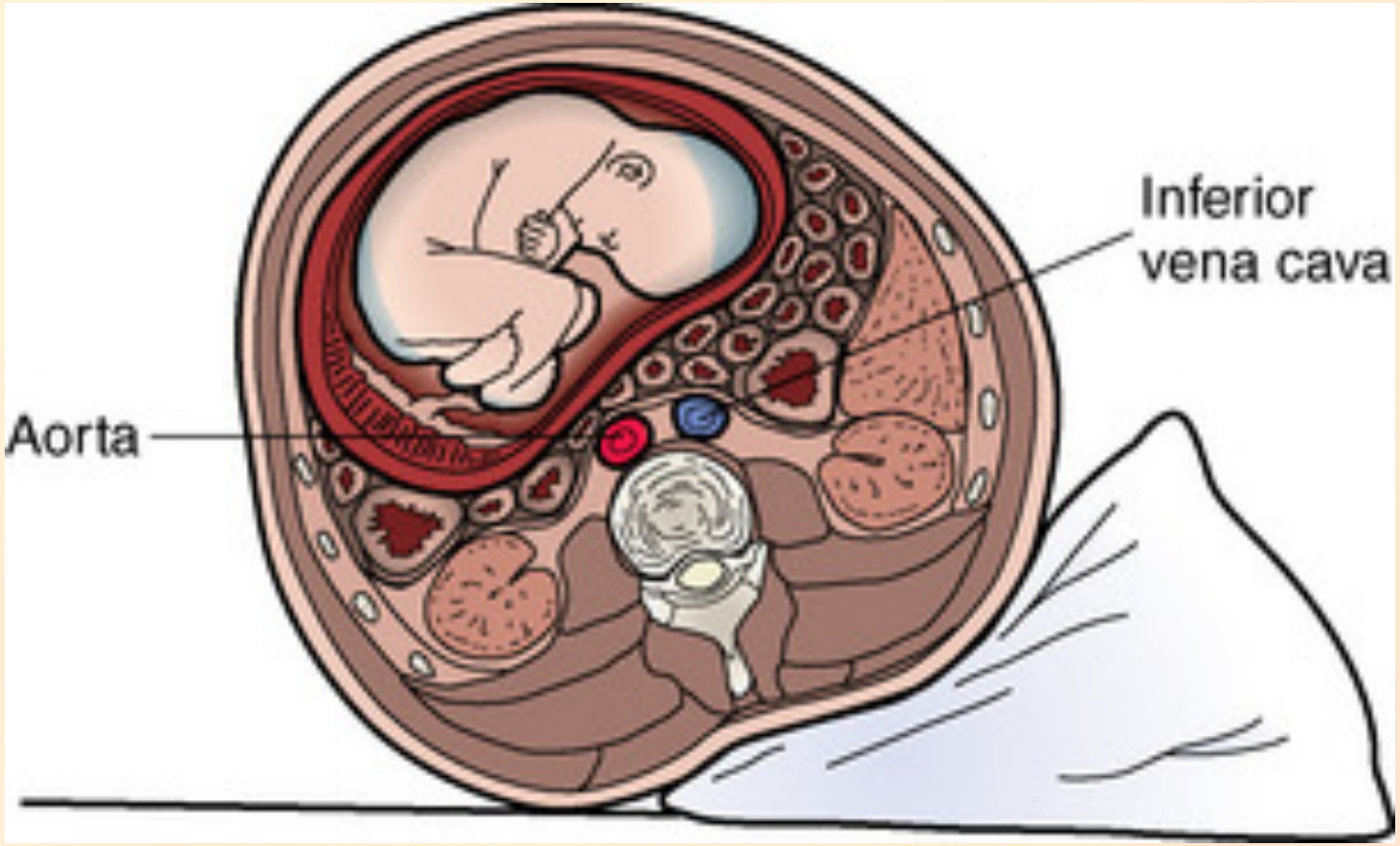
I. ***Be careful in epidural insertion*** - *Epidural space pressure loses the negativity and may even become positive making identification difficult and increasing the risk of inadvertent dural puncture at labour epidural and CSE.*

II. ***Careful about the volume of bupivacaine*** - *The bulging of epidural space compresses the subarachnoid space and reduces its volume. So volumes used in spinal anaesthesia need to be reduced in pregnancy*

Effects on supine position

- **Compression of IVC**
- Mother may feel faintish and fetal perfusion gets compromised making the fetus acidotic.
- If this happens immediately before delivery (eg transporting for an emergency LSCS) foetal APGAR scores and prognosis will be worse.
- **The aorta too may get compressed** in supine position(less likely due to its thick, muscular wall). This may compromise uteroplacental, renal and lower limb flow leading to pale cold pulseless lower limbs.

Both these effects are reversible with adopting a **15 degree** tilt during LSCS and while preparing for anaesthesia; **Strongly recommended in every case.**



Therefore following anaesthetic interventions are recommended

- Preparation for a PPH; **Large bore 17-16 G** iv access in all LSCS patients; more if at risk.
- Checking for availability of blood / group and save as indicated.
- Communication with Obstetric team to identify at risk mothers for a PPH.

Therefore following anaesthetic interventions are recommended

- Care with drug doses at spinal anaesthesia
- Maintenance of 15 degree Lateral tilt of bed (lateral position on transport)
- Supplemental oxygen until delivery

Liver blood flow is *not* increased

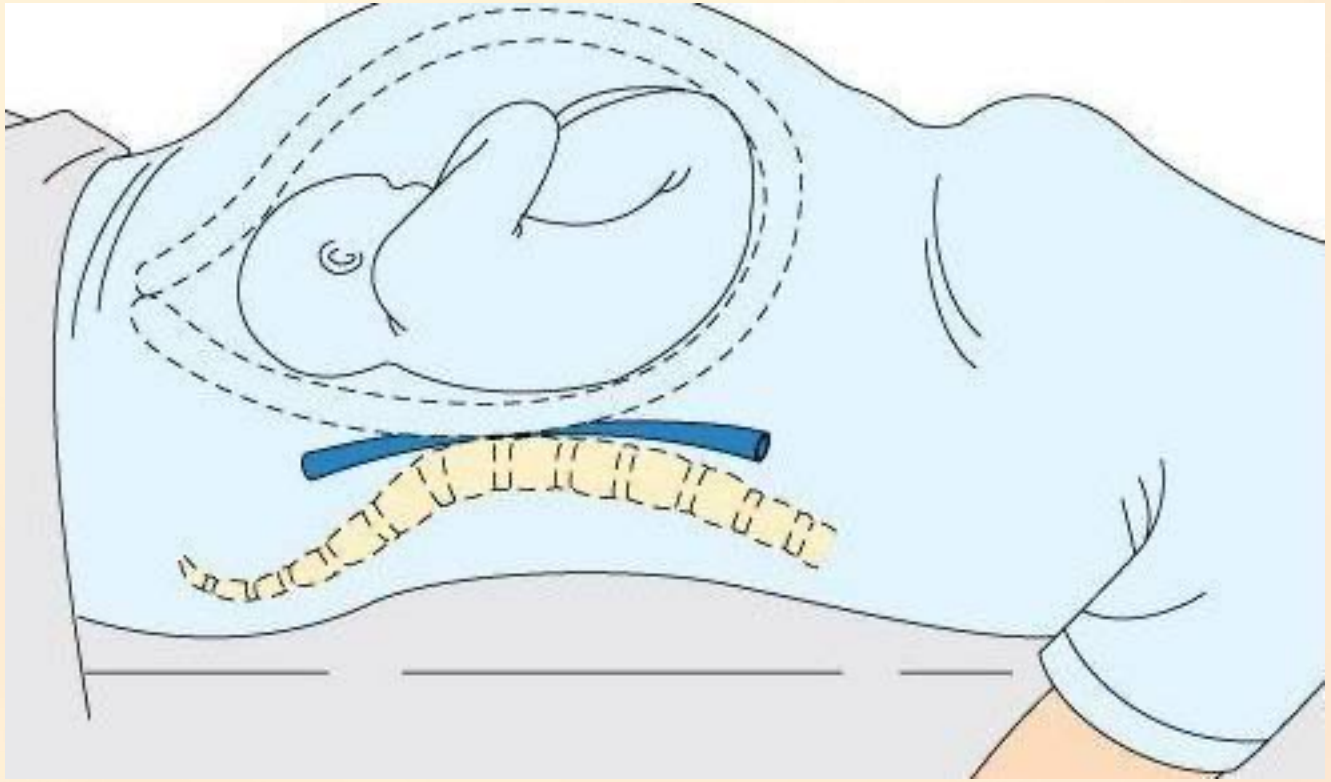
Blood flow to the nasal mucosa is increased

Increase in blood flow to the skin, resulting in warm, clammy hands and feet

Dissipate heat from the metabolically active feto placental unit

Oedema

Fetus, placenta, and amniotic fluid = ~8–10 kg at term compresses inferior vena cava and other smaller veins



Oedema

Compression causes venous pressures in the lower extremities to rise

This causes

Increases mean capillary pressure and

Increases net fluid filtration from blood to the interstitium

Oedema

Fall in colloid osmotic pressure

by 30%– 40% during pregnancy

(from ~25 mm Hg prior to pregnancy to ~15 mm Hg postpartum)

Respiratory system

O_2 demands of the mother and growing fetus increase rapidly during pregnancy (250ml ,I MET = 3.5ml/kg/min)

O_2 consumption at term is increased ~ 30 -40 % (350-400ml)

Respiratory system

Progressive increase in minute ventilation to ~50% over non-pregnant values during the second trimester

Respiratory system

Minute Ventilation increase is mainly by

An increase in **Tidal Volume** and

Small or no rise in respiratory rate

Respiratory system

Net effect is that

P_aO_2 rises by ~10 mm Hg, and

P_aCO_2 falls by ~8 mm Hg,

causing a slight respiratory alkalosis (<0.1 pH)

Respiratory system

20% decrease in (eg to<2000ml from 2300ml in non pregnant state)

Functional residual capacity (FRC)

Expiratory reserve capacity (ERC)

Residual volume (RV)

caused by the growing foetus pushes the diaphragm up (by about 4cm) and limits the FRC

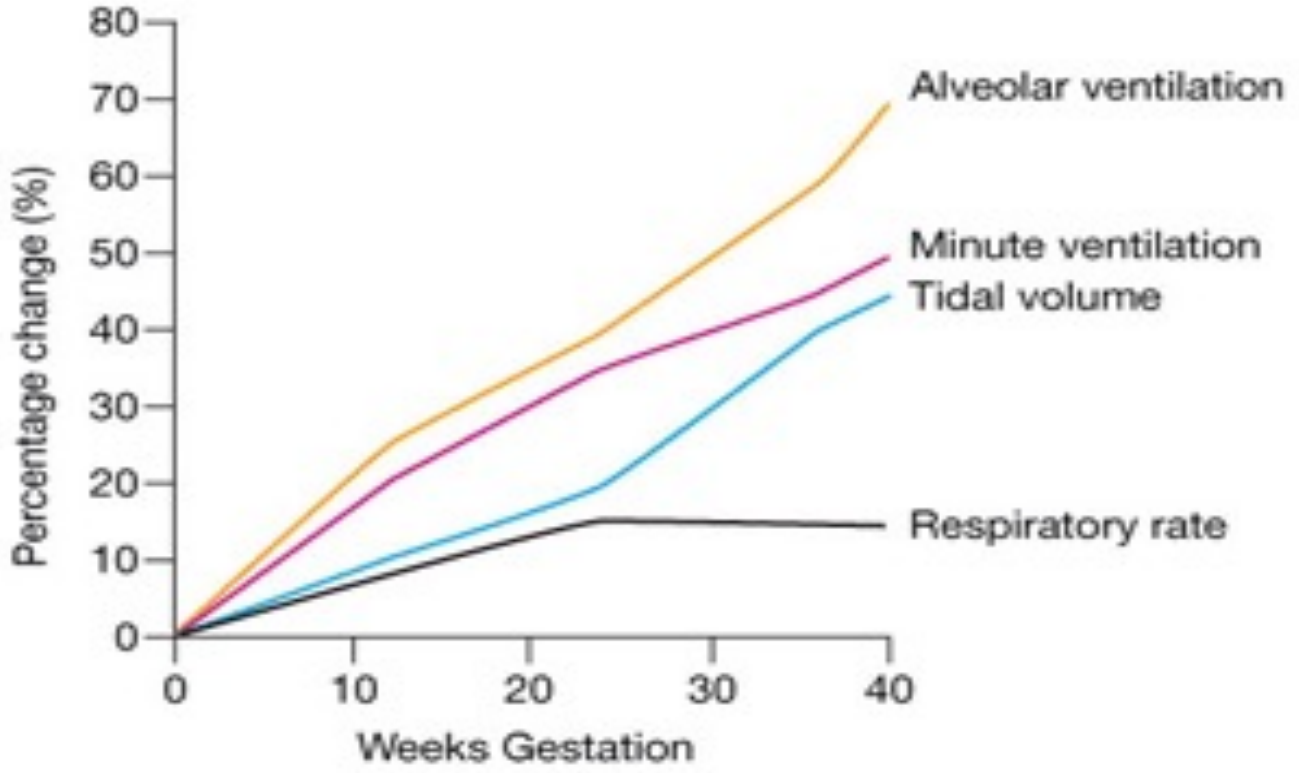
Respiratory system
Effects of the reduced FRC

- As the oxygen consumption has increased to 400ml /minute, there is inadequate oxygen reserve (about 1 minute's supply) in a non preoxygenated patient having a GA(RSI).
- They tend to desaturate very fast (by 30% per minute) once the oxygen reserves are gone.

Changes in the airway

- Mallampati and laryngoscopy view may increase by one as pregnancy advances.
- Airway odema, tendency for bleeding in mucosa, large breasts all contribute to difficulty in intubation
- Failed intubation is 7-10 times more likely compared to non pregnant population

Maternal Respiratory Changes



AnaesthesiaUK

Therefore following interventions are recommended in a GA

- Airway assessment and identification of difficult intubation patients and having equipment, personnel ready.
- Use of smaller sized ETT(6.5-7.0G)
- Effective preoxygenation with ETCO2, SPO2 monitoring in place with 4 vital capacity breaths or 3 minutes. ETO2 must be >85%
- Maintaining a head up position to ensure effective oxygenation

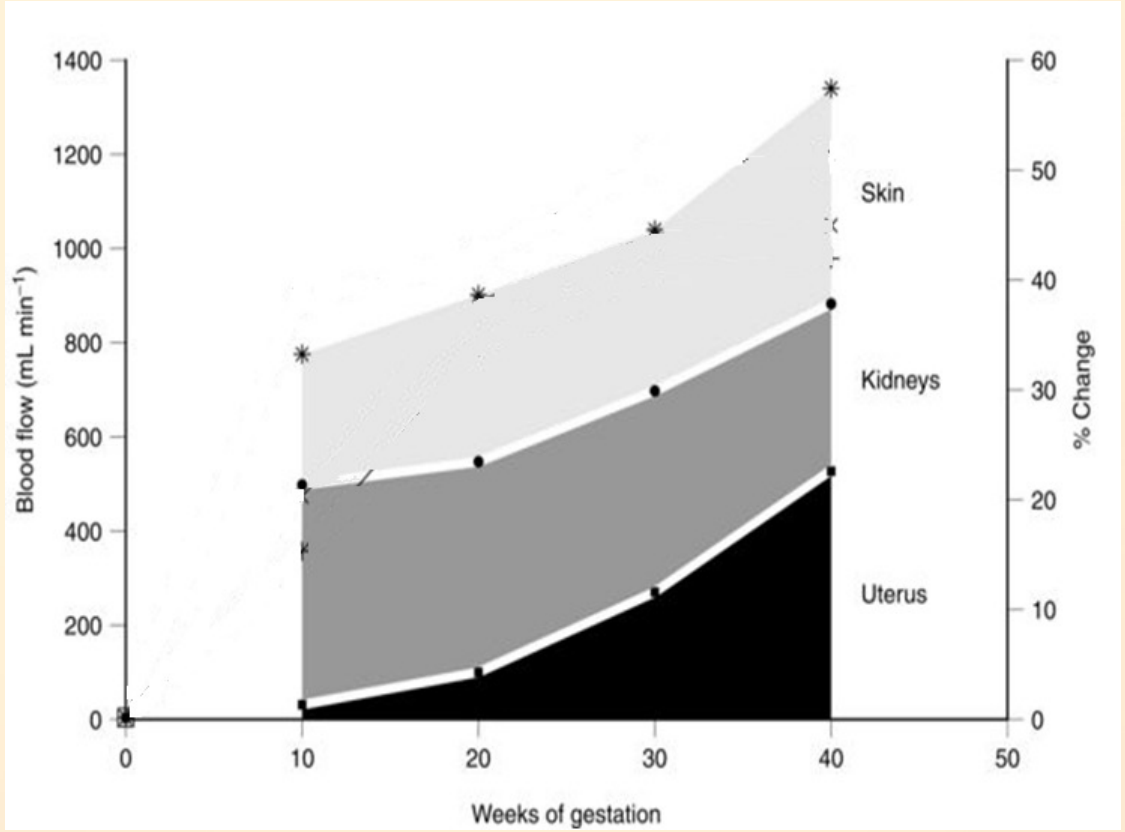
Progesterone exerts a stimulant action on the

respiratory centre and carotid body receptors

Physiological Changes of Pregnancy Which increase the risk of Hypoxaemia

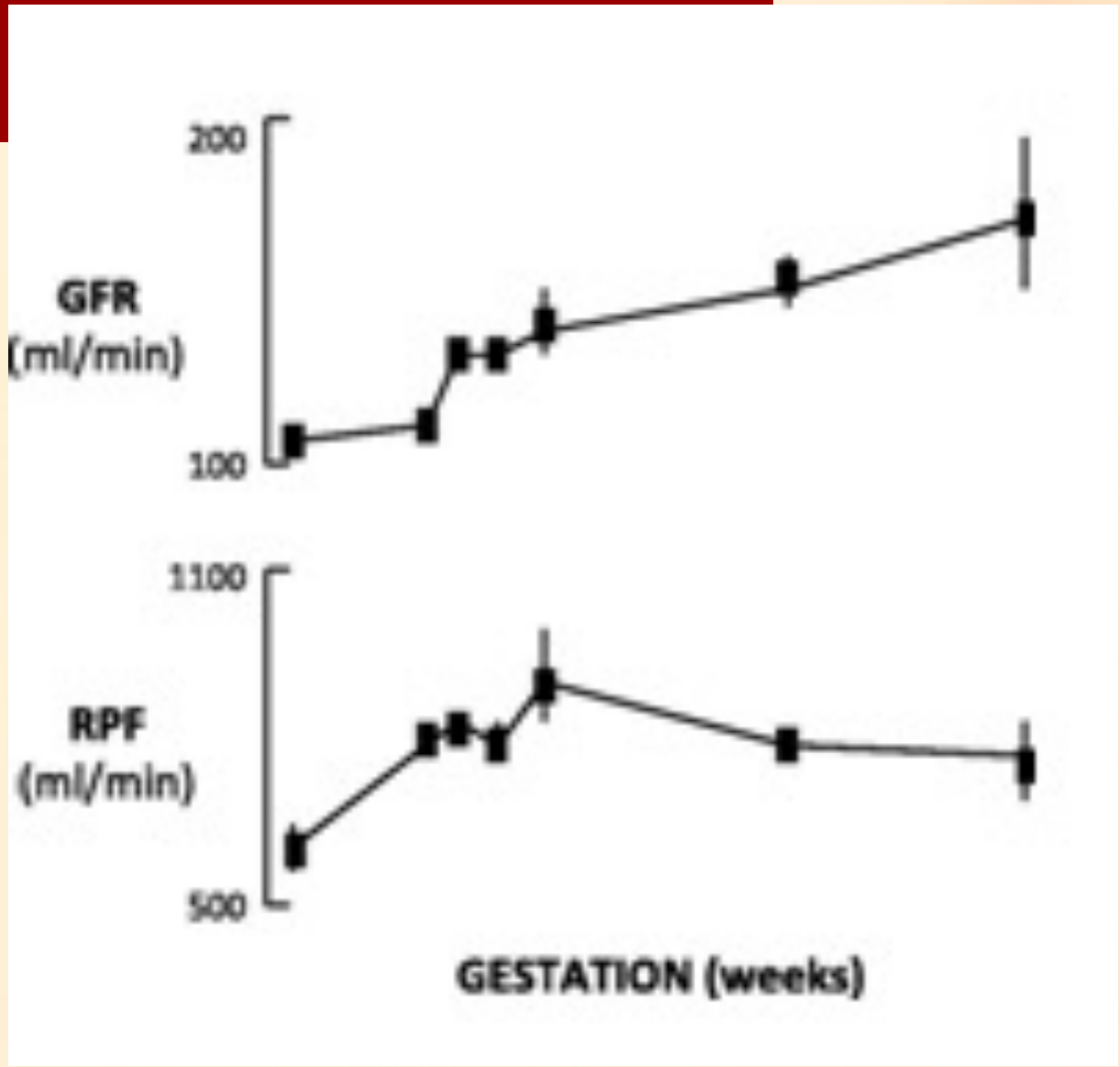
1. Interstitial oedema of the upper airway, especially in pre-eclampsia
2. Enlarged tongue and epiglottis
3. Enlarged, heavy breasts which may impede laryngoscope introduction
4. Increased oxygen consumption
5. Restricted diaphragmatic movement, reducing FRC

Renal blood flow is increased



Renal

Glomerular Filtration Rate rises steadily to **~50%** above normal values at 16 weeks' gestation



Renal Changes in Pregnancy

Parameter	Non-Pregnant	Pregnant
Urea (mmol L^{-1})	2.5–6.7	2.3–4.3
Creatinine (μmol L^{-1})	70–150	50–75
Urate (μmol L^{-1})	200–350	150–350

Gastrointestinal Changes

- Many pregnant women have reflux
- The gravid uterus may press upon the stomach and increase regurgitation risk
- The lower oesophageal sphincter pressure is reduced.

Gastrointestinal Changes

Gastrointestinal motility decreases but gastric emptying is not delayed during pregnancy

However, it is delayed during labour but returns to normal by 18 h after delivery

Gastrointestinal Changes

- All above increase the risk of acid aspiration at induction of anaesthesia;
- This used to lead to a fatal pneumonia called **Mendelson's syndrome** which caused a high maternal mortality a few decades ago.

Gastrointestinal system
Interventions to reduce aspiration risk

- Longer fasting time for solids; 6 hours or more for heavy meals. Two hours for clear fluids.
- Keeping all labouring patients only on liquids.

Gastrointestinal system
Interventions to reduce aspiration risk

1. *H_2Receptor antagonists (Ranitidine 150mg or Famotidine 40mg in 2 doses 10 H and 2 hours before surgery); this is the most important part of prophylaxis*
2. *Prokinetic - Metoclopramide 10 mg as above*

- *Same drugs given IV/ stat for emergencies; essential;*

Gastrointestinal system
Interventions to reduce aspiration risk

- *0.3M sodium citrate 30ml oral for LSCS patients undergoing LSCS immediately before anaesthesia- this is sometimes not given routinely; becomes important for GA*

Gastrointestinal system
Interventions to reduce aspiration risk (contd)

- Preference for spinal anaesthesia for LSCS (or post delivery procedures) whenever possible
- Use of **Rapid Sequence Induction** technique when GA is given
- These precautions are recommended from 16-20 weeks until approximately 2 weeks after delivery
- Promoting labour epidurals for all women in labour who may have a risk of difficult intubation.

Liver Function Changes in Pregnancy

Parameter	Change in Pregnancy
Albumin	Decreased
Alkaline phosphatase (from placenta)	Increased
ALT/AST	No change
Plasma cholinesterase	Decreased

Pregnancy induces a hypercoagulable state

Coagulation Changes in Late Pregnancy

Pregnancy induces a hypercoagulable state

- The **total leucocyte count** increases to close to upper limit of normal; This may cause confusion at diagnosis of sepsis.
- **Platelet count increases** to above average levels (>400,000) close to term.
- The **clotting factor levels go up** leading to a hypercoagulable state around term. These changes are adaptations to reduce blood loss at normal delivery.
- The **risk of DVT and PE** is high in pregnancy.

Haematological Changes Associated with Pregnancy

VARIABLE	NON-PREGNANT	PREGNANT
Haemoglobin	14 g dL^{-1}	12 g dL^{-1}
Haematocrit	0.40–0.42	0.31–0.34
Red cell count	4.2×10^{12} L^{-1}	3.8×10^{12} L^{-1}
White cell count	6.0×10^{9} L^{-1}	9.0×10^{9} L^{-1}
ESR	10	58–68
Platelets	$150–400 \times 10^{9}$ L^{-1}	$120–400 \times 10^{9}$ L^{-1}

Summary

- A significant increases in blood volume and uterine blood flow is seen
- Maintenance of left lateral position is important
- Changes in airway, oxygen consumption increase the risk of hypoxia and difficult intubation
- Aspiration prophylaxis is important