

Maternal Adaptations of Pregnancy

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Importance

- Transformations in nearly every organ system
- Fundamental to caring for pregnant women
- Misinterpreting normal adaptations
 can lead to unnecessary testing
- Help understand maternal symptoms
 and complications

Hormonal Adaptations



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Hormonal: Human chorionic gonadotrophin

- Source: placental synctiotrophoblasts
 - Detectable ~8 days post fertilization
 - Peaks at ~8-11 weeks gestation
- Functions:
 - Maintains corpus luteum
 - Promotes uterine angiogenesis
 - Suppresses maternal immune response to embryo



- Clinical relevance:
 - Marker of abnormal pregnancies, multiple gestation

Hormonal: Progesterone

• Source:

- Corpus luteum (first 8-10 weeks)
- Placenta

• Functions:

- Decidualization of stromal cells
- Promotes lobules and alveoli development in breast
- Relaxes smooth muscle
 - ${\scriptstyle \odot}$ Maintains uterine quiescence
 - GI (constipation, GERD)
 - Musculoskeletal changes



- Clinical relevance:
 - Marker for early pregnancy failure
 - Progesterone supplementation in shortened cervix
 - Luteal phase deficiency support

Hormonal: Estrogen

• Source:

- Corpus luteum (first 8-10 weeks)
- Placenta

• Functions:

- Stimulates proliferation of uterine stromal cells, glands, and vasculature
- Promotes proliferation and branching of breast ductal system
- Supports maternal immune tolerance of the fetus



- Clinical relevance:
 - Low levels of estriol in quad screen associated with Trisomy 18 & 21
 - High levels are associated with hyperpigmentation

Hormonal: Relaxin

• Source:



• Functions:

- Remodels reproductive tract connective tissue
- Increases renal blood flow
- Increases ligament laxity



Hormonal: Human placental lactogen

• Source:

Placental synctiotrophoblasts

• Functions:

- Induces insulin resistance in mother to ensure glucose availability for fetus
- Promotes lipolysis as an alternate maternal energy source

• Clinical relevance:

 Contributes to development of gestational diabetes



Jerome F. Strauss III, Sam A. Mesiano. Chapter 41 - Placental Production of Peptide, Steroid, and Lipid Hormones, Maternal-Fetal and Neonatal Endocrinology Physiology, Pathophysiology, and Clinical Management 2020, Pages 685-706

Cardiovascular

Cardiac output

- From 4.5 L/min \rightarrow 6.0 L/min
- Begins to increase as early as 5 weeks' gestation
- ↑ 30–50% by mid-pregnancy
- Peaks ~20–24 weeks

• Peripheral vascular resistance

- Nadir in second trimester
- BP rises toward baseline by term
- Due to progesterone and relaxin



Cardiovascular Physiology of Pregnancy. Monika Sanghavi, and John D. Rutherford. Circulation Volume 130, Number 12

Cardiovascular

Vasodilation

- Promotes uterine blood flow
- Increased risk of peripheral edema, varicosities, supine hypotension

Inferior vena cava compression

- Uterine enlargement compresses
 IVC when supine
- Relieved by left lateral position

• Heart sounds

- Increased blood volume, CO, SV, HR lead to hyperdynamic circulation
- Enhanced flow causes turbulent flow across aortic and pulmonic valves
- Physiologic:
 - \circ Grade \leq 2/6 systolic ejection murmur
- Pathologic
 - Diastolic component
 - $\,\circ\,$ Pansystolic or late systolic quality
 - \circ Grade ≥ 3/6
 - o Associated symptoms: dyspnea,

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Hematologic

• Plasma volume

- Increases by ~40–50% above baseline
- Begins at 6 weeks; Peaks by 32 weeks

Red blood cell mass

- Increases ~20–30%
- + erythropoietin
- Less than plasma volume increase
- Physiologic anemia
- Importance of iron intake



Weeks of pregnancy

Ezechi Oliver and Kalejaiye Olufunto. Management of Anaemia in Pregnancy. Anemia. 2012 DOI: 10.5772/28646

Trimester	1 st	2 nd	3 rd
Hemoglobin lower limit of normal (g/dL)	11.0	10.9	11.0

Coagulation

Procoagulants

- ↑ Fibrinogen, Factor VII, VIII, X
- Anticoagulants
 - \downarrow Protein S
- Fibrinolytics
 - Plasminogen activator inhibitors
- Prothrombotic state
 - Reduce hemorrhage risk at delivery
 - Increased risk of VTE

Coagulation factor	Change from non-pregnant state		
Antithrombin III	No change		
Plasma fibrinogen (factor I)	↑		
Factor II	No change		
Factor V	No change		
Factor VII	↑		
Factor VIII	↑		
Factor IX	No change		
Factor X	↑		
Free protein S	\downarrow		
Plasminogen activator inhibitor 1	↑		
Plasminogen activator inhibitor 2	\uparrow		
Protein C	No change		
von Willebrand factor	↑		

https://miscarriagehopedesk.org/blood-clotting-disorders-miscarriage/

Immunologic

Innate immunity

- Innate immune activity (NØ, MØ, NK cells)
- \uparrow Inflammatory cytokines (e.g. IL-6, TNF- α)
- Enhanced inflammatory responses to infections
 - Higher vascular permeability, leukocyte adhesion, coagulation activation

Adaptive immunity

- Cell-mediated immunity
- + Humoral immunity
- Varied effect on autoimmune diseases
 - Improved rheumatoid arthritis & multiple sclerosis
 - $_{\odot}$ Worsened lupus & asthma



Anuman I, Pienaar D, Suvakov S, Simic TP, Garovic VD, McClements L. Mechanisms of Key Innate Immune Cells in Early- and Late-Onset Preeclampsia. Front Immunol. 2020 Aug 18;11:1864. doi: 10.3389/fimmu.2020.01864. PMID: 33013837; PMCID: PMC7462000.

Respiratory

Increased CO2 Elimination

- Minute ventilation
 - Respiratory rate unchanged
 ↑ Tidal volume (30–40%)
- Normal to have chronic respiratory alkalosis
 - $\circ \downarrow \mathsf{PaCO}_2, \uparrow \mathsf{pH}$
- A "normal" CO₂ in pregnancy is abnormal and may indicate impending respiratory failure

Increased O2 Consumption

- Driven by metabolic demands of fetus, uterus, and maternal organs
- ↓ respiratory reserve
- More rapid desaturation during apnea or anesthesia

Table 3 Arterial blood gas measurement alterations in pregnancy						
Arterial blood gas measurement	1st trimester	3rd trimester	Nonpregnant			
pН	7.42-7.46	7.43	7.4			
PaO2 (mm Hg)	105-106	101-106	93			
PaCO2 (mm Hg)	28-29	26-30	37			
Serum HCO3 (mEq/L)	18	17	23			

Sarah Dotters-Katz. Treatment Considerations for COVID-19 in Pregnancy. SMFM Webinar

Respiratory

- \downarrow Functional residual capacity
 - Volume of air remaining in the lungs at the end of a passive exhalation
 - Due to elevated diaphragm by 4-5cm
 - FRC decreases by ~20% (400– 500 mL) by the third trimester
 - Lower respiratory reserve
 - Increased risk of hypoxemia & rapid desaturation during airway obstruction, sedation, or anesthesia



TLC - Total Lung Capacity FVC - Forced Vital Capacity IC - Inspiratory Capacity FRC - Functional Residual Capacity

Volume (L)

IRV - Inspiratory Reserve Volume VT - Tidal Volume ERV - Expiratory Reserve Volume RV - Residual Volume

Hegewald MJ, Crapo RO. Respiratory physiology in pregnancy. Clin Chest Med. 2011 Mar;32(1):1-13. 10.1016/j.ccm.2010.11.001.

Endocrine

• Thyroid

- - $_{\odot}$ Elevated bound T4 values
 - $_{\odot}$ No change in free T4 and T3 levels
 - Fetus depends on maternal T4 until 20 weeks
- Increased basal metabolic rate

Structural similarity of TSH and hCG

- High serum hCG levels can cause thyroid stimulation
- α-subunits are identical
- β-subunits differ amino acid sequence



Editors. In: Cunningham F, Leveno KJ, Dashe JS, Hoffman BL, Spong CY, Casey BM. eds. *Williams Obstetrics, 26e*. McGraw Hill; 2022. Accessed July 14, 2025. https://accessmedicine.mhmedical.com/content.aspx?bookid=2977§ionid=263812626

Endocrine

Hypothyroidism

- 2-10/1,000 pregnancies
- Risks of miscarriage, preeclampsia, preterm birth, stillbirth, neurodevelopment
- Anti-TPO Ab rarely cross placenta
- Treatment: Levothyroxine

• Hyperthyroidism

- 2-7/1,000 pregnancies
- Risks of preeclampsia, heart failure, thyroid storm, preterm birth, stillbirth, miscarriage
- TSH-binding Ab may cross placenta
- Treatment: Propylthiouracil (T1)

 Methimazole or PTU (T2, T3)

"Universal testing for thyroid disease in pregnancy is not recommended. Indicated testing of thyroid function should be performed in women with a personal or family history of thyroid disease, type 1 diabetes mellitus, or clinical suspicion of thyroid disease." ACOG PB 223: Thyroid Disease in Pregnancy

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Endocrine

Pituitary gland

- ↑ Prolactin prepares breasts for lactation
- Oxytocin surges in labor
- Placental growth hormone
 - ↑ metabolism to increase availability of nutrients for fetus

Adrenal gland

- Cortisol: Glucose for fetus
- Aldosterone: sodium retention and plasma volume expansion



Taofeek O. Usman, Goma Chhetri, Hsuan Yeh, H. Henry Dong. Beta-cell compensation and gestational diabetes. Journal of Biological Chemistry, Volume 299, Issue 12, 2023, 105405, https://doi.org/10.1016/j.jbc.2023.105405.

Pancreas

- Insulin resistance
- Driven by human placental lactogen, cortisol, progesterone, and placental growth hormone

Renal

Anatomic changes

- Kidneys: enlarge by 1-1.5cm
- Hydronephrosis: dilated renal calices, more prominent on the right
- Hydroureters: Ureters dilate and exhibit decreased peristalsis
- Bladder: compression by uterus



Kadam, Dipali, Saurabh Patil, Avinash Dhok, and Meenal Jain. "MR urography in evaluating obstructive uropathy: one stop shop." *International Surgery Journal* 6, no. 3 (2019): 944. http://dx.doi.org/10.18203/2349-2902.isj20190829

Renal

- Due to ↑ renal plasma flow and vasodilation
- Serum creatinine and BUN decrease
- Normal Cr: ~0.4–0.6 mg/dL
 - $_{\odot}$ 1.0 may indicate renal dysfunction
- Mild proteinuria is normal
 o (<300 mg/day)
- Mild glycosuria is normal

- Renin-Angiotensin-Aldosterone System (RAAS) Activation
 - Supports sodium and water retention
 - Maintains plasma volume expansion
 - Lower osmolality and thirst threshold leads to increased water intake and mild hyponatremia

Gastrointestinal

Decreased gastric motility

- J Gastric emptying

 Bloating, acid reflux
 NPO status prior to procedures
- 1 Intestinal transit time
 - Due to progesterone, gravid uterus, iron supplementation
 - $_{\odot}$ Constipation
 - $_{\odot}$ Hemorrhoids from straining

Gallbladder and biliary tract

- Gallbladder stasis
- ↑ Cholesterol saturation → increased risk of gallstones

• Liver

- Alkaline phosphatase
 (produced by the placenta)
- AST, ALT, bilirubin unchanged
- Serum albumin ↓ due to hemodilution

Genital Tract

Uterus

- Growth from ~70 g at conception to ~1100 g at term
 - Hypertrophy of muscle fibers, not hyperplasia

Vagina

- ↑ Glycogen in epithelial cells metabolized by Lactobacillus to lactic acid
 - Acidic pH (3.5–6.0)
 - \circ Protects against pathogens

• Cervix

- By 4-6 weeks, increased edema, vascularity, hypertrophy and hyperplasia of glands
 - Chadwick sign (bluish coloration)
- Endocervical glands proliferate
 - \rightarrow form the mucus plug
 - $_{\odot}$ Protect from ascending infection

Musculoskeletal & Skin

Posture

- Lumbar lordosis to maintain center of gravity
- Gait change due to pelvic ligament laxity, driven by relaxin and progesterone
- Shift in weight-bearing
- Abdominal wall
 - Striae gravidarum
 - Diastasis recti

https://drmaryamzamani.com/blog/what-is-melasma/. https://veincenter.doctor/child-dermatologist-for-facial-spider-veins/

Skin



- Hyperpigmentation due to ↑ melanocyte-stimulating hormone and estrogen
- Face, areolae, Linea nigra, perineum
- Spider angiomas, palmar erythema

• Hair

- Hair growth ↑ during pregnancy (anagen phase prolonged)
- Telogen effluvium: postpartum hair loss 2–4 months after delivery

Questions?

NERVOUS SYSTEM Normal pregnancy: Sedation and fatigue due to increasing levels of allopregnanolone. Complicated pregnancy: Reduced seizure threshold in PE. Risk of cerebral edema and stroke in severe PE. Hyperemesis.

> IMMUNE SYSTEM Normal pregnancy: Suppressed immune response. Complicated pregnancy: Severe, systemic infections.

MAMMARY GLAND Normal pregnancy: Enlargement due to increased number of alveoli, larger glands and more supportive tissue. Complicated pregnancy: Not known.

> LIVER Normal pregnancy: Decreased serum levels of transaminases and bilirubin due to increased blood flow and dilution. Increased production of cholesterol, triglycerides and procosgulants. Increased glucogenesis and glycogenolysis. Slower emptying of bile from the gall bladder.

Complicated pregnancy: Liver edema and high levels of transaminases in HELP syndrome. Choldithiasis. Fatty liver of pregnancy. Increased glucose production in GDM. Increased levels of bile acids and bilirubin in ICP.

PANCREAS

Normal pregnancy: Increased insulin production. Stable secretion of pancreatic enzymes. Complicated pregnancy: Pancreatitis. Reduced insulin production in GDM and increased demand for insulin in pregnant women with diabetes type 1.

DIGESTIVE TRACT Normal pregnancy: Decreased motility in the gut causes constipation. Relaxation of cardia causes reflux. Changed microbiota? Complicated pregnancy: Severe hyperemesis with frequent vomiting and dehydration. Esophagitis and gastritis.

BONE Normal pregnancy: Increased calcium metabolism. Complicated pregnancy: Osteoporotic fractures in lote pregnancy.

RESPIRATORY SYSTEM

Normal pregnancy: Increased oxygen consumption and increased minute ventilation. Decreased vital capacity due to shrinking space in the thoracic cavity in late pregnancy. Dyspnea. *Complicated pregnancy:* Pulmonary edems in severe PE. Pulmonary emboli. Pneumonia.

HEMATOLOGICAL SYSTEM Normai pregnancy: Increased blood volume by 1200 - 1600 ml. Decreased hemoglobin and platelets due to dilution. Increased need of iron, folic acid and vitamin B12 from the fetus. Increased white blood cell count and fibrinogen levels. Complicated pregnancy: Venous thrombosis due to a thrombophilic state of the coagulation system during pregnancy.

CARDIOVASCULAR SYSTEM

Normal pregnancy: Increased cardiac output and heart rate to support the increasing requirements from uterus, placenta and fetus. Enlargement of the heart. Dilatation of peripheral arteries and effect on baroreceptor function. Dilatation causes varicose veins. Reduced blood pressure during mid-pregnancy.

Complicated prognancy: Gestational hypertension and PE. Cardiomyopathy, High maternal mortality in cases of structural heart disease including pulmonary arterial hypertension.

SPLEEN

Normal pregnancy: Enlargement, probably due to increased blood flow. Complicated pregnancy: Not known. the u ureter Complik Urinar

RENAL SYSTEM due Normal pregnancy: w. Enlargement of kidneys and increased glomerular filtration rate. Decreased re-absorption by tubuli. Relaxation of the urinary tract. Compression of the ureter predominantly on the right side. Complicated pregnancy: Hydonephrotis. Urinary tract infection, pyelonephritis. Kidney stones. Anuria and increased creatinine levels in severe PE.

SKELETAL MUSCLE Normal pregnancy: Increased insulin resistance in skeletal muscles. Change in body posture. Complicated pregnancy: Severe back- and pelvic girdle pain.

> ADIPOSE TISSUE Normal pregnancy: Increased adipose tissue in early pregnancy, later reduced. Complicated pregnancy: Obesty, Excessive gestational weight gain in women with GDM.

Vinnars MT, Bixo M, Damdimopoulou P. Pregnancy-related maternal physiological adaptations and fetal chemical exposure. Mol Cell Endocrinol. 2023 Dec 1;578:112064. doi: 10.1016/j.mce.2023.112064. Epub 2023 Sep 6. PMID: 37683908.

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Thank you! (Time for RELAXIN on the beach...)

