12c. Anatomy and Physiological aspects of Puberty and Menopause

Unit 12C: Anatomy and Physiological Aspects of Puberty and Menopause

Learning Goals

By the end of this chapter, you should be able to:

- describe the anatomical structures and maturational changes of the **hypothalamic–pituitary–ovarian (HPO) axis**, ovaries, uterus, breasts and external genitalia at **puberty** and **menopause**;
- explain the **physiology** of pubertal onset (adrenarche, gonadarche, menarche) and menopausal transition (follicular depletion, neurovascular instability);
- identify clinical features, investigations and first-line management principles for **disorders of puberty** and **menopause**, linking these to underlying physiology;
- apply integrative reasoning using Ayurvedic terms (*ṛtuśuddhi*, *rajonivṛtti*) while retaining modern anatomical–physiological precision.

Perimenopause 3D model
Menopause 3D model

1) Puberty: Anatomical Foundations

Axis components. Puberty emerges from coordinated maturation of:

- **Hypothalamus** (arcuate and preoptic areas) that generates **pulsatile GnRH**;
- **Anterior pituitary** (gonadotrophs) that secrete **LH/FSH**;
- **Ovaries**, where **theca** and **granulosa** cells produce **oestrogens, progesterone, inhibin/activin**;
- **End organs**—uterus, cervix, vagina, breasts, external genitalia, skeleton and CNS.

Pelvic organ growth. Oestrogen causes:

- **Uterine enlargement**: from infantile (~3.5 cm, cervix>body) to pubertal/adult (~6–8 cm, **body>cervix**). Endometrium acquires proliferative–secretory cycling.
- **Ovarian growth**: increased stromal volume; appearance of multiple **antral follicles**.
- **Vaginal maturation**: epithelium becomes **oestrogenised, multilayered**, with glycogen; pH turns acidic.
- **Breast development (thelarche)**: lobuloalveolar growth, ductal branching; areolar enlargement.
- **External genitalia**: labia majora/minora hypertrophy; **pubarche** reflects adrenal androgens.

Skeletal and body composition. Oestrogen drives **epiphyseal maturation and closure**, producing the **peak height velocity (PHV)** just before menarche, alongside increase in **fat mass** (particularly gynoid deposition).

Tanner Sexual Maturity Staging (SMR)

Feature	SMR 1	SMR 2	SMR 3	SMR 4	SMR 5
Breast	Preadolescent	Breast bud	Further enlargement	Secondary mound	Mature contour
Pubic hair	None	Sparse, straight	Coarser, dark, spread	Adult-type limited area	Adult in quantity & spread

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2) Puberty: Physiological Milestones

Two preparatory processes precede regular ovulation:

1. **Adrenarche** (≈6–8 years): zona reticularis matures → **DHEA/DHEAS** rise → **pubarche, axillary hair, body odour**. It is **adrenal**, not gonadal.

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2. **Gonadarche** (≈8–13 years): hypothalamic **KNDy** (Kisspeptin–Neurokinin B–Dynorphin) neurons establish **nocturnal, then diurnal GnRH pulses**. Pituitary **LH/FSH** increase; ovaries produce **oestrogens**.

Sequence to menarche (typical):
Thelarche → Pubarche → PHV → Menarche (about 2–2.5 years after thelarche). The **first 1–2 years** after menarche are often **anovulatory** because **positive feedback** (LH surge generation) is still maturing.

Cycle maturation. Early post-menarche cycles may be irregular, long (immature follicular phase), or occasionally short; progressively the **follicular phase** standardises, ovulation becomes regular, and **luteal progesterone** achieves consistent endometrial transformation.

Physiological regulators.

- **Energy signals**: **leptin** (adequate fat stores) permits pulsatility; severe caloric deficit or over-exercise suppresses the axis (**functional hypothalamic amenorrhoea**).
- **Thyroid and adrenal milieu**: euthyroid status and moderate cortisol favour normal timing; **chronic stress** can delay or disrupt cycles.
- **Chronobiology**: GnRH pulses are initially **nocturnal**; sleep deprivation distorts timing.

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3) Puberty: What Changes Are You Expected to Spot Clinically?

- **Breasts**: symmetrical, sometimes tender; transient asymmetry is common.
- **Growth**: the **PHV** precedes menarche; after menarche, only ~5–7 cm further height gain.
- **Genital tract**: leukorrhoea may appear with oestrogenisation; reassure if non-offensive.
- **Psychosocial**: mood variability reflects neurosteroid effects; address nutrition, sport, sleep and menstrual education.

Disorders to recognise early

- **Precocious puberty**: secondary sexual characters **before 8 years**; evaluate for **central** (GnRH-dependent) vs **peripheral** causes.
- **Delayed puberty/primary amenorrhoea**: no thelarche by **13** or no menarche by **15** (or 3 years post-thelarche); map along the HPO pathway and outflow tract.

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4) Menopause: Anatomical Changes

Definition. Menopause is the **final menstrual period** after **12 months of amenorrhoea** not due to other causes. The transition (**perimenopause**) spans variable years before and after this point.

Ovaries. Lifelong follicle attrition accelerates in the late 30s; when the pool nears exhaustion, **oocyte/follicle number** and **granulosa function** fall. Anatomically, ovaries **shrink** (often <2–3 cm), surface becomes smoother with fewer dominant follicles.

Uterus and cervix. With hypoestrogenism:

- **Uterus** becomes smaller; **myometrium** thins; endometrium atrophies unless exogenous hormones are used.
- **Cervix** reduces in size; external os may narrow; cervical mucus becomes scant.

Vagina and vulva. Genitourinary syndrome of menopause (GSM) encompasses:

- **Vaginal epithelium thinning**, loss of rugae, reduced glycogen → ↑ **pH**, dryness, dyspareunia.
- **Vulvar** thinning with fissuring in severe cases; **urethral** mucosa atrophy contributes to frequency/urgency/dysuria.

Breasts. Involution—lobules shrink; fat replaces gland; stromal density decreases (mammographic changes).

Skeleton and body composition. Rapid **bone loss** (first 3–5 years) from accelerated **osteoclast** activity; **sarcopenia** increases; central (visceral) adiposity rises.

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5) Menopause: Physiological Transitions

Hormonal profile.

- **Estradiol (E2)** declines; **estrone (E1)** from peripheral aromatisation predominates.
- **Progesterone** is low due to anovulation.
- **Inhibin B/A** fall early → **FSH rises** (FSH > LH), a hallmark of ovarian insufficiency.
- **AMH** approaches zero (reflects follicle pool).
- **Androgens** (ovarian/adrenal) decline more gradually; relatively **higher androgen:oestrogen ratio** may produce hirsutism in some women.

Vasomotor symptoms (VMS).
Hot flushes and night sweats arise from **hypothalamic thermoregulatory set-point narrowing**. Oestrogen deficiency alters **KNDy** neuron activity (↑ neurokinin B signalling), making minor core temperature changes trigger heat-dissipation responses (flush/sweat).

Metabolic and vascular changes.
Loss of oestrogen's vascular protection increases **cardiometabolic risk** (lipids, endothelial function, insulin sensitivity). Central adiposity and sleep disruption (from VMS) amplify this risk.

Neurocognitive and mood.
Some experience sleep fragmentation, reduced concentration and low mood, linked to VMS and steroid withdrawal. Major depressive disorder is **not** inevitable; screen if symptoms persist.

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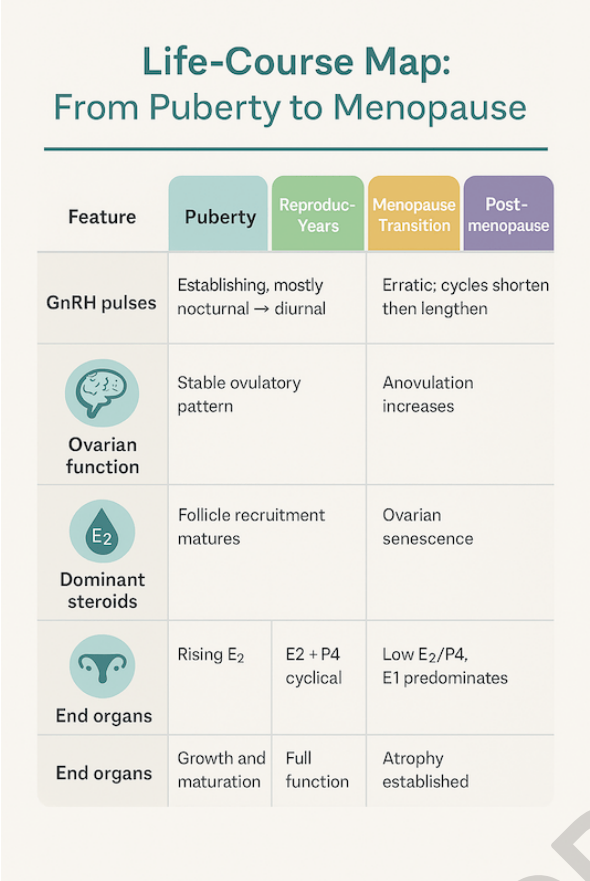
6) Life-Course Map: From Puberty to Menopause

Feature	Puberty	Reproductive Years	Menopause Transition	Postmenopause
GnRH pulses	Establishing, mostly nocturnal → diurnal	Stable ovulatory pattern	Erratic; cycles shorten then lengthen	Low gonadotropin response despite high FSH/LH
Ovarian function	Follicle recruitment matures	Regular ovulation	Anovulation increases	Ovarian senescence
Dominant steroids	Rising **E2**	**E2 + P4** cyclical	Falling **E2/P4**	Low **E2/P4**, E1 predominates
End organs	Growth and maturation	Full function	Atrophy begins	Atrophy established



7) Standardised Staging: STRAW+10

Stage	Label	Clinical cues
-2	Early menopausal transition	Cycle variability ≥7 days compared with usual
-1	Late transition	≥60 days amenorrhoea; VMS common
0	Final Menstrual Period (FMP)	Defined retrospectively after 12 months
+1a–c	Early postmenopause (first 5 years)	VMS peak; rapid bone loss
+2	Late postmenopause	Genitourinary changes dominate; stable low hormones

8) Investigations—Physiology Guides the Choice

Puberty concerns

- **Precocious puberty**: bone age, basal and **GnRH-stimulated LH/FSH**, pelvic ultrasound; MRI brain if central precocity suspected.
- **Delayed puberty/primary amenorrhoea**: **FSH/LH/E2**, thyroid profile, prolactin; pelvic ultrasound (uterus/ovaries), karyotype where indicated; screen for chronic illness/nutrition.

Menopause and perimenopause

- **Typical age/symptoms**: diagnosis is **clinical**; routine hormone testing is usually unnecessary.
- If uncertain or **premature ovarian insufficiency (POI)** suspected (<40 years): **FSH twice**, 4–6 weeks apart,

elevated; **E2 low**, **AMH very low**.
- Evaluate **lipids**, **glucose**, **thyroid** as baseline health screens; ensure **bone mineral density** testing if risk factors or after FMP with symptoms.

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9) Management Principles

A. Puberty

- **Normal variation**: reassure; teach menstrual literacy, nutrition (iron, calcium, vitamin D), sleep hygiene and sport.
- **Functional hypothalamic amenorrhoea**: restore energy balance; reduce training load; psychological support.
- **Central precocious puberty**: **GnRH agonists** suppress axis until appropriate age to preserve height and psychosocial well-being.
- **Peripheral precocity**: treat source (ovarian/adrenal tumour, exogenous hormones).
- **Delayed puberty/primary amenorrhoea**: treat cause—thyroid disease, coeliac, hyperprolactinaemia, POI; induce puberty gradually when indicated.

B. Menopause

- **Lifestyle**: weight management, resistance + impact exercise (bone), sleep regularity, limit alcohol, stop smoking.
- **Menopausal Hormone Therapy (MHT)**:
  - **Indication**: **moderate–severe VMS**, early menopause/POI, bothersome GSM, bone protection in symptomatic women <60 years or within 10 years of FMP, after risk assessment.
  - **Regimens**:
    - **Uterus present**: **oestrogen + progestogen** (sequential if <12 months amenorrhoea; continuous combined after).
    - **Post-hysterectomy**: **oestrogen-only**.
    - **Local vaginal oestrogen** for GSM (minimal systemic absorption).
  - **Contraindications (absolute)**: active or history of **breast cancer**, **oestrogen-dependent malignancy**, **unexplained vaginal bleeding**, **active VTE or thrombophilia**, **active liver disease**.
  - **Relative**: migraine aura, high CVD risk—consider **transdermal** routes and lowest effective dose.
- **Non-hormonal options**: SSRIs/SNRIs, gabapentin, clonidine for VMS when MHT is contraindicated or declined.
- **Bone health**: calcium (diet first), vitamin D sufficiency, exercise; **bisphosphonates** or **denosumab** if osteoporosis/fracture risk high.
- **Urogenital**: vaginal oestrogen, moisturisers; pelvic floor exercises; manage recurrent UTIs per protocol.
- **Cardiometabolic**: screen BP, lipids, glucose; manage risk factors early.

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10) Integrative Notes

While puberty and menopause are framed here with modern physiology, their clinical essence resonates with Ayurveda:

- **Puberty** parallels restoration of **ṛtuśuddhi** (appropriate cyclicity) supported by **āhāra–vihāra** balance. States of **alpāhāra** (caloric deficit), **ati-vyāyāma** (excess exercise) and **mano-duṣṭi** (stress) mirror hypothalamic suppression.
- **Menopause** corresponds to **rajonivṛtti** (cessation of menses) with emphasis on maintaining **dhātu-balā** (tissue strength)—bone (*asthi*), mind (*manas*), and **agni** stability through tailored diet, sleep and movement.
  (Direct śloka citation is not essential here because this is primarily a modern anatomy–physiology topic; you will find exact ślokas with references in classical pathya–apathya and cikitsā chapters.)

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11) Ten High-Yield Revisions

1. **Thelarche → Pubarche → PHV → Menarche** is the usual sequence.
2. Early post-menarche cycles are often **anovulatory**; this normalises within ~2 years.
3. **Leptin and energy sufficiency** permit GnRH pulsatility; severe deficits suppress it.
4. Pubertal uterus: **body>cervix**; infant uterus: **cervix>body**.
5. Menopause: **FSH rises** early as **inhibin** falls; **E2** declines, **E1** predominates.
6. **KNDy neuron** changes explain vasomotor symptoms.
7. **GSM** results from genital tract atrophy and higher vaginal pH; treat with **local oestrogen**.
8. **MHT** works best when started **<60 years or within 10 years of FMP**, after risk assessment.
9. In POI, **hormone therapy** is recommended till average menopausal age for bone/cardiovascular protection.
10. Always distinguish **central vs peripheral** precocity and **HPO vs outflow** causes of amenorrhoea.

Assessment

A) MCQs (one best answer)

1. The first endocrine event that typically heralds puberty in girls is:
   A. Gonadarche B. Adrenarche C. Menarche D. Peak height velocity
   Answer: B
2. The usual order of pubertal milestones is:
   A. Pubarche → Menarche → Thelarche → PHV
   B. Thelarche → PHV → Pubarche → Menarche
   C. Thelarche → Pubarche → PHV → Menarche
   D. PHV → Thelarche → Pubarche → Menarche
   Answer: C
3. In the pubertal uterus, the proportion of cervix to body becomes:
   A. Cervix>body B. Body>cervix C. Equal D. No change from infancy
   Answer: B
4. The hormone most responsible for epiphyseal closure in girls is:
   A. Growth hormone B. Oestradiol C. Progesterone D. Cortisol
   Answer: B
5. The earliest biochemical marker to rise as the menopausal transition begins is:
   A. Estradiol B. Progesterone C. Inhibin D. FSH
   Answer: D (FSH rises as inhibin falls)
6. Hot flushes are best explained by:
   A. Hyperthyroidism
   B. Narrowing of hypothalamic thermoneutral zone via KNDy changes
   C. Elevated prolactin
   D. Increased cortisol
   Answer: B
7. A 47-year-old has cycle variability >7 days for the last year and night sweats. STRAW+10 stage is:
   A. -2 (early transition) B. -1 (late transition) C. 0 (FMP) D. +1
   Answer: A
8. Which of the following is an **absolute** contraindication to systemic MHT?
   A. Controlled hypertension B. Prior VTE (active thrombophilia) C. Osteopenia D. Atrophic vaginitis
   Answer: B
9. A 12-year-old, 2 months post-menarche, has 45-day cycles. The most likely explanation is:
   A. Thyroid disease B. Physiological anovulation in early post-menarche years C. PCOS D. Hyperprolactinaemia
   Answer: B
10. The most appropriate first-line therapy for GSM with dyspareunia in a healthy postmenopausal woman is:
    A. Systemic MHT B. Vaginal oestrogen C. SSRI D. Clonidine
    Answer: B

B) Short Answer Questions (3–5 lines each)

1. Outline the anatomical differences between the infantile and pubertal uterus and cervix.
2. Explain the roles of adrenarche and gonadarche in female puberty.
3. List three physiological mechanisms for vasomotor symptoms in menopause.
4. Enumerate absolute contraindications to systemic menopausal hormone therapy.
5. Define premature ovarian insufficiency and name two investigations that support the diagnosis.

C) Long Answer Questions

1. **Describe** the anatomical and physiological changes during female puberty, including HPO maturation, skeletal effects, genital tract changes and sequence to menarche. **Discuss** common deviations (precocious, delayed puberty) with first-line evaluation.
2. **Explain** menopausal physiology and anatomy—ovarian senescence, hypothalamic thermoregulation, GSM, bone and cardiovascular changes. **Outline** evidence-based indications, regimens, and contraindications for MHT, and non-hormonal options.

D) Case-Based (OSCE-style)

A 49-year-old teacher has 3 months of amenorrhoea after years of 26–28 day cycles, with hot flushes disturbing sleep.

- a) Assign a STRAW+10 stage based on her history.
- b) List two lifestyle and two pharmacological options for vasomotor relief.
- c) What baseline health checks will you offer before starting therapy?