William obstetric 26th -- Maternal Physiology

R2 劉子榕

Content

- REPRODUCTIVE TRACT
- BREASTS
- SKIN
- METABOLIC CHANGES
- HEMATOLOGICAL CHANGES
- CARDIOVASCULAR SYSTEM
- RESPIRATORY TRACT
- URINARY SYSTEM
- GASTROINTESTINAL TRACT
- ENDOCRINE SYSTEM
- MUSCULOSKELETAL SYSTEM
- CENTRAL NERVOUS SYSTEM

REPRODUCTIVE TRACT

Uterus

Uterine hypertrophy

Shape and position

Uterine Contractility

Uteroplacental Blood Flow

Uteroplacental Blood Flow Regulation

Cervix

Ovaries

- Relaxin

Fallopian Tubes

Vagina and Perineum

BREASTS

SKIN

Abdominal all

Hyperpigmentation

Vascular Changes

Hair Changes

Anagen

catagen

telogen effluivium

METABOLIC CHANGES

TABLE 4-1. Additional Energy Demands During Normal Pregnancy[a]

	Rates of Tissue Deposition			
	1st Trimester g/d	2nd Trimester g/d	3rd Trimester g/d	Total Deposition g/280 d
Weight gain	17	60	54	12,000
Protein deposition	0	1.3	5.1	597
Fat deposition	5.2	18.9	16.9	3741

Energy Cost of Pregnancy Estimated from Basal Metabolic Rate and Energy Deposition					
	1st Trimester kJ/d	2nd Trimester kJ/d	3rd Trimester kJ/d	Total Energy Cost MJ	Kcal
Protein deposition	0	30	121	14.1	3370
Fat deposition	202	732	654	144.8	34,600
Efficiency of energy utilization[b]	20	76	77	15.9	3800
Basal metabolic rate	199	397	993	147.8	35,130
Total energy cost of pregnancy	**421**	**1235**	**1845**	**322.6**	**77,100**

[a]Assumes an average gestational weight gain of 12 kg.
[b]Efficiency of food energy utilization for protein and fat deposition estimated as 0.90.
Adapted from the World Health Organization, 2004.

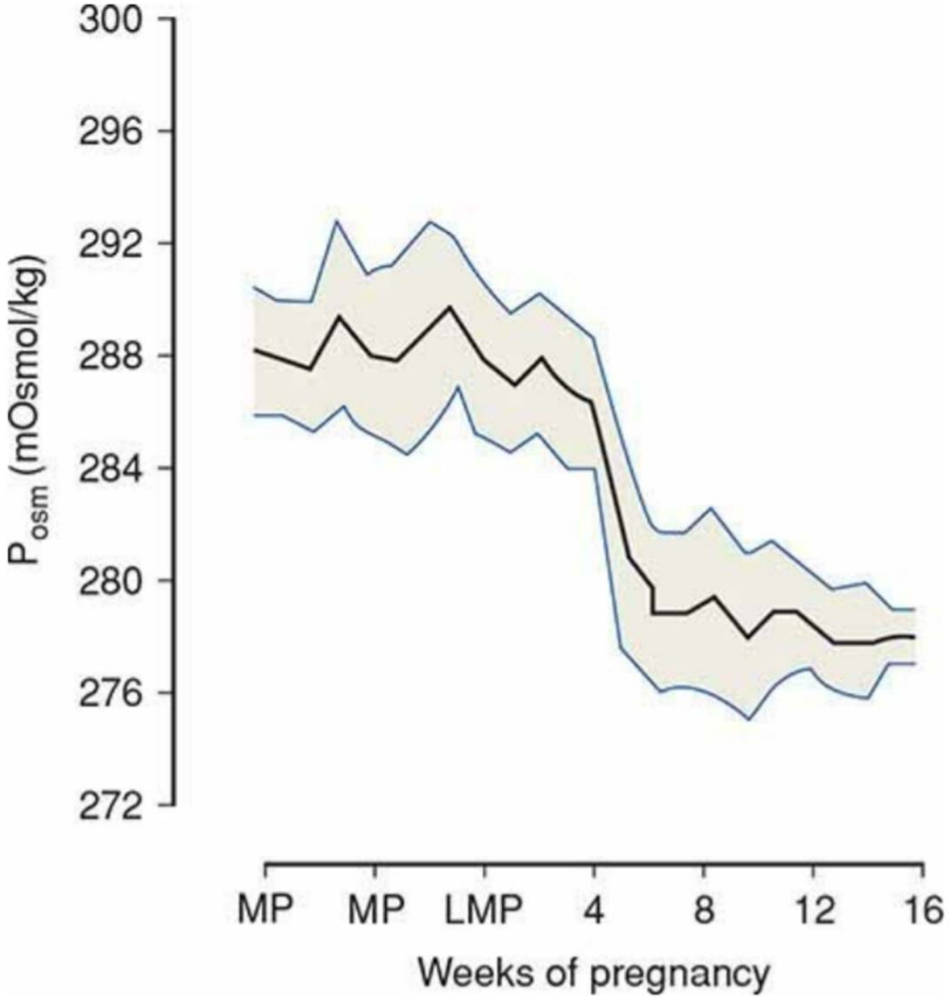
Weight gain—maternal reserves

TABLE 4-2. Weight Gain Based on Pregnancy-Related Components

Tissues and Fluids	Cumulative Increase in Weight (g)			
	10 Weeks	20 Weeks	30 Weeks	40 Weeks
Fetus	5	300	1500	3400
Placenta	20	170	430	650
Amnionic fluid	30	350	750	800
Uterus	140	320	600	970
Breasts	45	180	360	405
Blood	100	600	1300	1450
Extravascular fluid	0	30	80	1480
Maternal stores (fat)	310	2050	3480	3345
Total	**650**	**4000**	**8500**	**12,500**

Modified from Hytten, 1991.

Water metabolism



Protein metabolism

Normally grown fetus and placenta : 4 kg (500 g of protein)

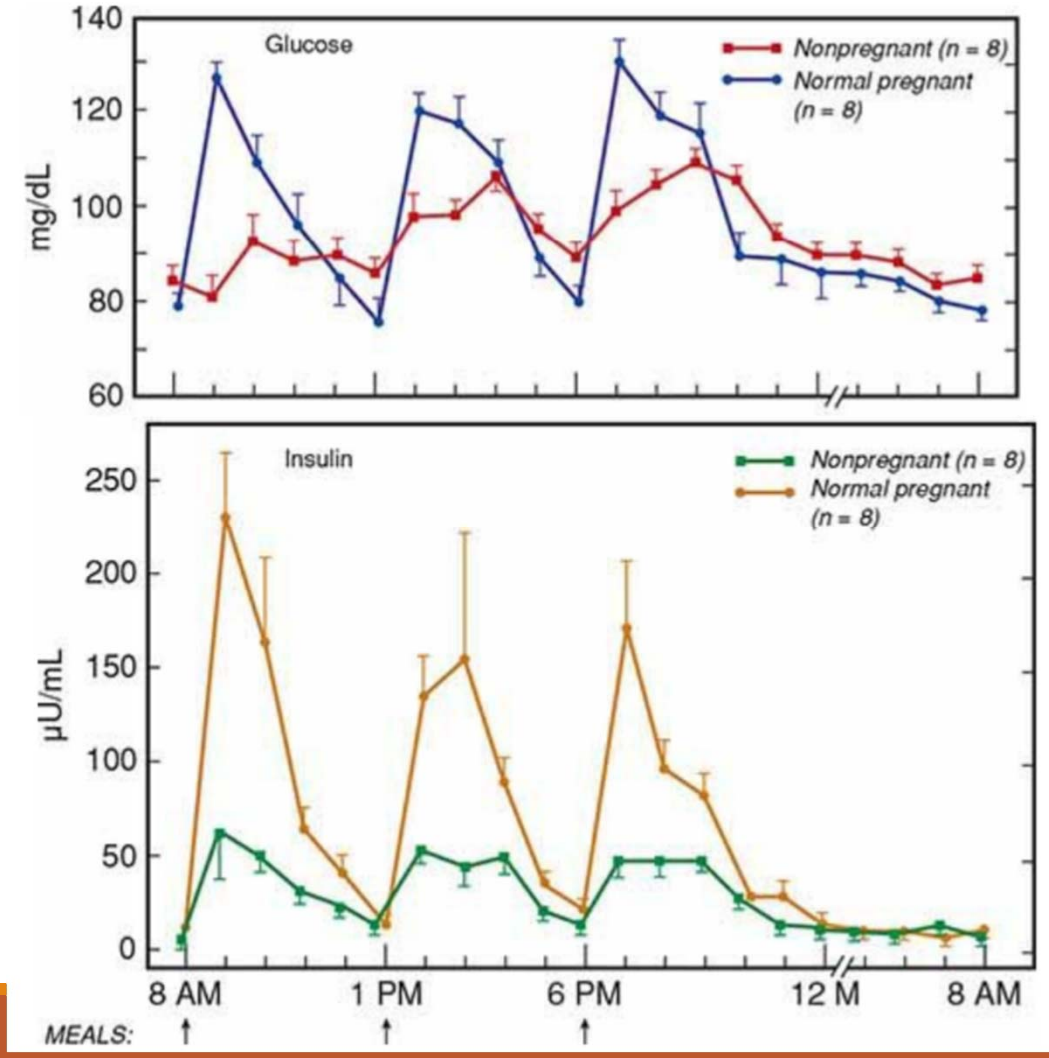
- uterus → contractile protein
- breasts →primarily in the glands
- Maternal blood → hemoglobin and plasma proteins

Amino acid concentration : Fetal > Maternal compartment

Current recommendation: 0.88 g/kg/d

- Early pregnancy : 1.22 g/kg/d
- Late pregnancy : 1.52 g/kg/d

Carbohydrate metabolism



Fat metabolism

TABLE 4-3. Plasma Concentrations of Lipids

Lipid	Nonpregnant	Third Trimester[a,b]
Total cholesterol	<200 mg/dL	267 ± 30 mg/dL
LDL	<100 mg/dL	136 ± 33 mg/dL
HDL	40–60 mg/dL	81 ± 17 mg/dL
Triglycerides	<150 mg/dL	245 ± 73 mg/dL

[a]Values from the Appendix (p. 1231).
[b]Values expressed as mean ± standard deviation.
HDL = high-density lipoprotein; LDL = low-density lipoprotein.

Electrolyte and mineral metabolism

Na+ k

Ca

Mg

Phosphate

Iodine

Hematological Changes

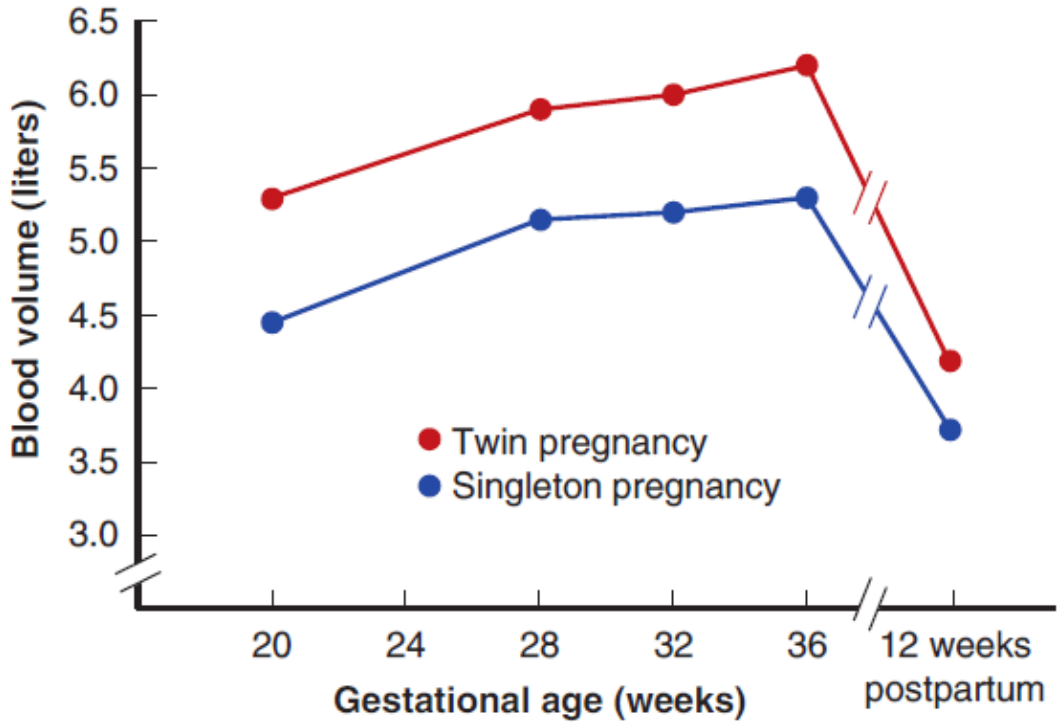
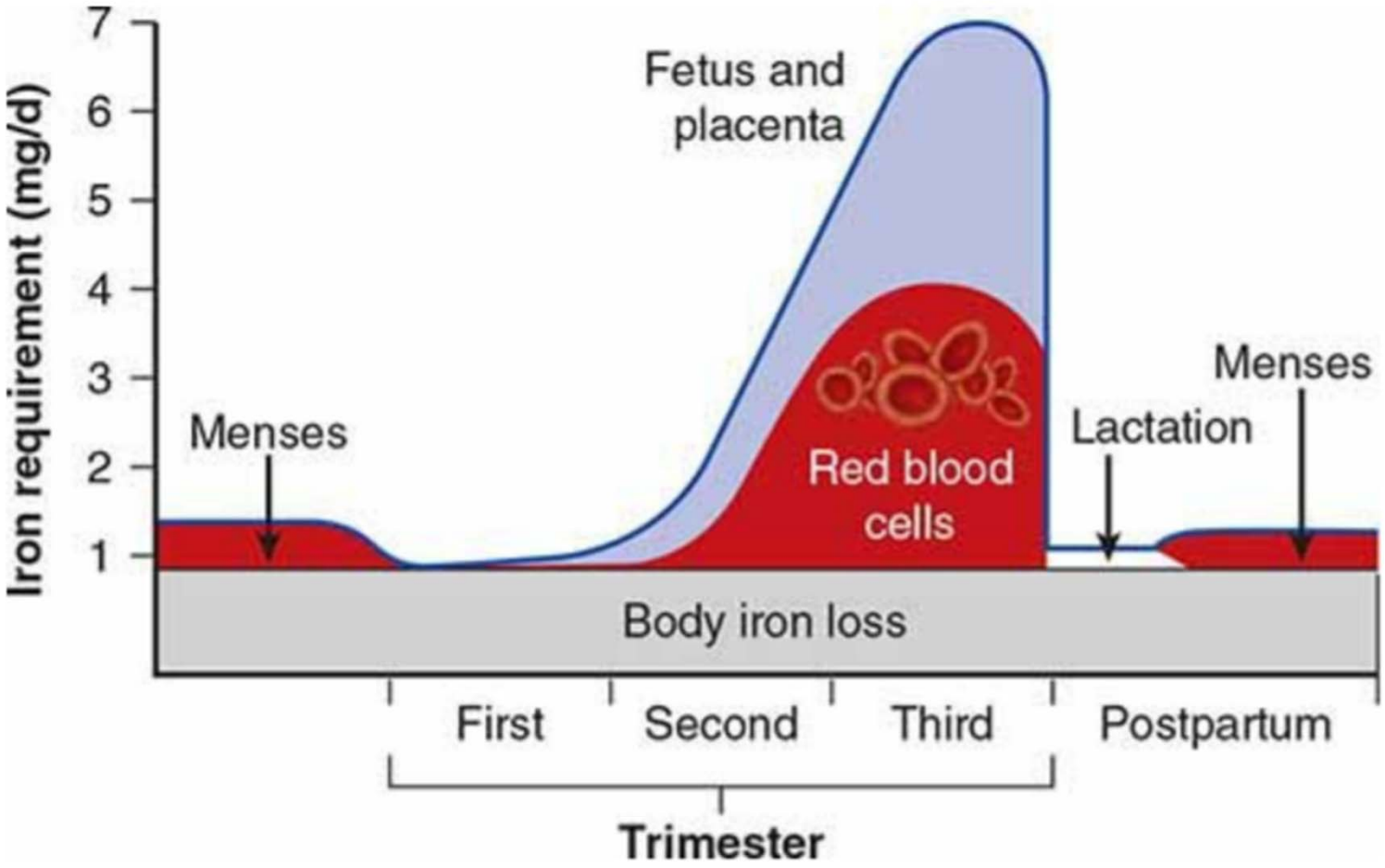


FIGURE 4-4 Blood volume expansion during pregnancy in twins (n = 10) and singletons (n = 40). Data shown as medians.

Iron metabolism



Leukocytes and Lymphocytes

Normal leukocyte counts during pregnancy can be higher than nonpregnant values

Distribution of lymphocyte cell types is also altered during pregnancy.

- B lymphocytes numbers are unchanged
- Absolute numbers of T lymphocytes rise and create a relative increase.
- The ratio of CD4 to CD8 T lymphocytes does not change

Inflammatory Markers

Tests for inflammation cannot be used reliably during pregnancy.

- leukocyte alkaline phosphatase levels
- C-reactive protein
- erythrocyte sedimentation rate (ESR)
- Complement factors C3 and C4
- procalcitonin

	Nonpregnant Adult[a]	1st Trimester	2nd Trimester	3rd Trimester	References
C3 complement (mg/dL)	83–177	62–98	73–103	77–111	42
C4 complement (mg/dL)	16–47	18–36	18–34	22–32	42
C-reactive protein (CRP) (mg/L)	0.2–3.0	Not reported	0.4–20.3	0.4–8.1	28
Erythrocyte sedimentation rate (ESR) (mm/hr)	0–20[d]	4–57	7–47	13–70	71
IgA (mg/dL)	70–350	95–243	99–237	112–250	42
IgG (mg/dL)	700–1700	981–1267	813–1131	678–990	42
IgM (mg/dL)	50–300	78–232	74–218	85–269	42

Coagulation and Fibrinolysis

TABLE 4-3. Changes in Measures of Hemostasis During Normal Pregnancy

Parameter	Nonpregnant	Term Pregnant
Activated PTT (sec)	31.6 ± 4.9	31.9 ± 2.9
Fibrinogen (mg/dL)	256 ± 58	473 ± 72[a]
Factor VII (%)	99.3 ± 19.4	181.4 ± 48.0[a]
Factor X (%)	97.7 ± 15.4	144.5 ± 20.1[a]
Plasminogen (%)	105.5 ± 14.1	136.2 ± 19.5[a]
tPA (ng/mL)	5.7 ± 3.6	5.0 ± 1.5
Antithrombin III (%)	98.9 ± 13.2	97.5 ± 33.3
Protein C (%)	77.2 ± 12.0	62.9 ± 20.5[a]
Total protein S (%)	75.6 ± 14.0	49.9 ± 10.2[a]

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f the

Regulatory Prote

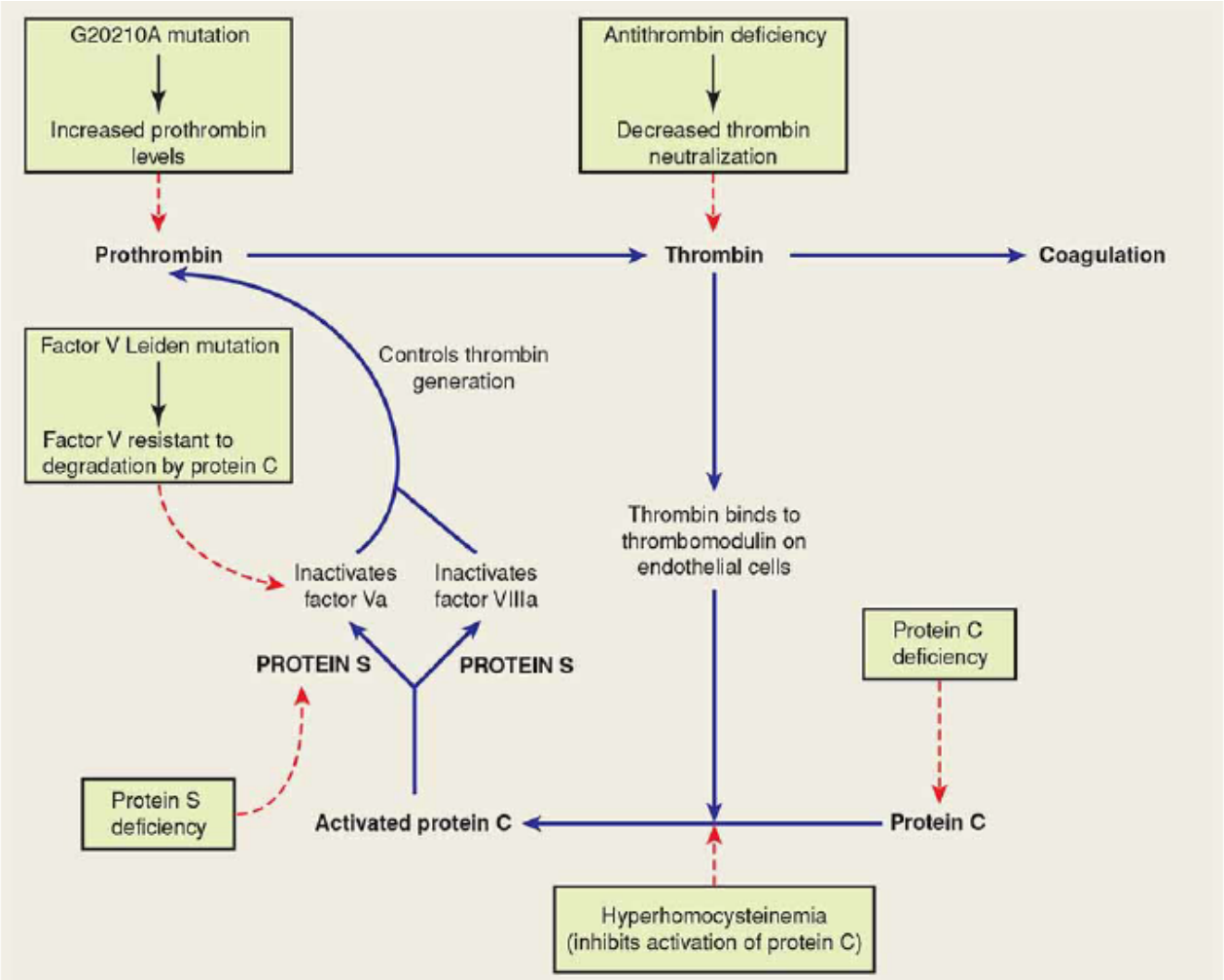
Several proteins are natural inh

Activated protein C, along with
an anticoagulant by neutralizin

During pregnancy, resistance to
concomitant drop in free prote

Between the first and third trim
- Activated protein C: 2.4 -> 1.9 U/m

Between mid-pregnancy and te
- Antithrombin levels decrease by 1



Cardiac output ↑ as early as th

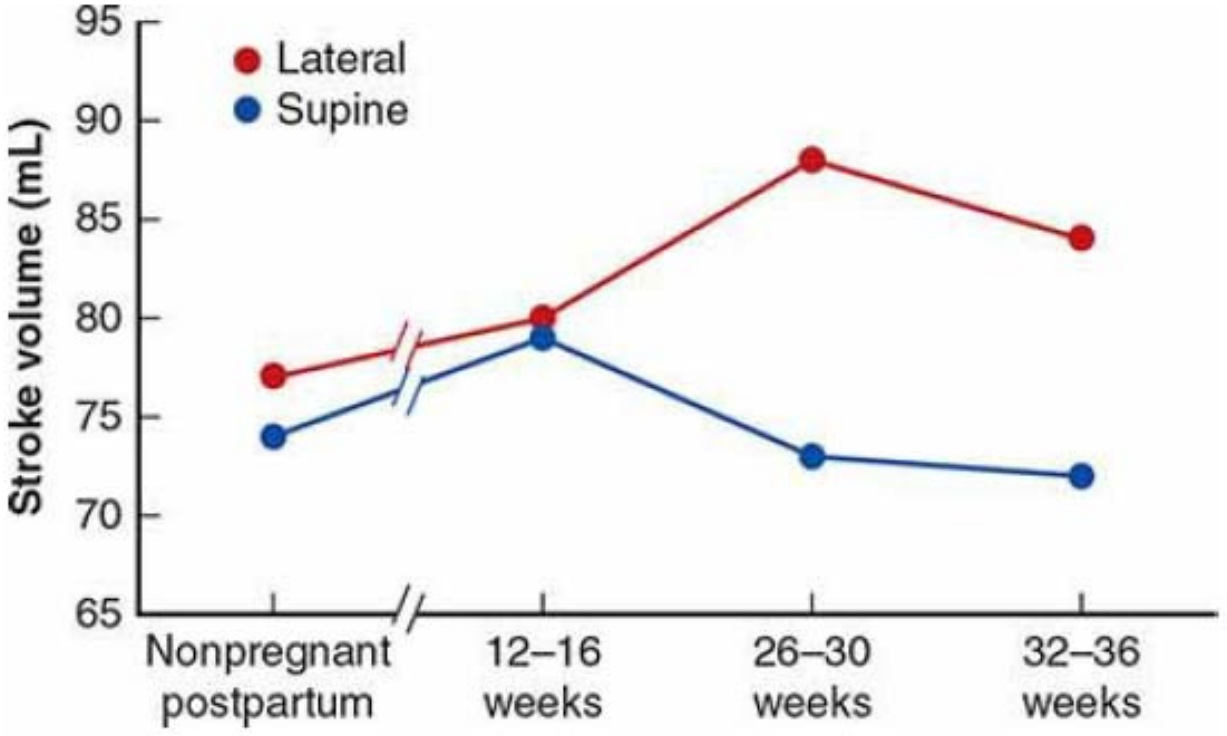
- Reflects systemic vascular resis
- Heart rate↑

Brachial SBP, diastolic BP, and c
menstrual period

The resting pulse rate rises ～1
heart rate↑ 12-16 weeks and 3

Weeks 10 and 20, plasma volu
significantly larger left atrial vo

Ventricular performance during
vascular resistance and change

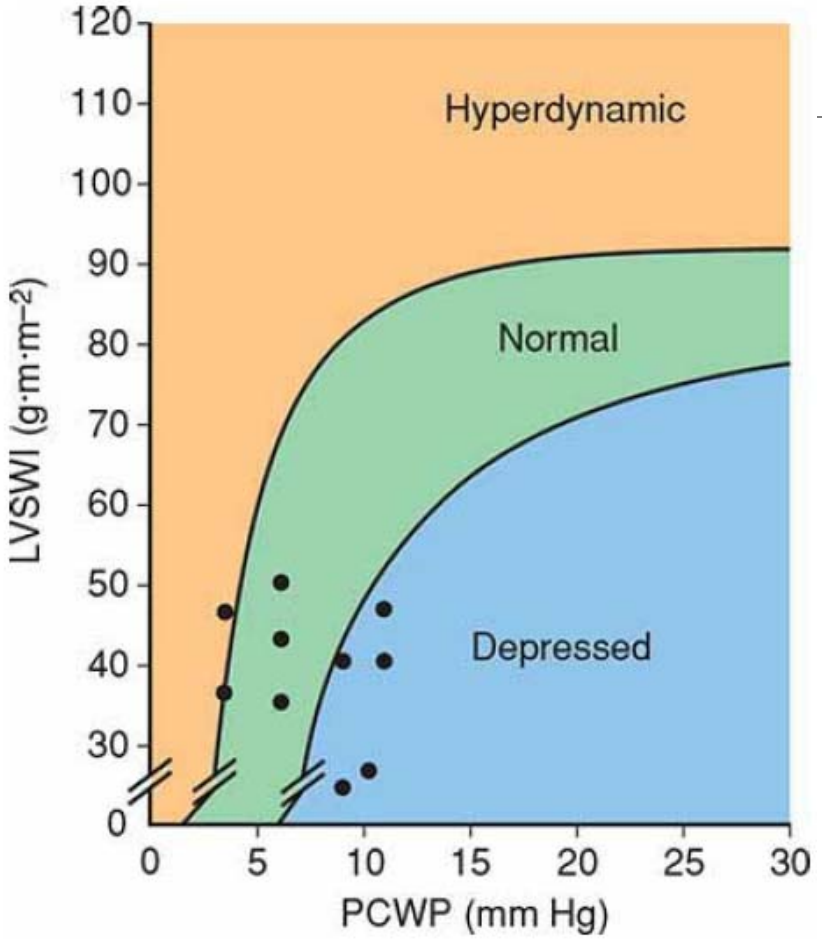


Hemodynamic Function in late Pregnancy

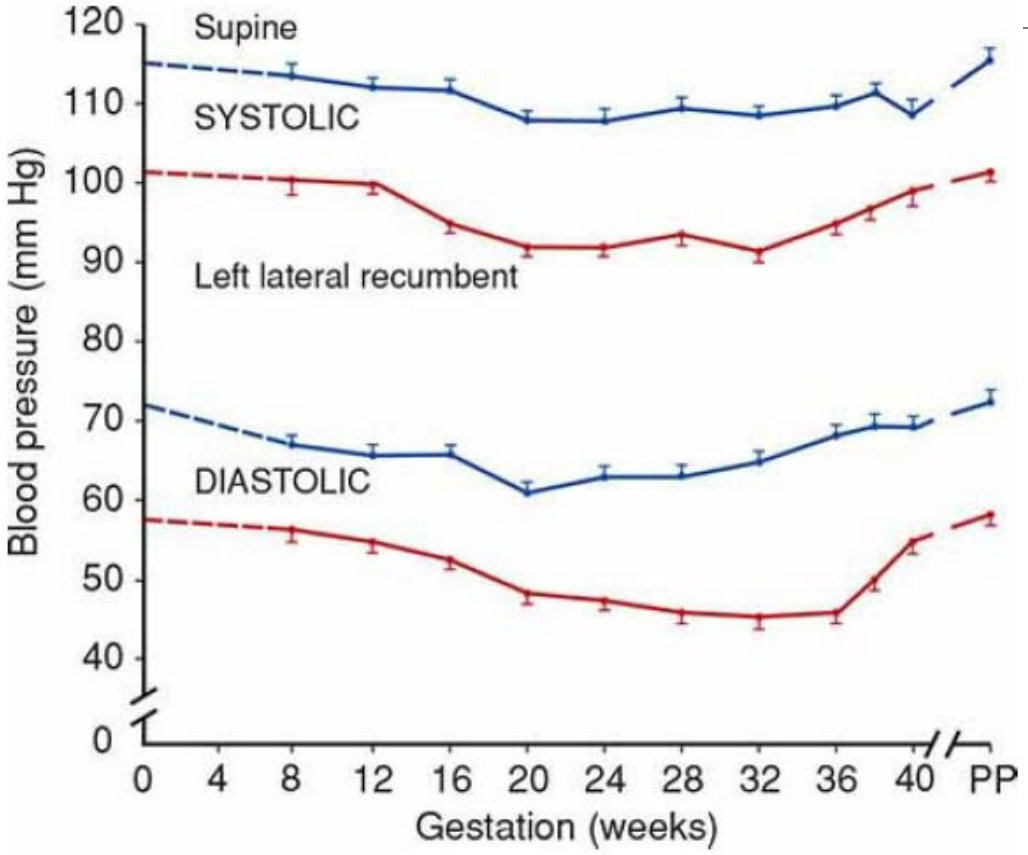
TABLE 4-4. Central Hemodyna
Near Term and Pos

Mean arterial pressure (mm Hg)	
Pulmonary capillary wedge pressure (m	
Central venous pressure (mm Hg)	
Heart rate (beats/min)	
Cardiac output (L/min)	
Systemic vascular resistance (dyn/sec/c	
Pulmonary vascular resistance (dyn/sec/	
Serum colloid osmotic pressure (mm Hg	
COP-PCWP gradient (mm Hg)	
Left ventricular stroke work index (g/m/	

[a]Measured in lateral recumbent position
[b]Changes significant unless NSC = no si
COP = colloid osmotic pressure; PCWP
Data from Clark, 1989.

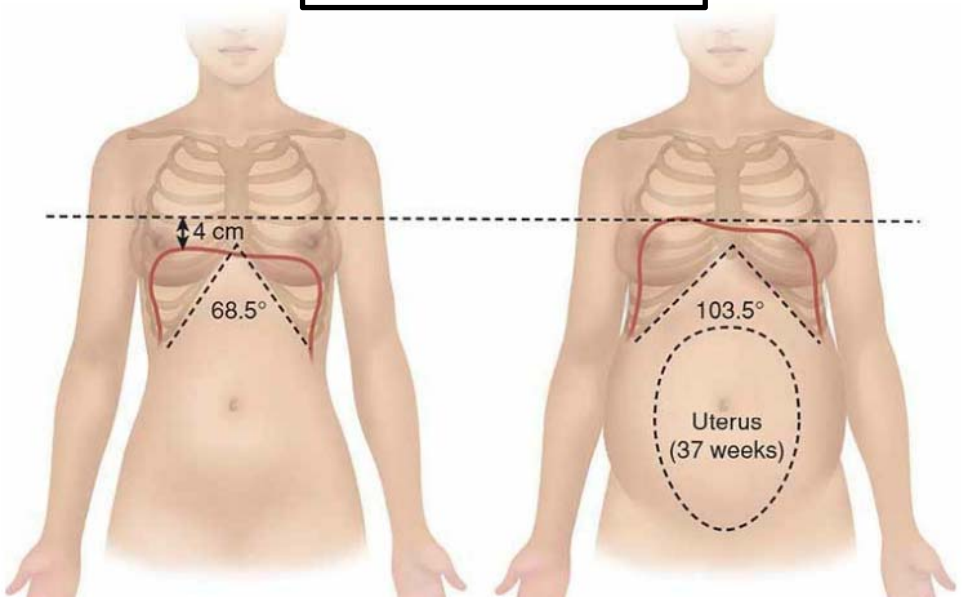


Circulation and Blood Pressure

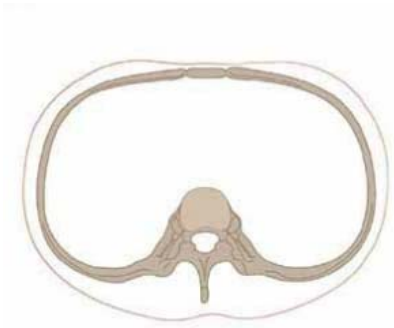


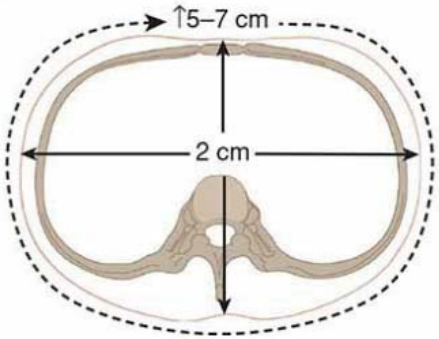
Anatomic change

1. Diaphragm rises approximately 4 cm



2. Thoracic cage lengthens increases approximately 2 cm





3. Thoracic circumference increases about 6 cm

- **Total lung capacity(TLC) is not significantly reduced**

Pulmonary function

(Inspiratory capacity)

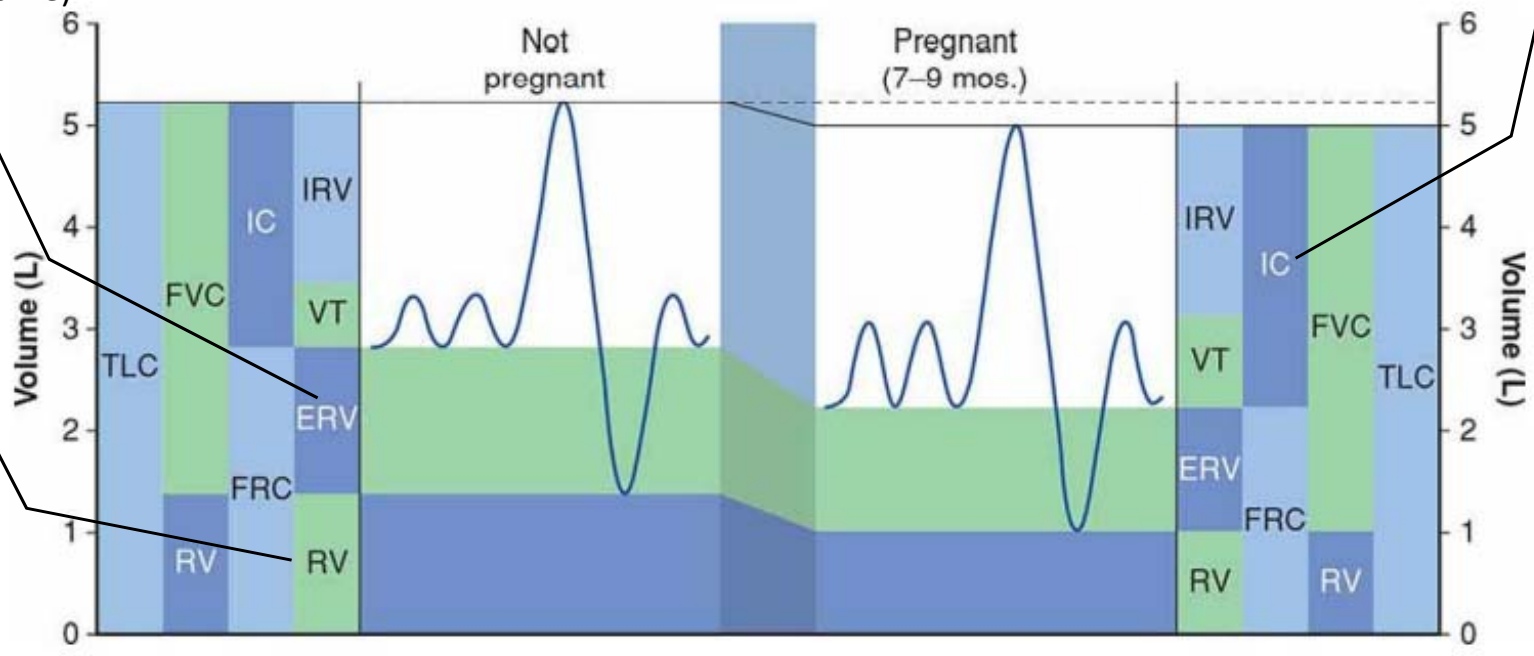
IC rises 5-10%(200-350ml)

(expiratory reserve volume)

ERV drops 15-20%(200-300ml)

(residual volume)

RV drops 20-25%(200-400ml)



- **Total lung capacity (FRC + IC) is unchanged or decreases by less than 5 % at term**

Pulmonary function

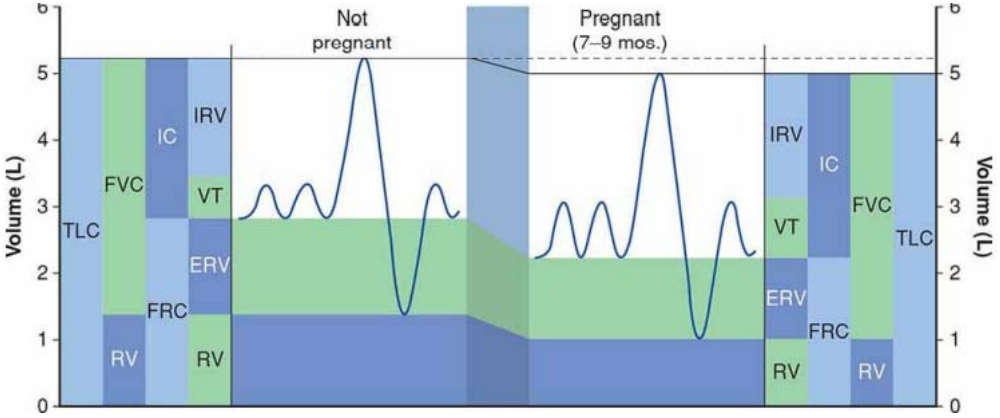
↑	IC	VT
		IRV
↓	FRC	ERV
		RV

1. Greater mean tidal volumes(VT)—0.66 to 0.8 L/min (normal: 0.4-0.6L/min)
2. Greater resting minute ventilations—10.7 to 14.1 L/min (normal: 5-6L/min)

   (1) Stimulatory action of progesterone

   (2) Compensated respiratory alkalosis

   (3) Low expiratory reserve volume

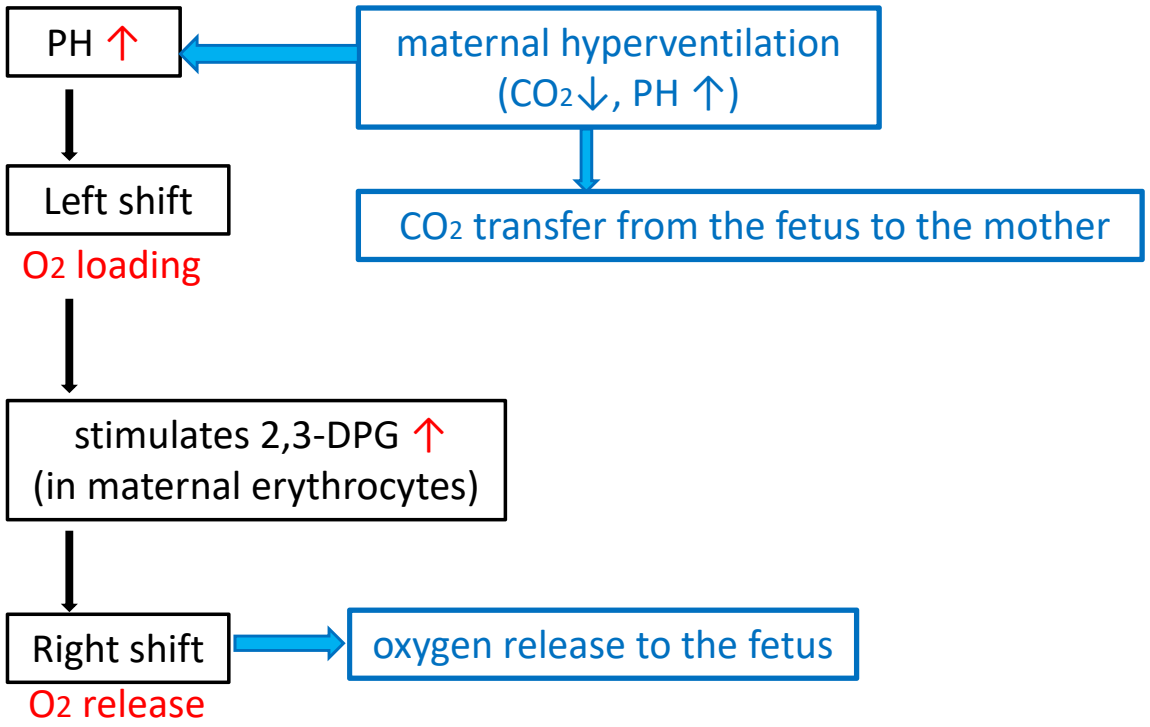


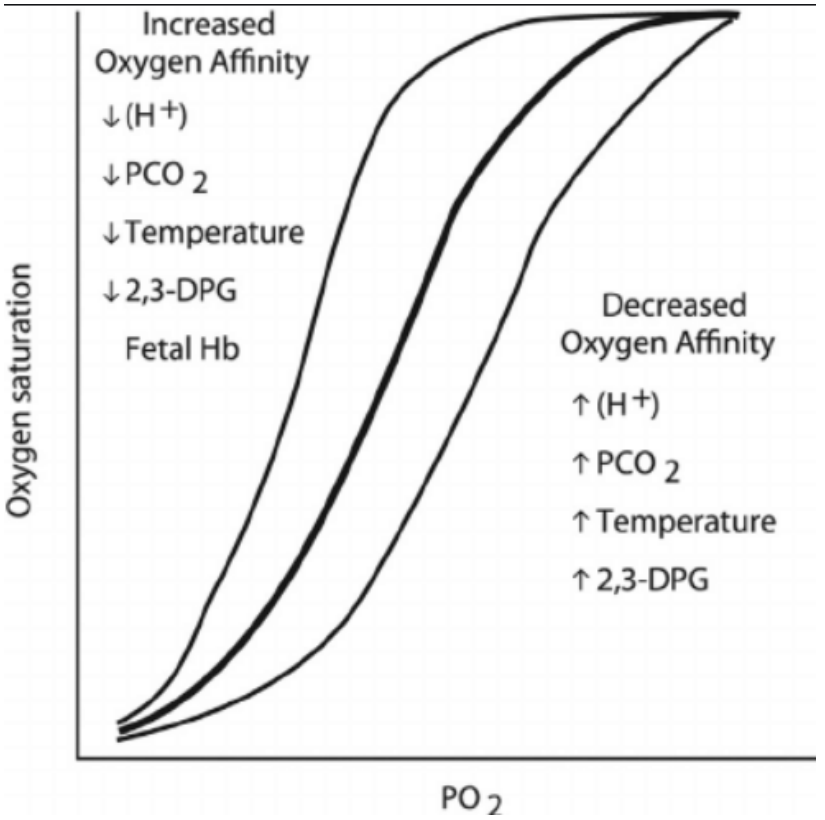
Oxygen delivery

1. Tidal volume ↑ → Oxygen delivered into lung ↑
2. Total hemoglobin mass ↑ → Total oxygen-carrying capacity ↑
3. Cardiac output(CO) ↑
4. Oxygen consumption ↑

- Increases 20% during pregnancy
- 10% higher in multifetal gestations
- Increases 40 to 60% during labor

Acid–Base Equilibrium



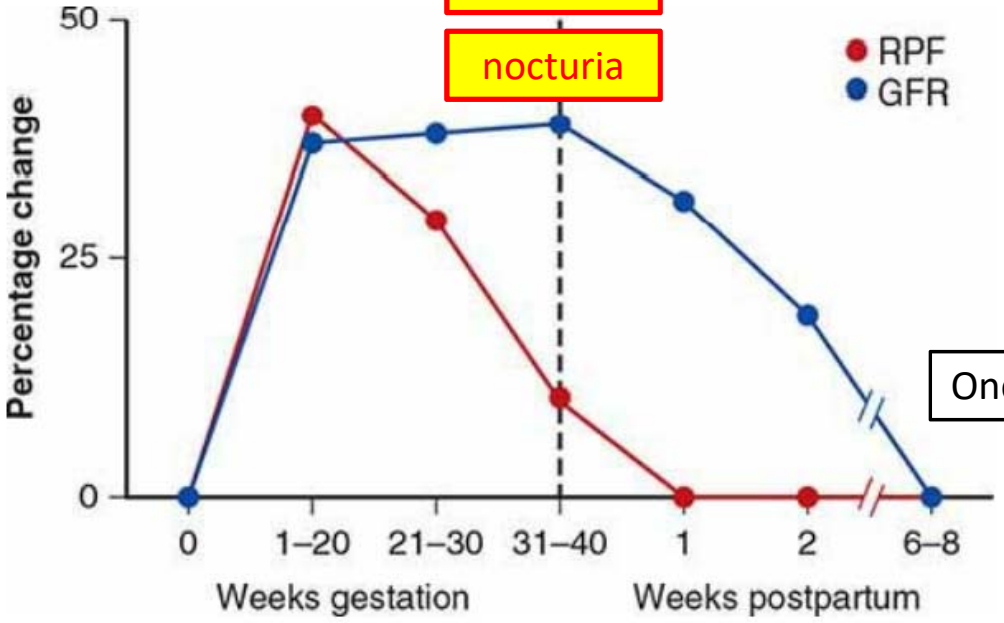


Kidney

1. **Kidney size grows approximately 1.0 cm**

frequency

nocturia



2. **Glomerular filtration rate (GFR) increase~ 50%**

RPF increases by 80%

Hypervolemia-induced hemodilution

Protein concentration ↓

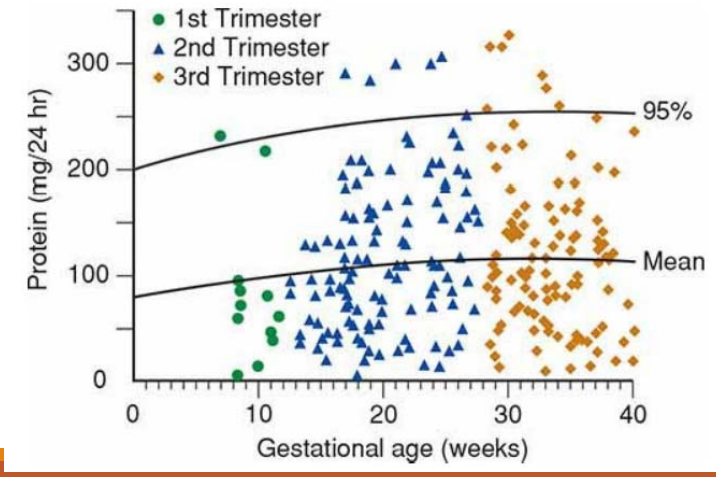
Oncotic pressure of plasma entering the glomerular microcirculation ↓

GFR ↑

Urinalysis

1. Proteinuria

- **In nonpregnant : more than 150 mg/day**
- **During pregnancy : at least 300 mg/day is considered significant**
- Mean 24-hour excretion for all three trimesters was 115 mg (95% confidence limit was 260 mg/d)
- **Proteinuria increases with gestational age**



Bladder

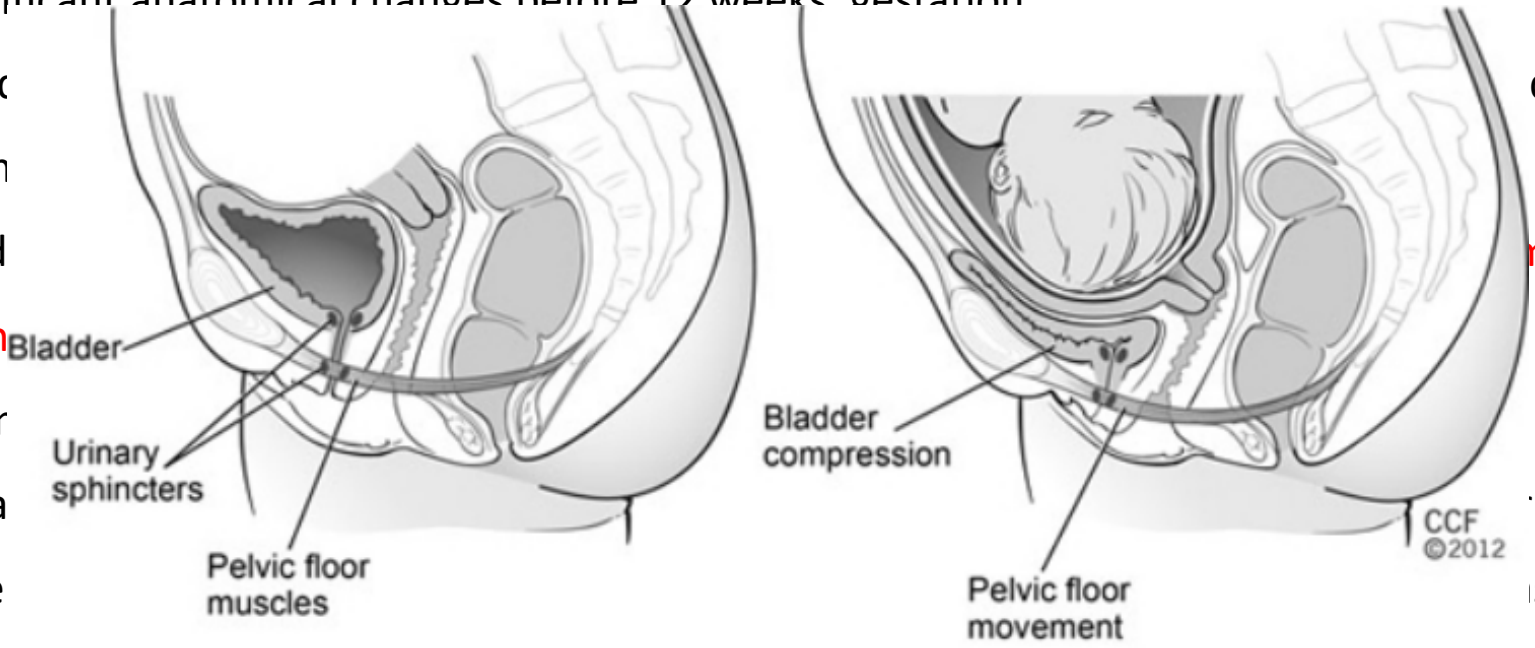
1. Few significant anatomical changes before 12 weeks' gestation
2. Increased
   and conn
   (1) Bladd
   (2) Ureth
   (3) Maxir
   (4) At lea
3. Pressure

dder muscle

n H_2O at term

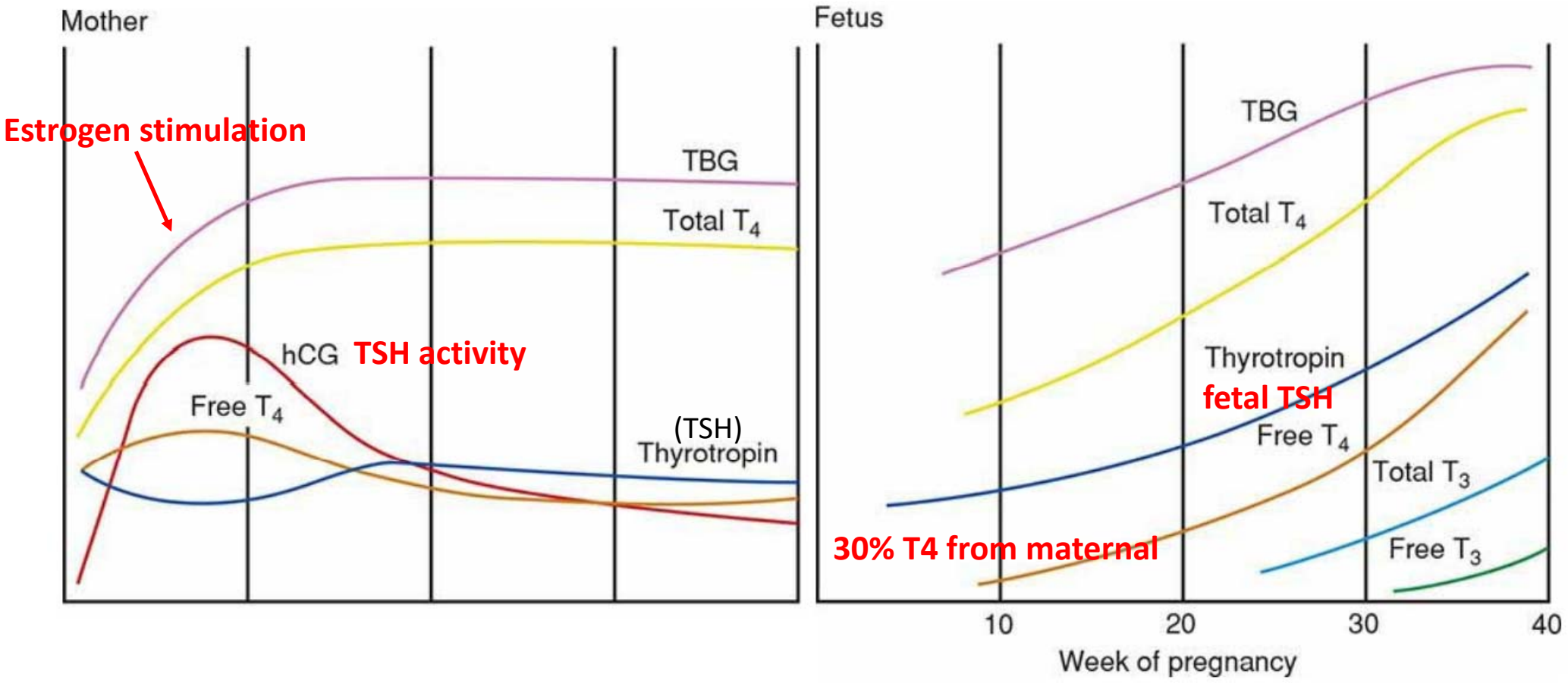
imester

se, often



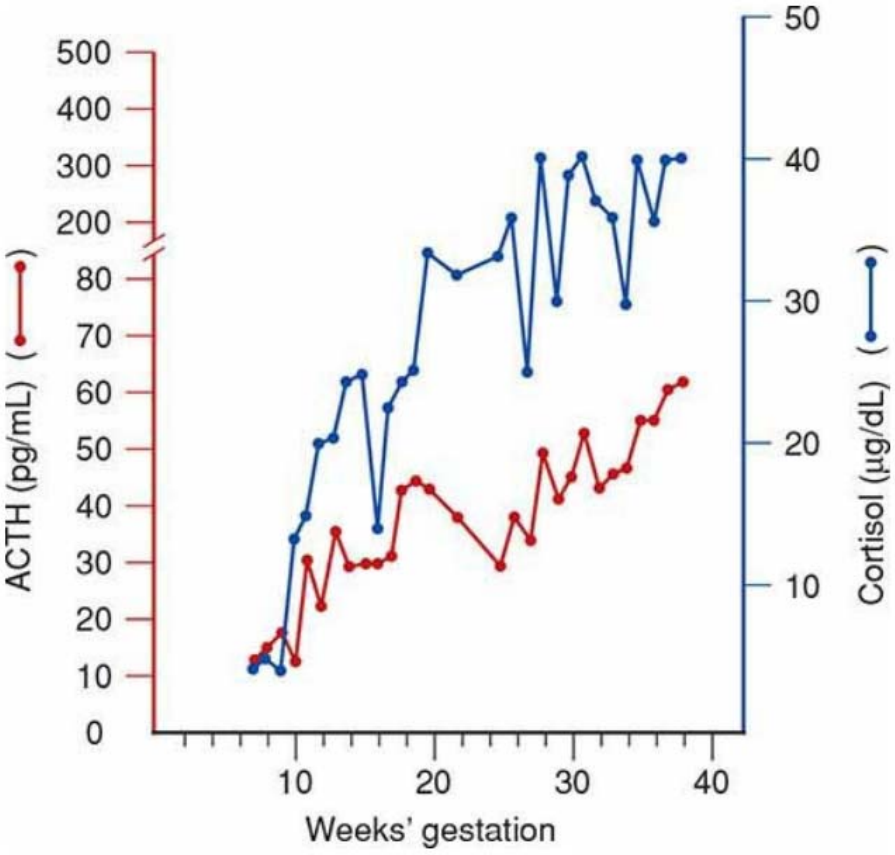
rendering the area edematous, easily traumatized, and possibly more susceptible to infection.

Thyroid Gland



Adrenal -- Cortisol

- Serum cortisol concentration ↑
  ∵ Cortisol secretion rate is not elevated, clearance rate ↓
- But much of it is bound by transcortin.



REFERRENCE

Thank you for attention