Maternal Adaptations of Pregnancy

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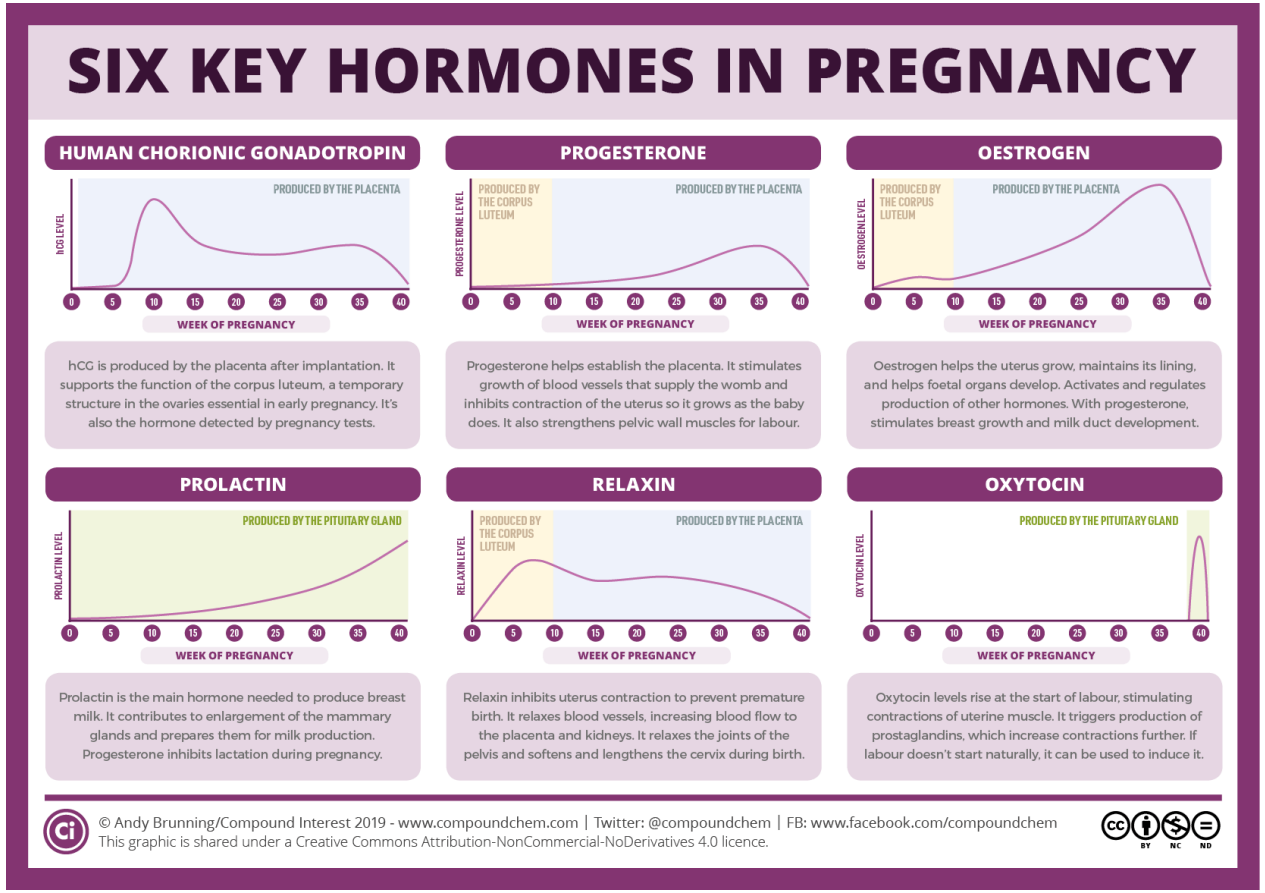
Importance

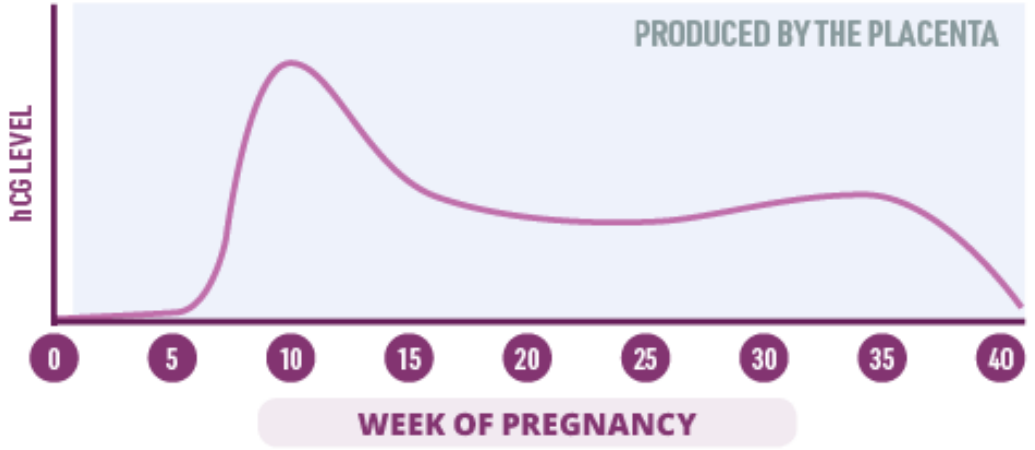
- Transformations in nearly every organ system
- Fundamental to caring for pregnant women
- Misinterpreting normal adaptations can lead to unnecessary testing
- Help understand maternal symptoms and complications

Hormonal Adaptations



Hormonal: Human chorionic gonadotrophin

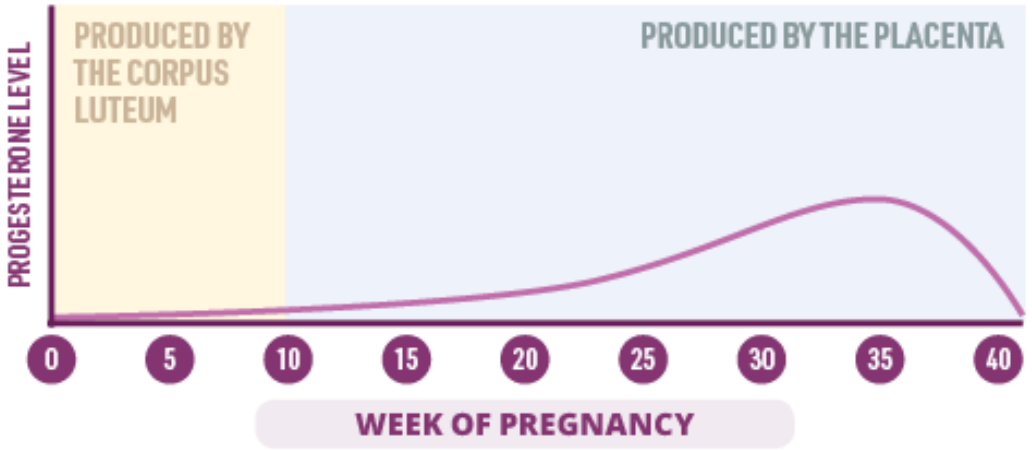
- Source: placental synctiotrophoblasts
  - Detectable ~8 days post fertilization
  - Peaks at ~8-11 weeks gestation
- Functions:
  - Maintains corpus luteum
  - Promotes uterine angiogenesis
  - Suppresses maternal immune response to embryo



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

Hormonal: Progesterone

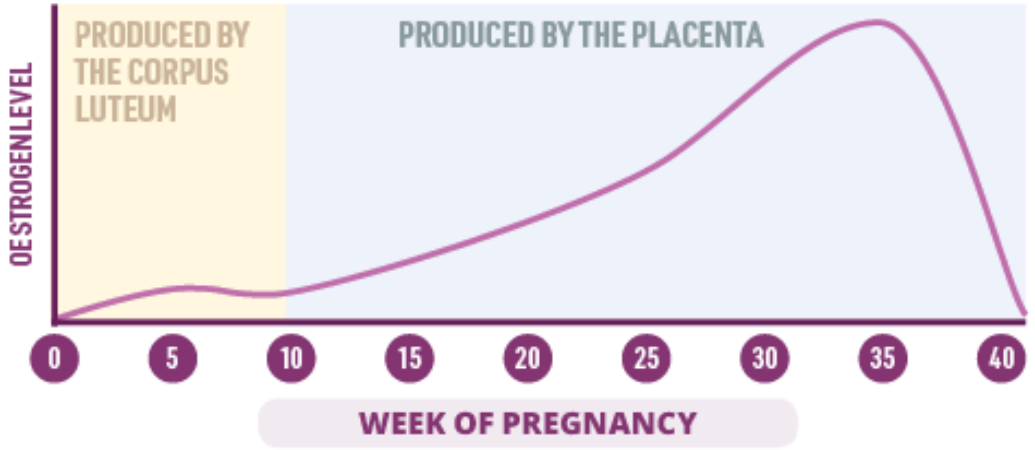
- Source:
  - Corpus luteum (first 8-10 weeks)
  - Placenta
- Functions:
  - Decidualization of stromal cells
  - Promotes lobules and alveoli development in breast
  - Relaxes smooth muscle
    - Maintains uterine quiescence
    - GI (constipation, GERD)
    - Musculoskeletal changes



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

Hormonal: Estrogen

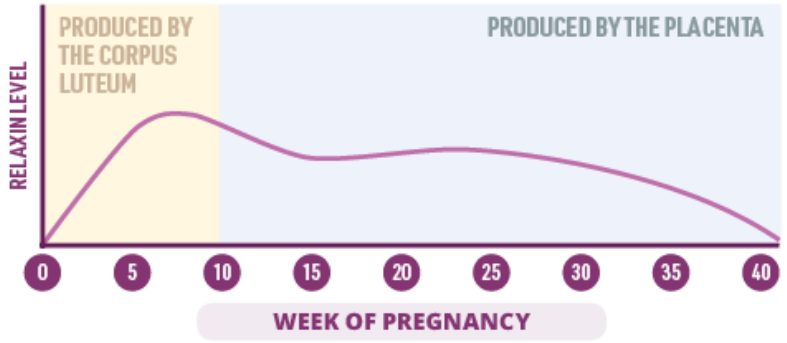
- Source:
  - Corpus luteum (first 8-10 weeks)
  - Placenta
- Functions:
  - Stimulates proliferation of uterine stromal cells, glands, and vasculature
  - Promotes proliferation and branching of breast ductal system
  - Supports maternal immune tolerance of the fetus



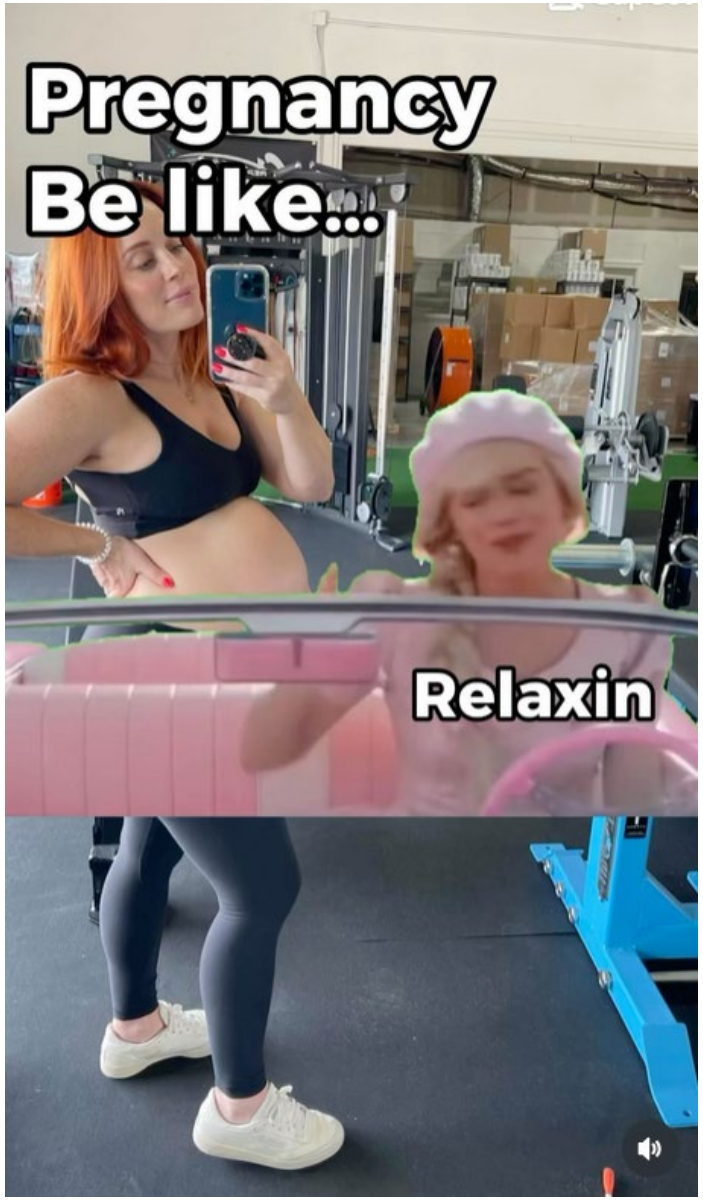
- Clinical relevance:
  - Low levels of estriol in quad screen associated with Trisomy 18 & 21
  - High levels are associated with hyperpigmentation

Hormonal: Relaxin

- Source:

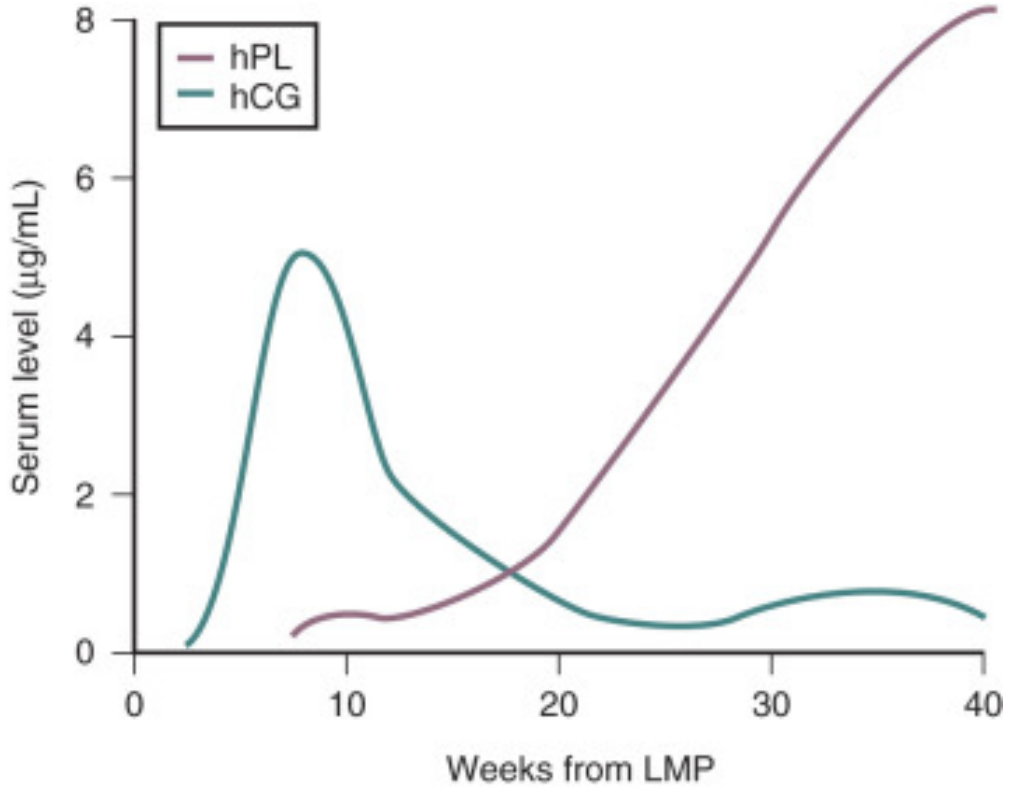


- Functions:
  - Remodels reproductive tract connective tissue
  - Increases renal blood flow
  - Increases ligament laxity



Hormonal: Human placental lactogen

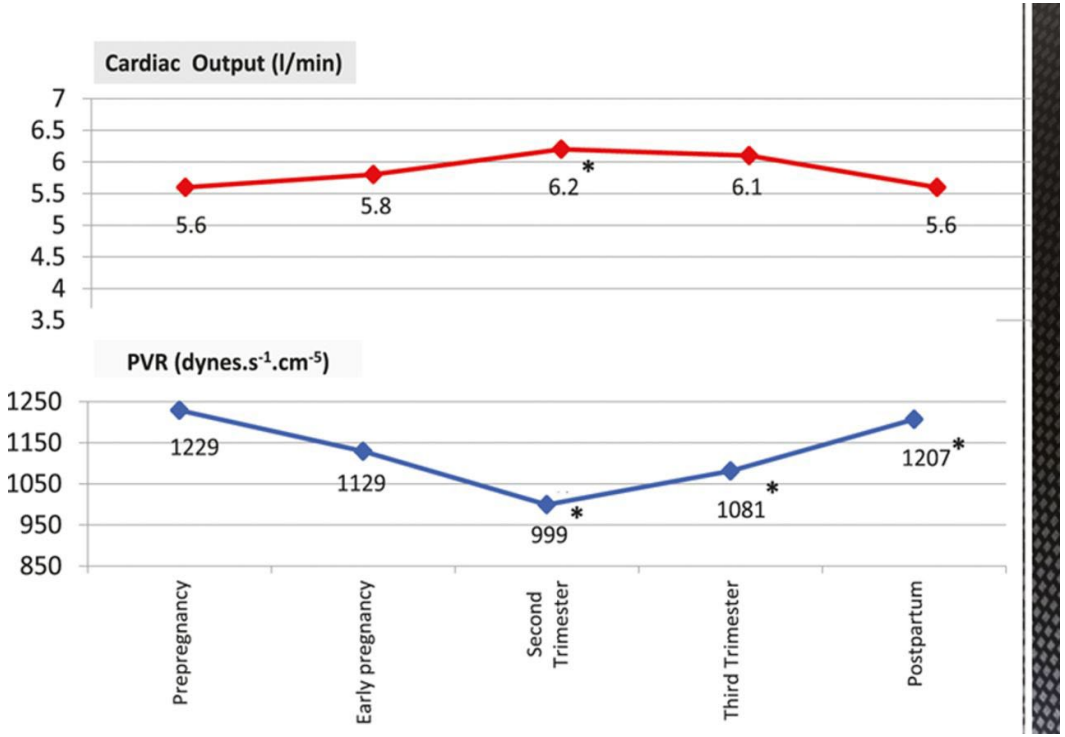
- Source:
  - Placental synctiotrophoblasts
- Functions:
  - Induces insulin resistance in mother to ensure glucose availability for fetus
  - Promotes lipolysis as an alternate maternal energy source
- Clinical relevance:
  - Contributes to development of gestational diabetes



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 → 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



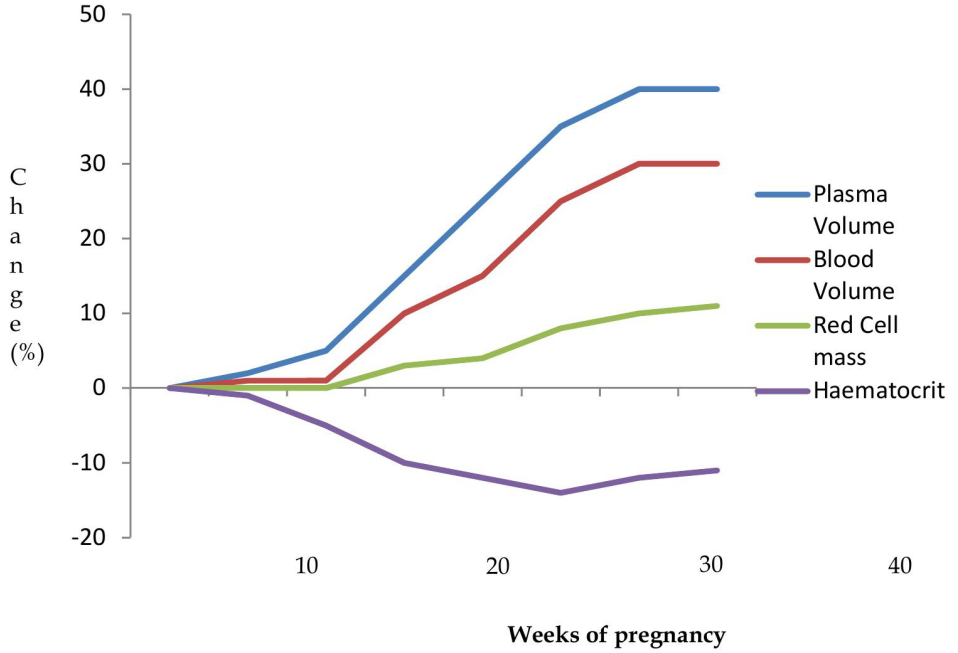
Cardiovascular Physiology of Pregnancy. Monika Sanghavi, and John D. Rutherford. Circulation Volume 130, Number 12

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:
    - Grade ≤ 2/6 systolic ejection murmur
  - Pathologic
    - Diastolic component
    - Pansystolic or late systolic quality
    - Grade ≥ 3/6
    - Associated symptoms: dyspnea, syncope, cyanosis

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



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

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

Coagulation

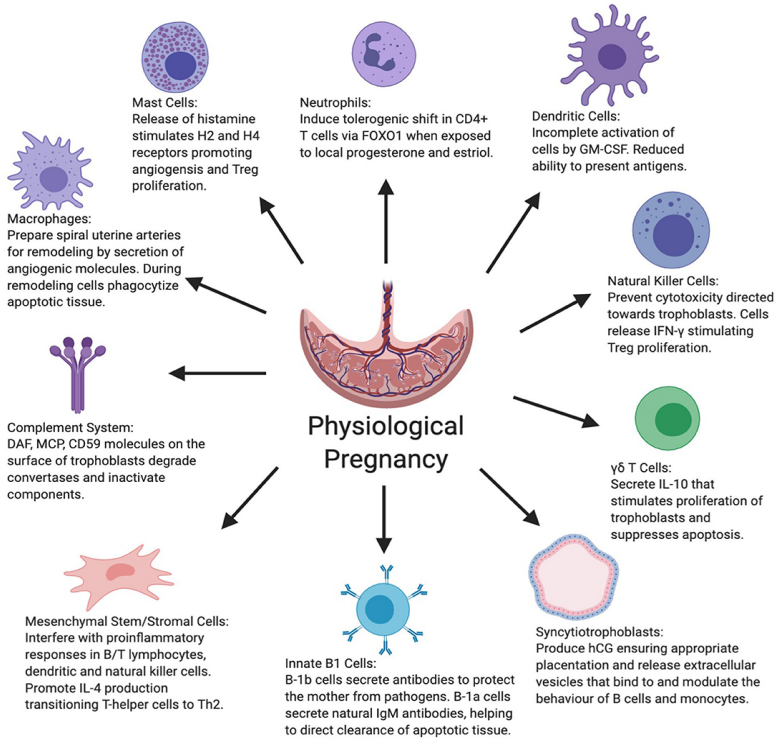
- Procoagulants
  - ↑ Fibrinogen, Factor VII, VIII, X
- Anticoagulants
  - ↓ Protein S
- Fibrinolytics
  - ↓ Plasminogen activator inhibitors
- Prothrombotic state
  - Reduce hemorrhage risk at delivery
  - Increased risk of VTE

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	↓
Plasminogen activator inhibitor 1	↑
Plasminogen activator inhibitor 2	↑
Protein C	No change
von Willebrand factor	↑

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

Immunologic

- Innate immunity
  - ↑ Innate immune activity (NØ, MØ, NK cells)
  - ↑ 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
    - 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
    - ↓ $PaCO_2$, ↑ pH
  - A "normal" CO_2 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

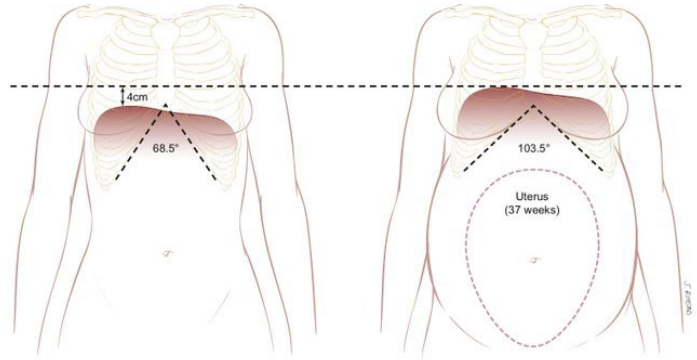
Table 3 Arterial blood gas measurement alterations in pregnancy

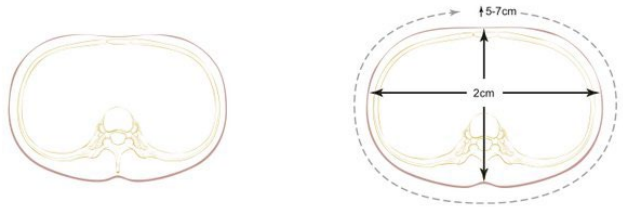
Arterial blood gas measurement	1st trimester	3rd trimester	Nonpregnant
pH	7.42–7.46	7.43	7.4
PaO2 (mm Hg)	105–106	101–106	93
PaCO2 (mm Hg)	28–29	26–30	37
Serum HCO3 (mEq/L)	18	17	23

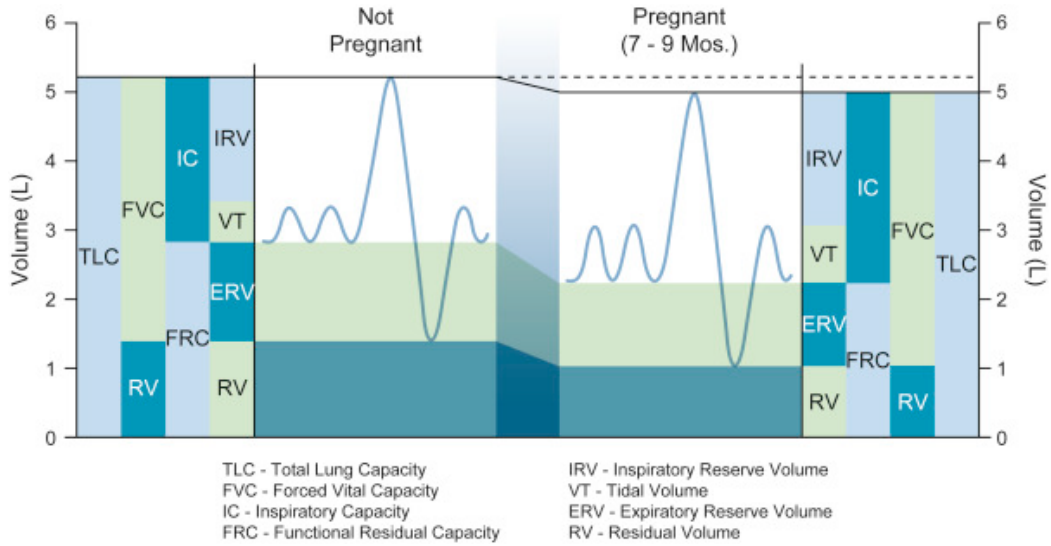
Sarah Dotters-Katz. Treatment Considerations for COVID-19 in Pregnancy. SMFM Webinar

Respiratory

- ↓ 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



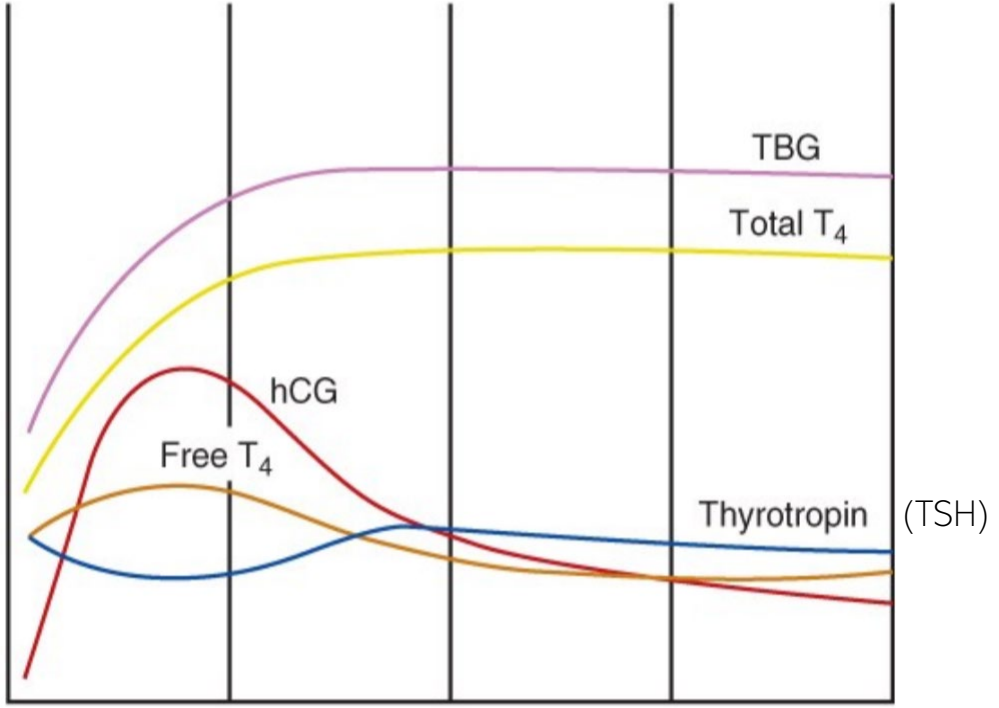




Hegewald MJ, Crapo RO. Respiratory physiology in pregnancy. Clin Chest Med. 2011 Mar;32(1):1-13. 10.1016/j.ccm.2010.11.001.

Endocrine

- Thyroid
  - Estrogen ↑ hepatic production of thyroid binding globulin
    - Elevated bound T4 values
    - 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&sectionid=263812626

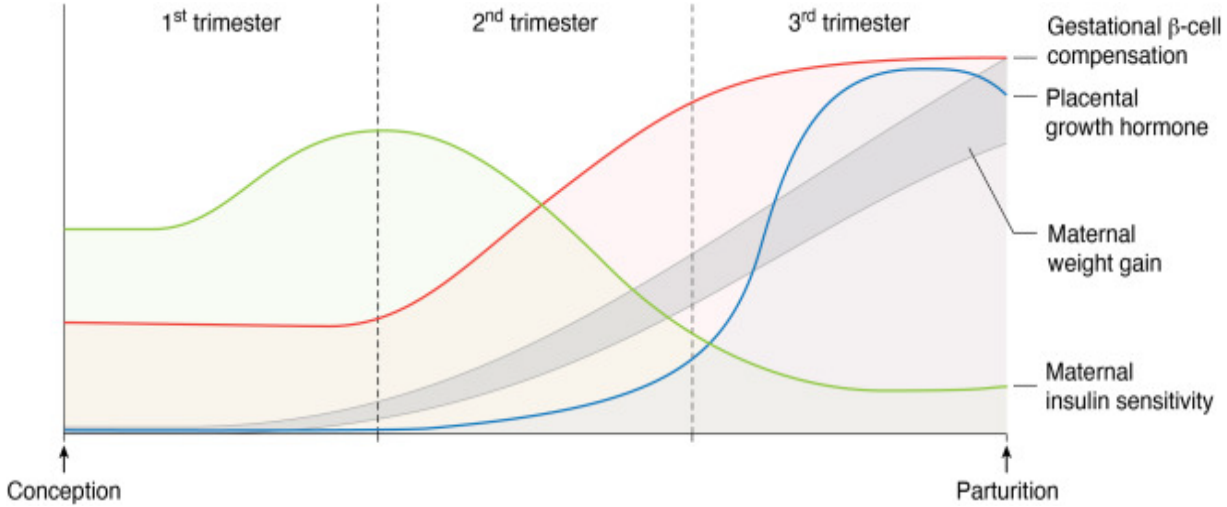
Endocrine

- 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

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

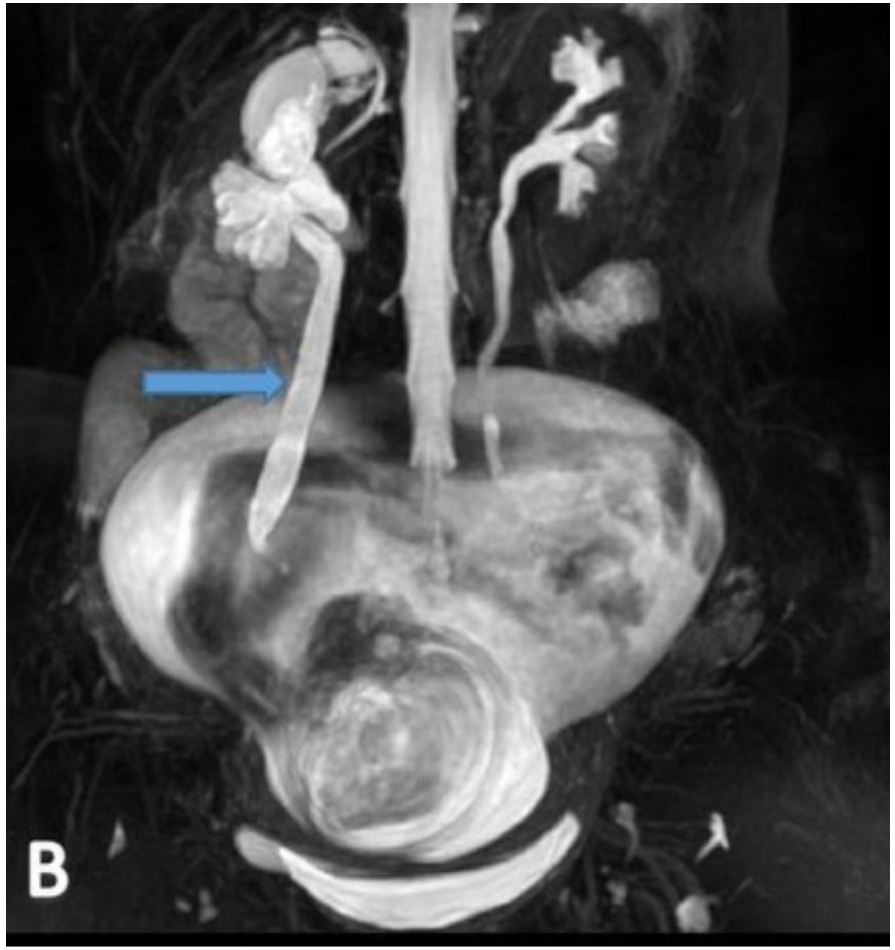


Taofeek O. Usman, Goma Chhetri, Hsuan Yeh, H. Henry Dong. Beta-cell compensation and gestational diabetes. Journal of Biological Chemistry, Volume 299, Issue 12, 2023, 105405, https://doi.org/10.1016/j.jbc.2023.105405.

- 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

- ↑ Glomerular filtration rate
  - Due to ↑ renal plasma flow and vasodilation
  - Serum creatinine and BUN decrease
  - Normal Cr: ~0.4–0.6 mg/dL
    - 1.0 may indicate renal dysfunction
  - Mild proteinuria is normal
    - (<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
  - ↑ Nausea and emesis
  - ↓ Gastric emptying
    - Bloating, acid reflux
    - NPO status prior to procedures
  - ↑ Intestinal transit time
    - Due to progesterone, gravid uterus, iron supplementation
    - Constipation
    - 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

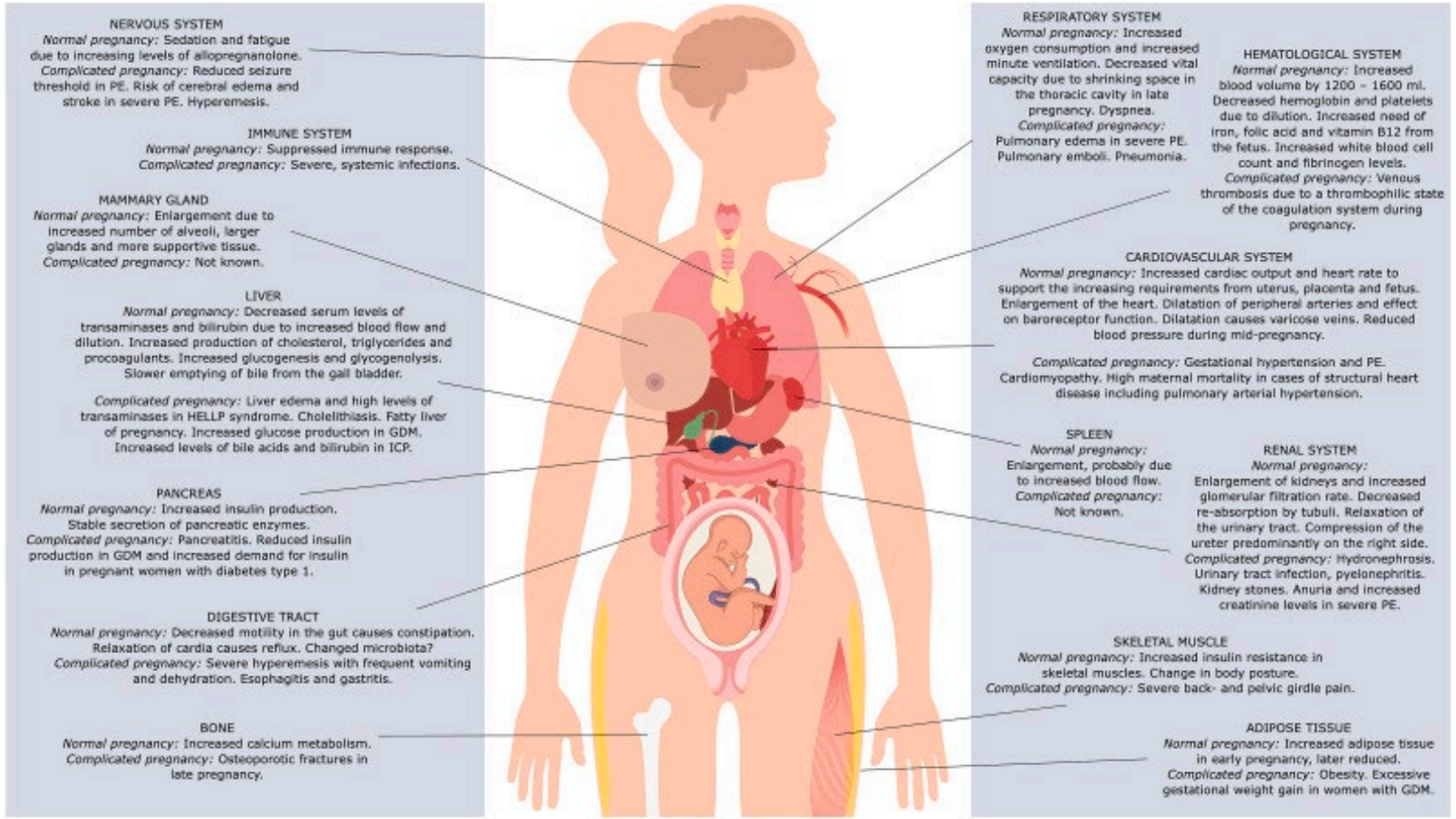
- Uterus
  - Growth from ~70 g at conception to ~1100 g at term
    - Hypertrophy of muscle fibers, not hyperplasia
- Vagina
  - ↑ Glycogen in epithelial cells metabolized by Lactobacillus to lactic acid
    - Acidic pH (3.5–6.0)
    - Protects against pathogens
- Cervix
  - By 4-6 weeks, increased edema, vascularity, hypertrophy and hyperplasia of glands
    - Chadwick sign (bluish coloration)
  - Endocervical glands proliferate → form the mucus plug
    - 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
- 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

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

Questions?



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

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