Learning Objectives

- Understand Tanner staging and recognize how it is used in evaluating pubertal disorders
- Distinguish between normal and abnormal pubertal development
- Recognize the signs and symptoms of precocious puberty and delayed puberty
- Understand normal stages of adolescent psychologic and cognitive development

Pubertal Development

- **Transition** from sexual immaturity to potential fertility during which secondary sexual characteristics develop
- Decreasing sensitivity of the HPG axis and increasing pulsatile release of GnRH, LH and FSH
What is the first sign of pubertal development in girls?

- a) estrogenization of vaginal mucosa
- b) pubarche
- c) menarche
- d) breast buds
- e) talking back to their mothers

Puberty

- Significant variations in onset, timing, tempo, and magnitude of pubertal changes are normal
- Despite expected variability, the progression through puberty is predictable
What is the first sign of pubertal development in boys?

- a) penile growth
- b) growth spurt
- c) pubarche
- d) increased muscle mass
- e) testicular growth
Normal Puberty

- Mean age of onset of **11.2 years** in girls and **11.6 years** in boys
- Girls - Breast development
- Boys - Increase in testicular size, length > 2.5 cm or volume > 4 cc
- Progression from Tanner stage II – V takes 2-4 years

What is the typical chronologic progression of pubertal changes in girls?

a) thelarche→adrenarche→menarche→peak height velocity (PHV)
b) thelarche→menses→PHV→adrenarche
c) adrenarche→thelarche→PHV→menarche
d) thelarche→adrenarche→PHV→menarche
e) thelarche→PHV→adrenarche→menarche
What is the typical chronologic progression of pubertal changes in boys?

a) testicular growth → PHV → penile growth → adrenarche

b) Penile growth → testicular growth → adrenarche → PHV

c) testicular growth → adrenarche → PHV → penile growth

d) testicular growth → adrenarche → penile growth → PHV

Biological Maturity in Girls

Tanner, 1962
Normal Pubertal Variants

- Premature thelarche
  - early breast development without other signs of puberty
  - occurs before age 2 years or after age 6 years

- Premature adrenarche
  - early development of pubic hair
  - usually occurs between ages 6 and 8 years
  - No height acceleration or advancement in the bone age
  - Re-evaluation every 4-6 months is needed
## Mean Ages (± SD) of Tanner Stages in American Girls

<table>
<thead>
<tr>
<th>Tanner Stage</th>
<th>Age (years)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>II breast development</td>
<td>11.2 ± 1.1</td>
<td>elevation of breast and papilla, enlargement of areola, sparse, long, lightly pigmented hair</td>
</tr>
<tr>
<td>pubic hair</td>
<td>11.6 ± 1.2</td>
<td></td>
</tr>
<tr>
<td>III breast development</td>
<td>12.0 ± 1.0</td>
<td>further enlargement of breast and areola, hair is darker, coarser and spreads onto pubes</td>
</tr>
<tr>
<td>pubic hair</td>
<td>11.8 ± 1.0</td>
<td></td>
</tr>
<tr>
<td>IV breast development</td>
<td>12.4 ± 0.8</td>
<td>projection of areola and papilla to form a secondary mound, hair is adult in type but covers a smaller area</td>
</tr>
<tr>
<td>pubic hair</td>
<td>12.4 ± 0.9</td>
<td></td>
</tr>
<tr>
<td>V breast development</td>
<td>14.0 ± 1.2</td>
<td>mature stage, projection of papilla only</td>
</tr>
<tr>
<td>pubic hair</td>
<td>14.0 ± 1.3</td>
<td>hair is adult in quantity and type, inverse triangle</td>
</tr>
</tbody>
</table>

## Mean Ages (± SD) of Tanner Stages in American Boys

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<tr>
<th>Tanner Stage</th>
<th>Age (years)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>II genital development</td>
<td>11.6 ± 1.1</td>
<td>testes 4 cc, scrotal thinning, sparse, long, lightly pigmented hair at base of penis</td>
</tr>
<tr>
<td>pubic hair</td>
<td>13.4 ± 1.1</td>
<td></td>
</tr>
<tr>
<td>III genital development</td>
<td>12.9 ± 0.8</td>
<td>growth of the penis in length and breadth, further testes and scrotal growth</td>
</tr>
<tr>
<td>pubic hair</td>
<td>13.9 ± 1.0</td>
<td>hair is darker, coarser and spreads over pubes</td>
</tr>
<tr>
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<td>13.8 ± 1.2</td>
<td>penis, testes enlarge further</td>
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<td>pubic hair</td>
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</tr>
<tr>
<td>V genital development</td>
<td>14.9 ± 0.8</td>
<td>penis is adult size and shape, testes 20 cc</td>
</tr>
<tr>
<td>pubic hair</td>
<td>15.2 ± 1.1</td>
<td>hair is adult in quantity and type, inverse triangle, spread onto medial thighs</td>
</tr>
</tbody>
</table>
Gynecomastia

- Transient breast development, typically resolves within 2 years
- 75% of males affected
- Occurs Tanner Stage II/III
- Etiology – estrogen/androgen imbalance, increased tissue sensitivity, ??
- Pathology – Klinefelter syndrome, estrogens, drugs, breast tumors
- Treatment – reassurance, surgery, treatment of the underlying condition

PREOCIOUS PUBERTY

- Onset before age 8 years in girls or age 9 years in boys
- Central - reactivation of the HPG axis
  - 5 times more common in girls
  - most cases are idiopathic
  - neurologic causes in > 60% of boys
- Peripheral
PREOCIOUS PUBERTY

1) Differentiate central from peripheral precocious puberty

2) Identify and appropriately treat the cause of the precocious puberty

Differential Diagnosis of Precocious Puberty

Central Precocious Puberty (CPP)
- Idiopathic
- Central Nervous System Lesions
  - Hypothalamic hamartomas
  - Other tumors (neurofibromas, craniopharyngioma, etc.)
  - Malformations (septo-optic dysplasia, hydrocephalus, arachnoid cyst, etc.)
  - Infection (brain abscess, meningitis, etc.)
  - Trauma (post-surgical, irradiation, injury, etc.)
- Peripheral Precocious Puberty States

Peripheral Precocious Puberty (PPP)
- Congenital Adrenal Hyperplasia
- Ovarian cysts
- Autonomous (McCune-Albright syndrome, testotoxicosis)
- Exogenous hormones
- Severe primary hypothyroidism
- Tumors – adrenal, gonadal (gonadoblastomas, etc.), hepatoblastomas, etc.

PHYSICAL EXAM

- Tanner staging
  - True breast development vs. fatty tissue
  - Visual inspection of the vagina to assess estrogen stimulation
    - non-stimulated mucosa - glistening red
    - stimulated mucosa - pinkish
HISTORY
- Determine the growth pattern
- General assessment - health, nutrition, medications
- CNS trauma/infections, HAs, visual changes
- Pubertal symptoms - duration, progression
- Onset of puberty in other family members
- Exposure to exogenous hormones

PHYSICAL EXAM
- Tanner staging
  - True breast development vs. fatty tissue
  - Visual inspection of the vagina to assess estrogen stimulation
    - non-stimulated mucosa - glistening red
    - stimulated mucosa - pinkish
- Other pubertal changes
  - acne, body odor and axillary hair

PHYSICAL EXAM (cont.)
- Funduscopic and visual field evaluations
- Pigmented lesions (McCune-Albright syndrome, neurofibromatosis)
- Neurologic assessment
Congenital Adrenal Hyperplasia

- Ambiguous genitalia
- Virilization in females
- Males incomplete masculinization
- Advanced somatic development
- Precocious puberty
- Adult short stature
- Diagnose with clinical and laboratory findings

Which of the following children has precocious puberty?

a) 8 y/o thin girl whose breasts form a secondary mound
b) 8 y/o overweight boy with fatty breast tissue
c) 12 y/o girl who has regular menses
d) 12 y/o boy with enlarged testes
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The most common cause of precocious puberty in girls is:

a) idiopathic
b) congenital adrenal hyperplasia
c) CNS tumor
d) ovarian cyst
e) severe acquired hypothyroidism
LABORATORIES AND IMAGING STUDIES

- **Bone age x-ray**
  - advanced with precocious puberty
  - children with premature thelarche or premature adrenarche will not have advanced bone ages

- **Gonadotropins**
  - random levels may not be elevated
  - in most cases *don’t do them!*

LABORATORIES (cont.)

- **GnRH stimulation test**
  - children with CPP will have a brisk rise in LH and FSH
  - prepubertal children or those with PPP will not show a rise in LH and FSH levels

- **Estradiol or testosterone**

LABORATORIES (cont.)

- **T₄, TSH, DHEA-S, 17-hydroxyprogesterone**
  - severe primary hypothyroidism
  - late onset congenital adrenal hyperplasia
  - adrenal tumors

- **Pelvic ultrasound**
  - identify large ovarian cysts or neoplasms
  - assess development of the uterus and ovaries

- **High resolution head MRI**
  - girls younger than 5 years old, all boys with CPP

- **Imaging of the adrenals/gonads**
**THERAPY**

- Central PP
  - GnRH agonists
    - bind to and stimulate the GnRH receptors
    - continuous stimulation stops gonadotrope secretion of LH and FSH
- Tumors
  - CNS
    - resection, chemotherapy and/or radiation therapy as indicated
    - hypothalamic hamartoma can be treated with a GnRH agonist
  - Adrenal/Gonadal tumors - resection

**THERAPY (cont.)**

- Congenital adrenal hyperplasia
  - physiologic glucocorticoid replacement
- Hypothyroidism – thyroid replacement
- Large ovarian cysts - resection
- McCune-Albright syndrome, et al
  - Ketoconazole, testolactone or spironolactone

**DELAYED PUBERTY**

- Lack of secondary sexual characteristics by age 14 years in boys or 13 years in girls
  - smaller than their peers
  - short stature exaggerated by lack of pubertal growth spurt
- More common in **boys** than girls
- Lack of progression through the stages of puberty within 4.5 to 5 years after onset
- Psychologically and socially devastating
Differential Diagnosis of Delayed Puberty

Constitutional Growth Delay
- Hypopituitarism – idiopathic or acquired
  - Multiple pituitary hormone deficiencies
- Kallmann syndrome
- Chronic illness, malnutrition
- Hypothyroidism
- Hyperprolactinemia
- Gonadal failure
  - **Turner syndrome**
  - Klinefelter syndrome
- Miscellaneous disorders

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**EVALUATION**

- **History**
  - delayed puberty in one or both parents
  - trauma or medical injury
  - eating disorders, nutritional status
  - anosmia
  - rigorous physical training
- **Physical exam**
  - dysmorphic features
  - body measurements

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**Evaluation**

- **Bone age x-ray** – onset of puberty correlates better with bone age than with chronologic age
- Gonadotropins - random LH and FSH levels helpful only if elevated
- TSH, T₄, prolactin
- CNS imaging - suspected intracranial pathology
- Karyotype – Turner syndrome, Klinefelter syndrome
Constitutional Growth Delay

- Short stature in childhood
- Low/normal growth velocity
- Delayed bone age
- Family history
- Final height

The most common cause of delayed puberty in boys is:

- a) CNS lesion
- b) hypothyroidism
- c) Noonan’s syndrome
- d) constitutional growth delay
- e) Klinefelter syndrome
Constitutional Growth Delay

- Short stature in childhood
- Low/normal growth velocity
- Delayed bone age
- Family history
- Final height

Reassurance or a short course of hormonal treatment
A 13 y/o girl is referred for evaluation of short stature and delayed puberty. Her PMH is significant for a congenital heart defect repaired as an infant. The following feature is commonly associated with her condition:

a) abnormal sense of smell
b) low gonadotropins
c) type 1 diabetes
d) early pubic hair growth
e) early gonadal failure

Turner syndrome

- 1:5000 live born females
- 45, XO
- Clinical findings
  - Skeletal growth disturbances
    - short stature
    - otitis
  - Cardiovascular anomalies
  - Lymphatic obstruction
  - Renal and renovascular anomalies
  - Gonadal failure
  - Others – nevi, ptosis, hypothyroidism, GI disorders
### Turner syndrome
- 1:5000 live born females
- 45, XO
- **Clinical findings**
  - Skeletal growth disturbances
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  - **Cardiovascular anomalies**
  - Lymphatic obstruction
  - Renal and renovascular anomalies
  - **Gonadal failure**
  - Others – nevi, ptosis, hypothyroidism, GI disorders

### LABORATORIES (cont.)
- T₄, TSH, prolactin
- Additional chemistries (metabolic panel, CBC, etc.)
- CNS imaging - suspected intracranial pathology
- **Karyotype**
  - Turner syndrome
  - Klinefelter syndrome

### THERAPY
- Treat underlying medical disorders appropriately
- Replacement with gonadal steroids at the normal age at onset of puberty
- Constitutional growth delay
  - reassurance and follow up
  - low dose testosterone, oxandrolone, conjugated estrogen
A 14 year old boy is brought in for evaluation of short stature. He is at the 5th percentile for height. He has early Tanner stage II pubic hair and 2 cc testes. Further evaluation is most likely to reveal:

a) growth hormone deficiency  
b) elevated serum testosterone  
c) elevated serum gonadotropins  
d) a delayed bone age  
e) a family history of acquired hypothyroidism

What finding would you expect in central precocious puberty?

a) Ovarian cyst  
b) elevated gonadotropins in response to GnRH  
c) Contrasexual pubertal changes  
d) Low estradiol level in girls  
e) Low testosterone level in boys
What finding would you expect in central precocious puberty?

- a) Ovarian cyst
- b) Elevated gonadotropins in response to GnRH
- c) Contrasexual pubertal changes
- d) Low estradiol level in girls
- e) Low testosterone level in boys

Which one of these statements is true about adolescent growth?

- a) Average pre-pubertal ht velocity is 7-8 cm/yr (5-6 cm/yr)
- b) PHV occurs 1 year later for boys than for girls
- c) Pubertal growth accounts for 10% of final adult ht.
- d) Average growth velocity is 9-10 cm/yr in the peak adolescent growth spurt
**Weight and Body Composition Growth**

- Onset of peak weight velocity is highly variable
- Pubertal weight gain accounts for about 50% of ideal body weight
- Lean body mass % increases for males and decreases for females
- 33-66% of adult bone mass accrues in adolescence
- Erythrocyte mass increases in males and is more level in females
- Blood pressure rises related to age, weight and height

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**Adolescent Board Simulation**

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Section of Adolescent Medicine
The Cleveland Clinic Foundation
9/1/11

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**Case #1**

15 yo slender boy presents with delayed puberty, HR 42, and orthostasis by pulse - what is the most likely diagnosis to explain all these findings?

- a) well conditioned athlete
- b) new onset IDDM
- c) Eating Disorder NOS
- d) POTTS
- e) Inflammatory Bowel Disease
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Which of these statements about adolescent psychological development is false?

- a) parental approval of an adolescent's separation from family enables the adolescent to psychologically return to the family later
- b) the peer group is important for adolescent-parental separation
- c) the peer group has a powerful influence on the adolescent's healthy and unhealthy behaviors
- d) pubertal maturation requires role readjustments between family members
- e) adolescents do not consider parental views/values on sex when deciding about their own sexual activity
Case #2

A 15 yo girl who had menarche at age 13 presents with CC of 4 months of amenorrhea. One month before loss of menses, she started a “health kick” with increased fruits and veggies and 20 minutes exercise daily. She has lost only 3 lb. She has also noticed “orange tinged” skin in the last month. What is the most likely cause of her amenorrhea?

a) Exercise-induced amenorrhea
b) HPO axis immaturity
c) Eating Disorder
d) PCOS
e) Hepatitis
Which one of these statements about adolescent cognitive development is false?

- a) Concrete thinking characterizes the early adolescent
- b) experience and environment can substantially influence cognitive development
- c) Early adolescents do not easily link cause and effect in regard to health behavior
- d) The late adolescent is not capable of abstract reasoning
- e) the adolescent's concept of immortality influences risk taking behavior

Case #3

A 15 yo girl is admitted to the hospital with severe Anorexia Nervosa. She weighs 35 kg and is 160 cm tall. She has bradycardia and orthostatic hypotension. You plan to stabilize her medically and begin re-feeding. Of the following, the electrolyte abnormality that is most likely to occur during the first week of her treatment is:
Case #3

A) hypercalcemia
B) hyperphosphatemia
C) hypocalcemia
D) hyponatremia
E) hypophosphatemia