TEAM-BASED LEARNING SESSION

Growth & Stature

A case-based framework for interpreting pediatric growth curves and diagnosing disorders of childhood growth and stature.

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Objectives

By the end of this session, students will be able to:

Interpret pediatric growth curves — using percentiles, growth velocity, and mid-parental height — to distinguish normal variation from a true growth disorder.

Construct a differential diagnosis for abnormal growth spanning nutritional, environmental, psychosocial, chronic illness, genetic, and endocrine causes.

Recognize the clinical presentation and diagnostic workup of growth hormone deficiency and congenital hypopituitarism.

Identify genetic and medication-related causes of short stature (e.g., Turner syndrome/SHOX haploinsufficiency, stimulant medications) and their distinguishing features.

Five Categories that Influence Growth

Nutrition

- Average needs for a healthy child with no catch-up requirements
  - Premature infant: 120-150 kcal/kg/day
  - 0-6 mos: 100-110 kcal/kg/day
  - 6-12 mos: 95-100 kcal/kg/day
  - 1-3 yrs: 1000-1400 kcal/day
  - 4-8 yrs: 1200-2000 kcal/day
  - 9-13 yrs: 1400-2600 kcal/day
  - 14-18 yrs: 1800-3200 kcal/day

Environment

- Toxins (lead and other heavy metals, endocrine disrupting chemicals like pesticides, phthalates)
- Hypoxia (living at high altitude or severe OSA),

Chronic Illness

- Increases metabolic demand, shunting energy from growth

  Examples: celiac, IBD, cystic fibrosis, congenital heart disease, chronic kidney disease, malignancy etc

Hormones

- Directly: TSH & T3/T4, GH & IGF-1
- Via modulation: Sex hormones & gonadotropins, cortisol, insulin

Psychosocial

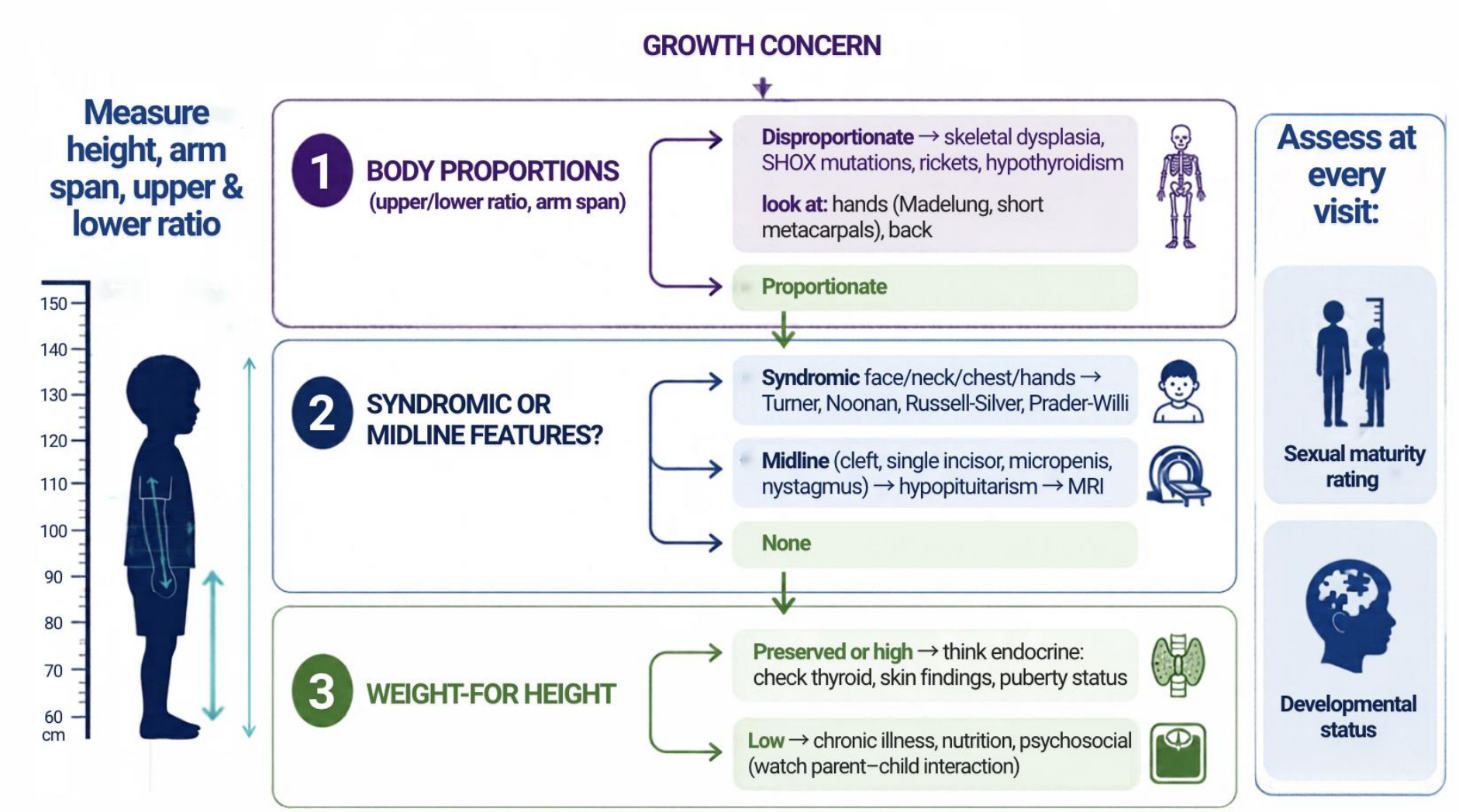
- Trauma, emotional deprivation, or neglect.

INTRODUCTION

Physical Exam: What to Consider

- Features of genetic syndromes
- Midline abnormalities
- Developmental status
- Eye positions, palate, gums
- Body proportions — short limb or trunk, arm span
- Signs of chronic illness
- Thyroid, neck, back (scoliosis)
- Puberty status — pubic hair, testicular/breast development
- Skin — hyperpigmentation, acanthosis, striae, birth marks
- Hands, fingers (shortened metacarpals)
- Parent–child interaction

Physical Exam: Approach



INTRODUCTION

Physical Exam: Interpreting the Findings

Skin

- **Hyperpigmentation** → ACTH excess (adrenal insufficiency)
- **Café-au-lait** → NF1, McCune-Albright
- **Striae + weight gain** → Cushing's; dry skin → hypothyroidism

Puberty (Tanner stage)

- **Late + delayed bone age** → constitutional delay
- **Absent or stalled** → hypogonadism (Turner, hypopituitarism)
- **Early puberty** → tall now, short adult height

Thyroid

- **Goiter** → primary thyroid disease (e.g., Hashimoto's)
- **No goiter** does not rule out central hypothyroidism

Hands

- **Short 4th/5th metacarpals** → Turner, pseudohypoparathyroidism (check Ca/PTH)
- **Madelung deformity** → SHOX deficiency
- **Clinodactyly** → Russell-Silver, Down

Developmental status

- **Normal** → isolated cause (GH deficiency spares cognition)
- **Delayed** → syndromic, hypothyroidism, deprivation
- **Regression** → acquired hypothyroidism, intracranial process

Parents & interaction

- **Measure the parents** → mid-parental height; similar features → dominant syndrome
- **Withdrawn, food hoarding**

Also consider

Growth velocity first — the best test of normal vs. pathologic

Most short children are normal variants — familial short stature, constitutional delay

Karyotype any short girl — Turner may cause short stature alone

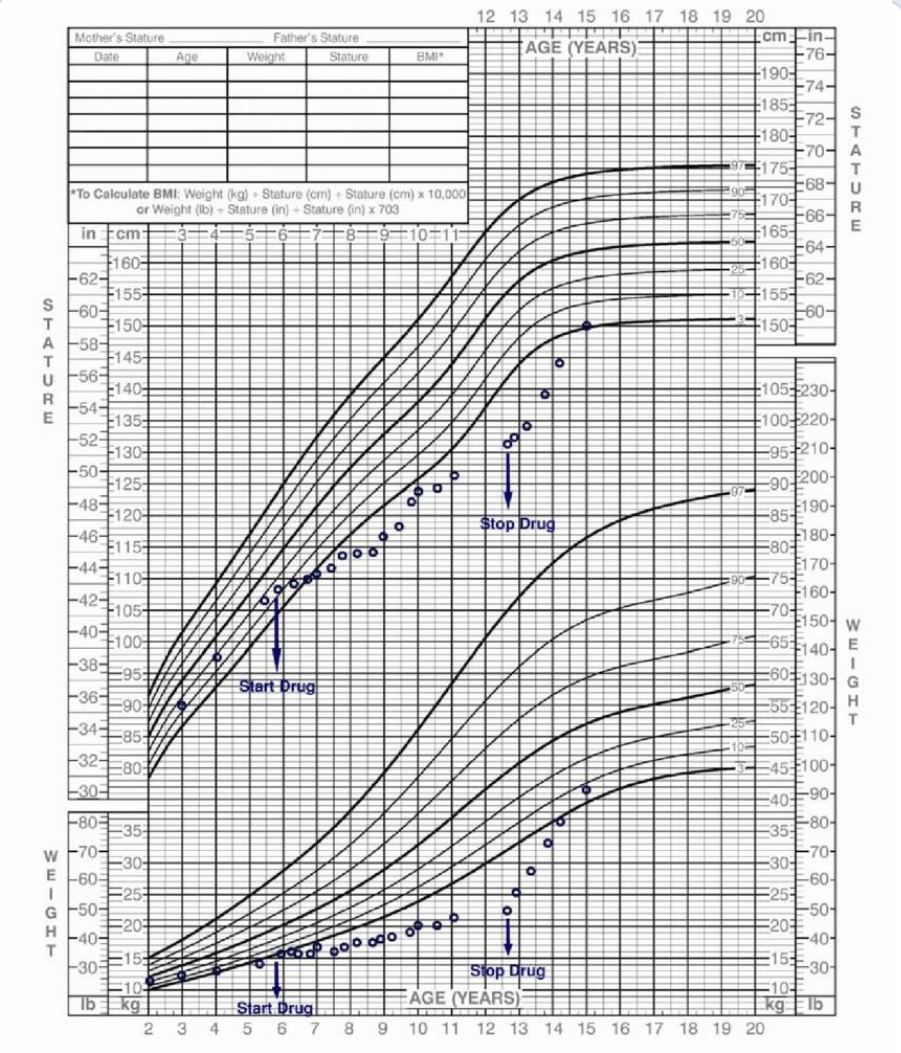
ADHD and Stimulant Medications

Stimulant medications (amphetamine, dextroamphetamine, lisdexamfetamine, methylphenidate, dexmethylphenidate) are associated with poor linear growth.

Postulated mechanism: reduced appetite → decreased weight gain

Direct effect on linear growth suggested.

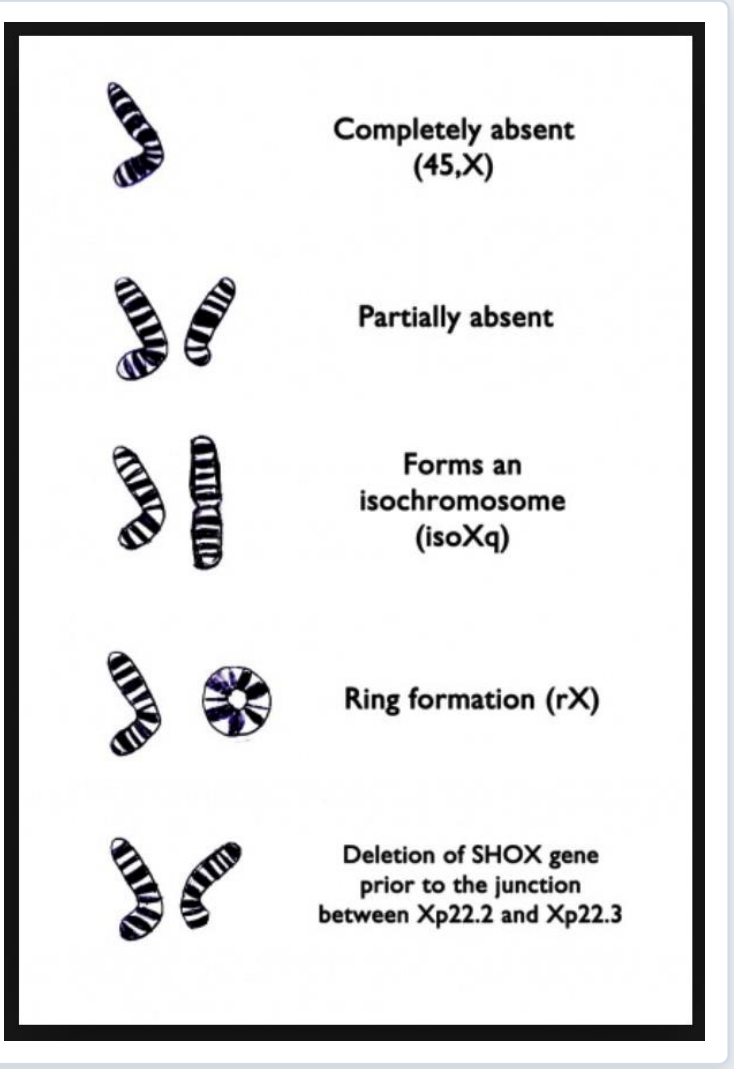
Children with ADHD have slightly shorter stature than peers without the condition, but this disappears post-puberty.



INTRODUCTION

Turner Syndrome

- Skeletal disturbances due to haploinsufficiency (a single functional copy rather than two) of the SHOX gene on the pseudo-autosomal region of the X chromosome.
- SHOX gene (need 2 copies) transcribes a homeodomain transcription factor involved in chondrocyte proliferation.
- Located on the distal short arm of the X chromosome — escapes X-chromosome inactivation.



SHOX Gene Mutations

Heterozygote SHOX mutations (80% deletions) were detected in…

2–15%

Formerly “idiopathic” short stature

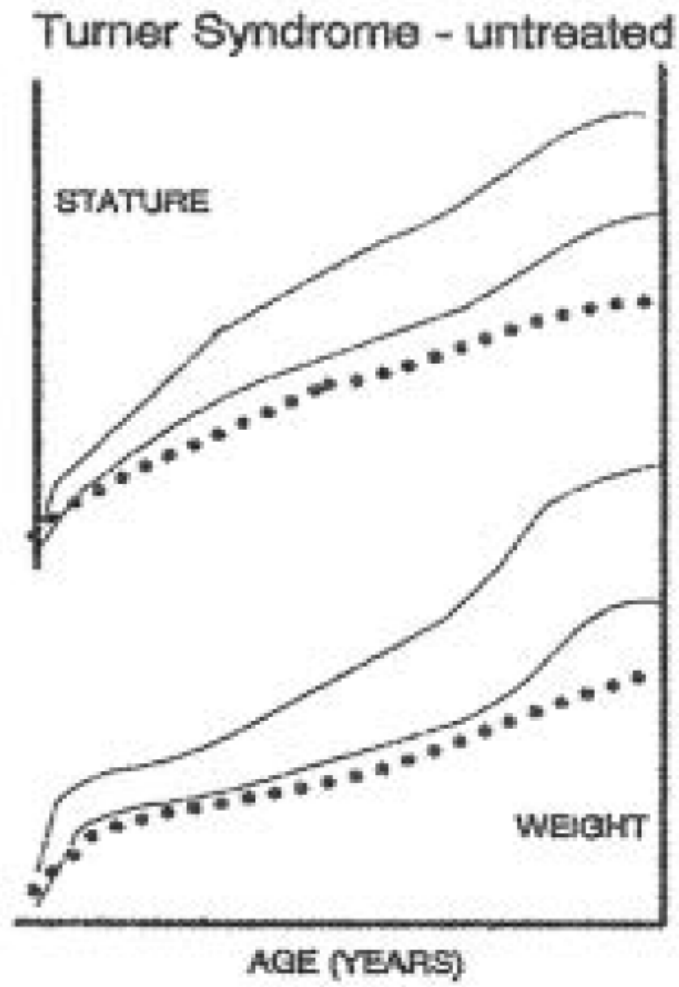
50–90%

Leri-Weill dyschondrosteosis

100%

Girls with Turner syndrome

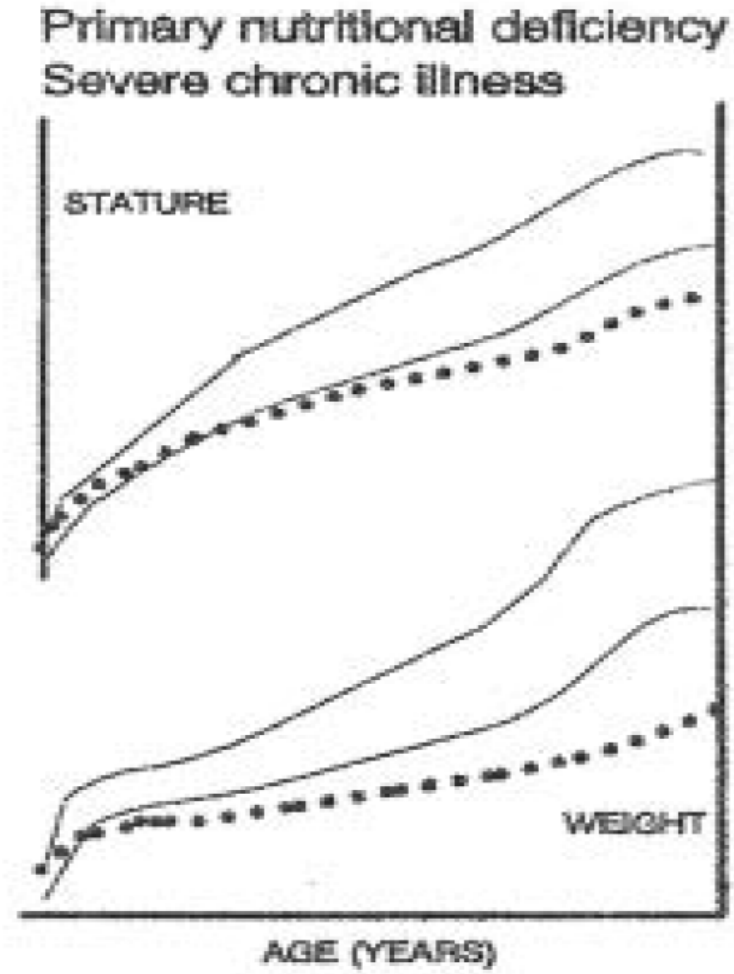
Growth Curve Archetype: Genetic Disorder



- Tracking further from the curve in both height and weight over time.
- Height has tracked further away from the curve than weight.
- Growing poorly for most of life with a slower than normal growth velocity.
- Final adult height is much lower than mid-parental height (genetic potential).

Genetic disorders of short stature (Turner's, Noonan's); other endocrine disorders would look similar if untreated.

Growth Curve Archetype: Nutritional / Psychosocial



- Weight declines BEFORE heigh
- Weight decline more pronounced.

PRE-SESSION KNOWLEDGE CHECK

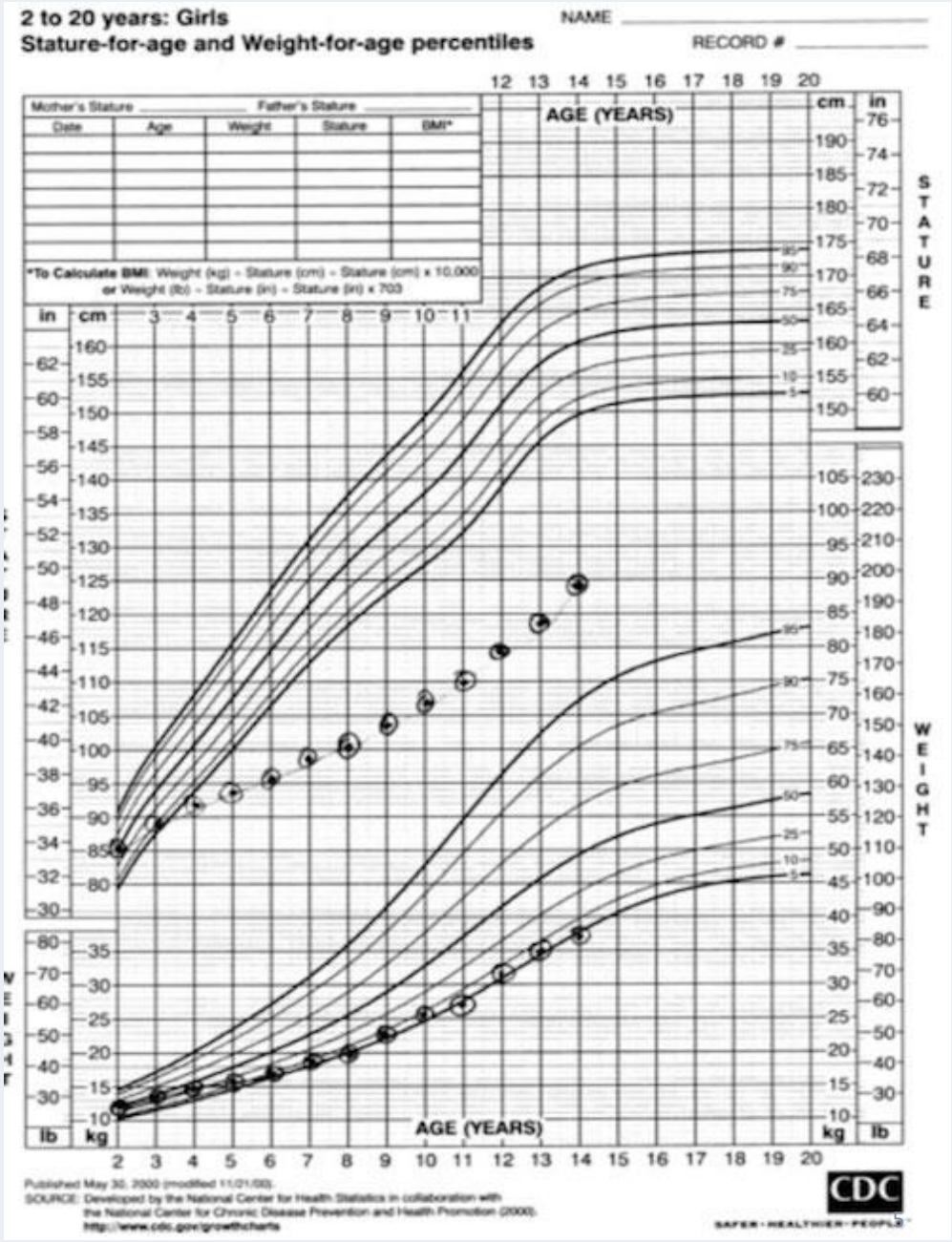
Five Questions

To assess what you learned from the pre-reading.

QUESTION 1

You are seeing a 14-year-old girl referred for delayed puberty. She has had no breast development thus far. Her mid-parental height is 50th percentile. Based on the growth curve, what potential diagnoses are on your differential?

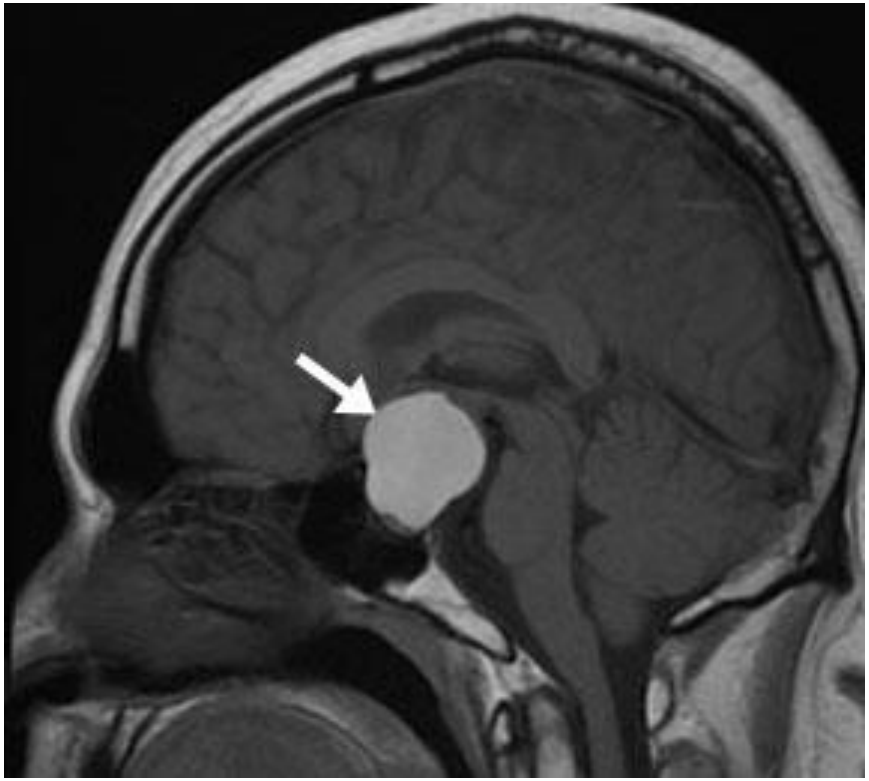
- **A** Turner Syndrome
- **B** Celiac disease
- **C** ADHD medication exposure
- **D** Anorexia nervosa
- **E** Constitutional delay of puberty



QUESTION 2

You are seeing an 8-year-old boy for height concerns. His birth weight was ~50th %ile, birth length was ~75th %ile. At age 2 he reached the 25th %ile for weight and 50th %ile for height. From ages 2 to 7, he continued along these percentiles. Six months ago, he stopped growing in both height and weight.

His mother mentions that he has been having headaches that wake him up from sleep at night and are associated with vomiting for the past 3-4 months. He has also been wetting the bed at night, even though this has not happened in several years. His MRI is shown to the right.



Source: pituitary.ucla.edu/

What is the most likely diagnosis?

QUESTION 3

Which of the following medications does not have an impact on growth or final adult height?

A Glucocorticoids

B Chemotherapy

C Stimulant Medications

D Anti-histamines

E Radiation Therapy

QUESTION 4

Which of the following is a normal feature of growth?

A. Arm span is 6 cm longer than height

B. Slowing of growth velocity just prior to puberty

C. A child with shortened 4th & 5th metacarpals

D. Bone age is 7 years when the chronological age is 4 years

E. Child is growing along height at 5th percentile while mid-parental height is 80th percentile

QUESTION 5

You are seeing a 15-year-old with a history of growth delay. Which aspect of the medical history is unlikely to contribute to the patient's final adult height?

A Rickets in infancy

B Hypothyroidism in childhood

C Exposure to drugs in utero

D Cannabis use 2 years after menarche

E Mosaic Turner Syndrome

THE ARC OF GROWTH

Pregnancy → Birth → Childhood → Puberty

Different hormonal and metabolic factors drive growth at each stage. Today's focus is growth during childhood.

CASE 1

History of Present Illness

John is a 5-year 8-month-old boy with a history of seasonal allergies who is otherwise healthy, presenting for "growth deceleration" diagnosed by his pediatrician. Growth became a concern after age 2. Fatigue emerged when he started preschool at age 4 — he becomes tired after ½ day of school, and his mother is concerned he may not "handle" a full day of kindergarten. He is doing well academically, but teachers suggested he repeat Pre-K.

Pre- and Perinatal History

- Pregnancy: uncomplicated, appropriate pre-natal care.
- Birth: full-term, born via C-section (failure to progress).
- Hospitalized 5 days after birth for hypoglycemia & jaundice.

Birth Measurements

Weight: 9 lb 14 oz (99th %ile)
Length: 22 in (56 cm) (97th %ile)
Head circumference: 14.5 in (37 cm) (90th %ile)

Interpreting Birth Information

- Large for gestational age
- No clear cause yet for hypoglycemia and jaundice

Clues Suggesting Thyroid, Pituitary, or Bone Disorders

Consider birth weight, length, and head circumference — congenital hypopituitarism can present with a large or normal birth size followed by growth failure.

Timing of Dental Eruption, Tooth Loss

Parallels skeletal maturity — delayed dentition can be another clue to a systemic growth or hormonal disorder.

CASE 1

History (continued)

Past Medical History
- No chronic illnesses, just mild seasonal allergies.

Medications
- Children's Claritin PRN for allergy symptoms
- Tylenol PRN fever

Nutrition
- Regular diet
- Two 8-ounce glasses of milk/day

Social History
- Lives with mom, dad, and 6-month-old sister.
- No psychosocial concerns.

Developmental*
- Met all early motor milestones on time
    - Sat unassisted ~6 months, crawled ~9 months, walked independently ~13 months
- Language on track
    - ~12 months, two-word phrases ~24 months, speaking in full sentences by age 3
- Passed newborn hearing & metabolic screens.

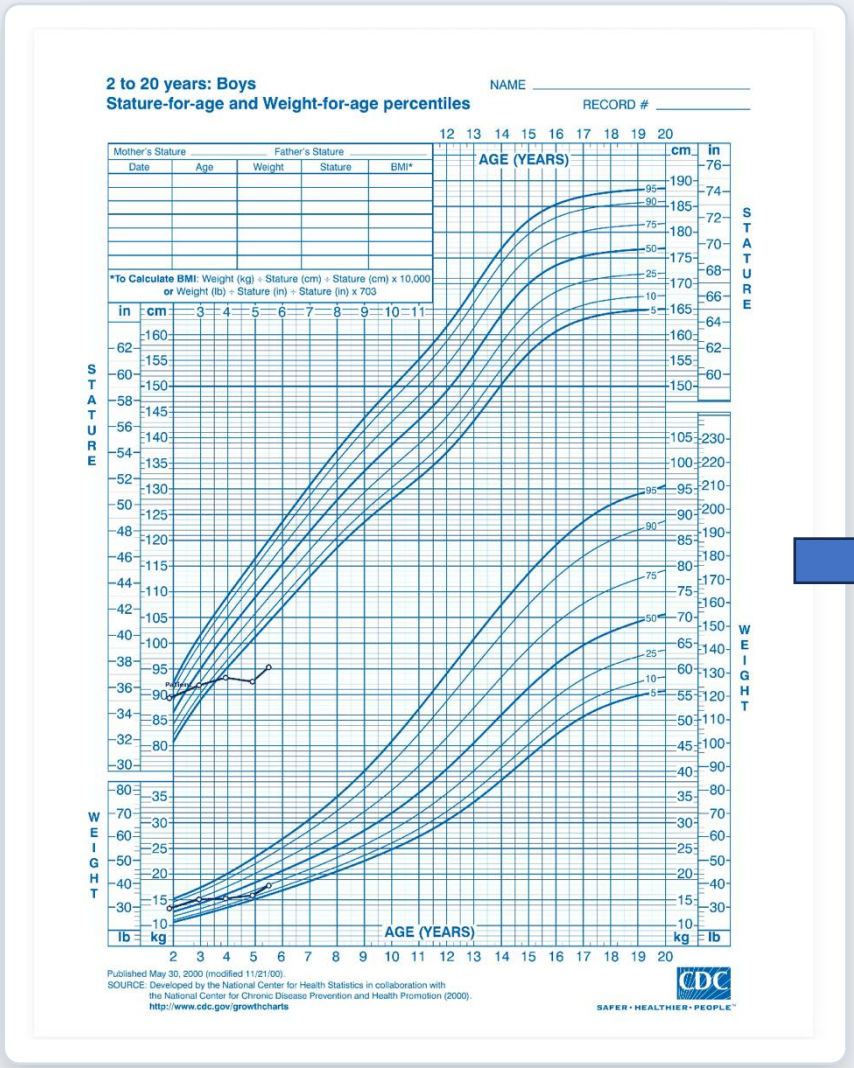
Family History
- Background: Caucasian/European.
- Mother had menarche at age 16; father's puberty unknown.
- Maternal uncle with delayed puberty. No family members under 5' tall.
- Maternal grandmother & grandfather with diabetes.
- No other major medical problems, hormone problems, developmental delays, or consanguinity.

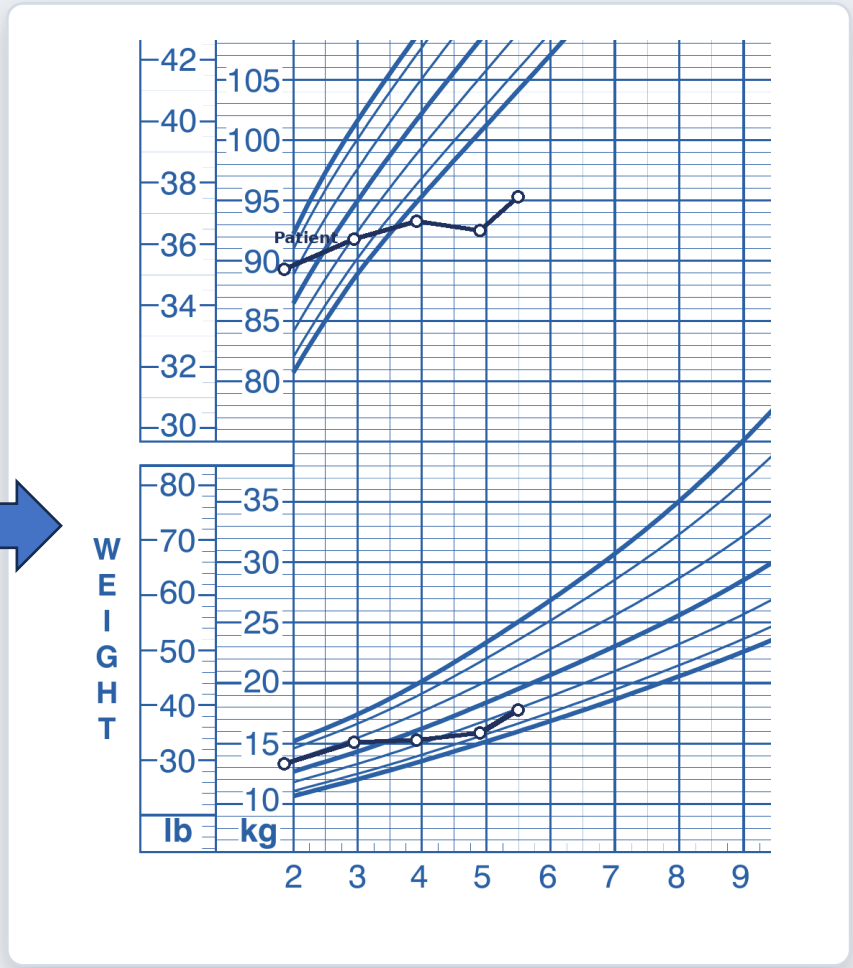
***Refer to Development I and Development II**

CASE 1

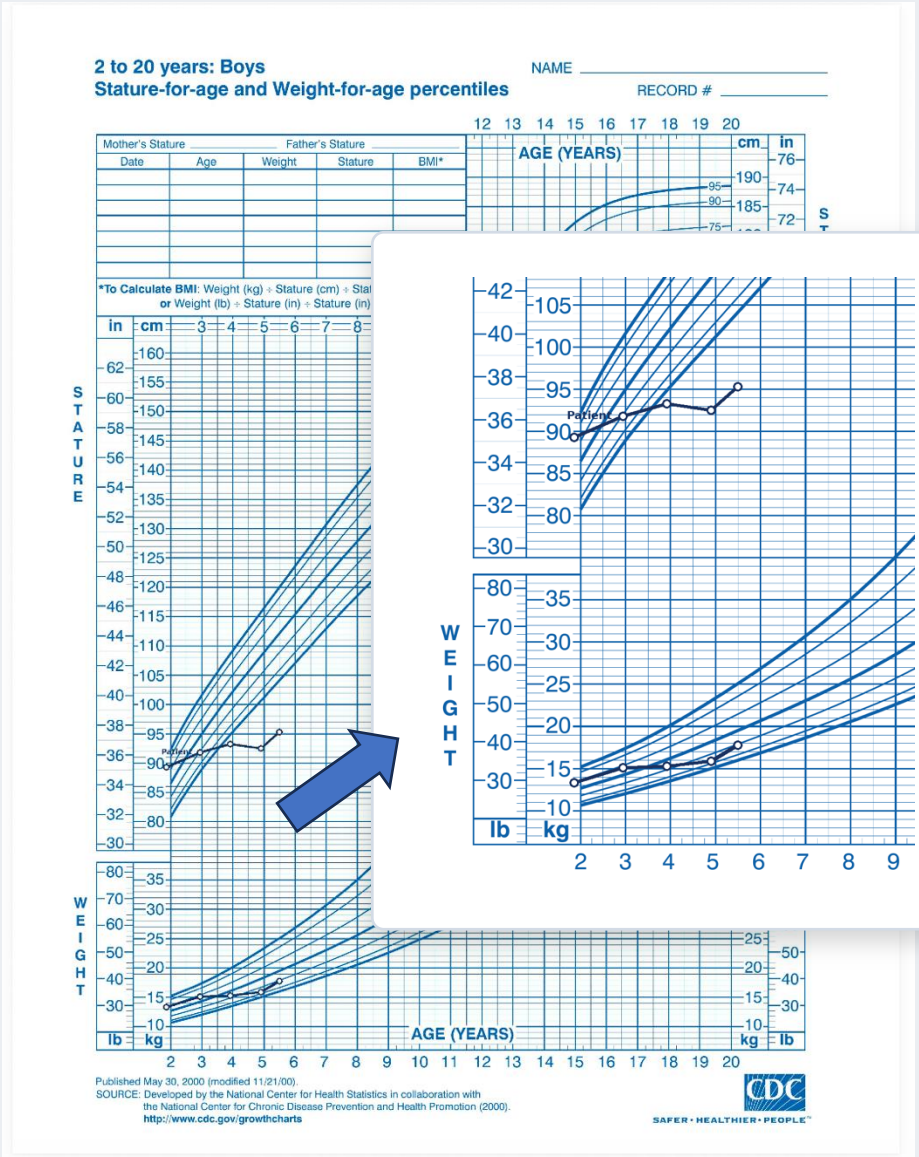
History of Present Illness

His growth charts:



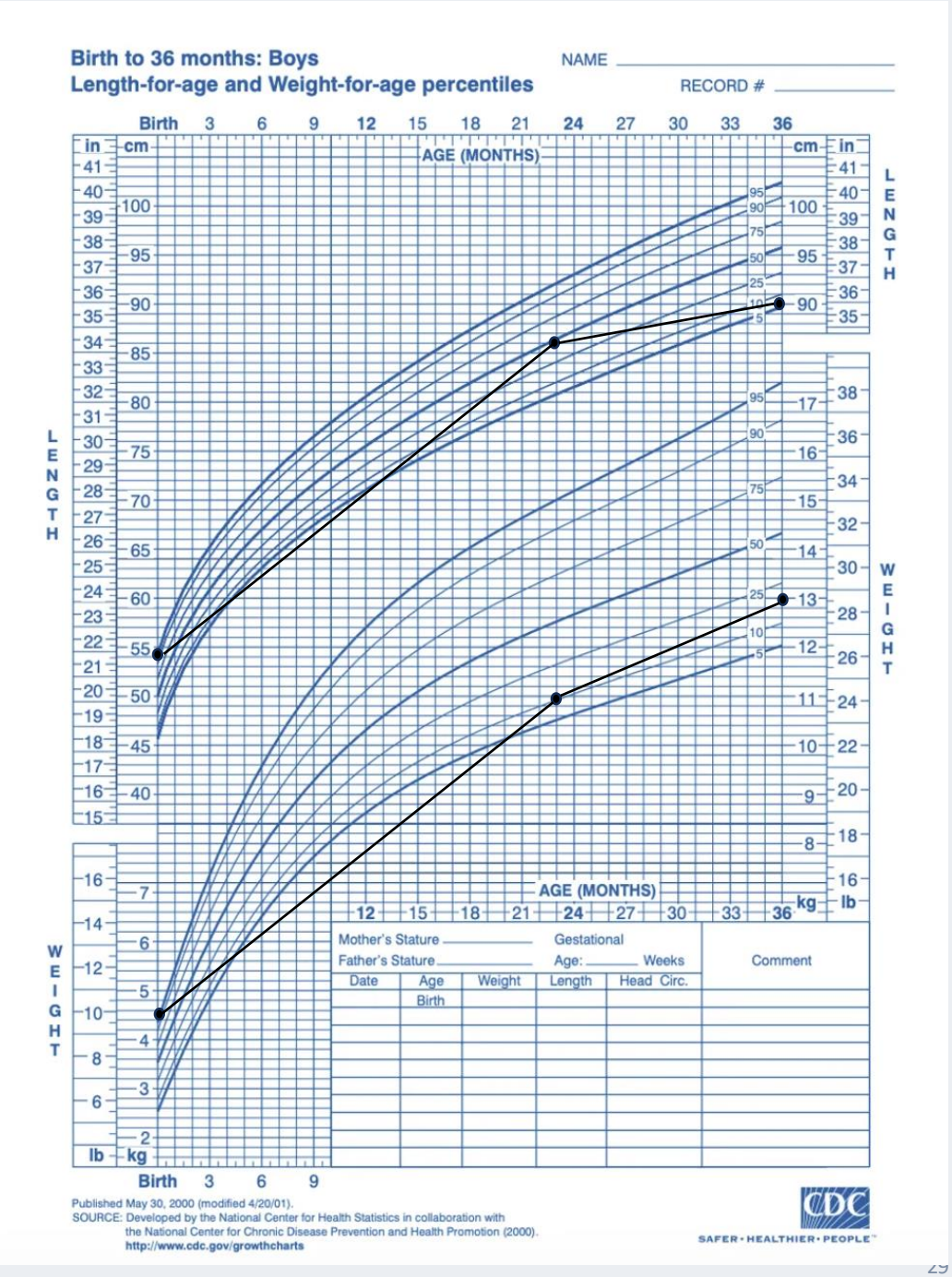


What to Consider First



- What data does this growth chart show?
  - *Age 2 to 5y8m only*
- Are the measurements accurate? *Children are no easy to measure.*
- Absolute height and height percentile.
- Growth velocity.
- How does weight %ile compare with height %ile
  - Current height is <1st percentile.
  - Not tracking along the growth curve.
  - Has not grown since age 3

Weight and Height: Ages 0–3 Years



CASE 1

Rank Your Differential

Based on the growth chart, rank these from most to least likely:

Variation on normal growth	Genetic syndrome	Endocrine / hormones	Chronic illness
Psychosocial factors	Environment	Nutrition	

RANKED, WITH RATIONALE

1. **Endocrine disorder —** more likely to have subtle signs/symptoms; weight generally preserved.
2. **Genetic syndrome (Turner's, Noonan's) —** appears to be longstanding.
3. **Chronic illness —** could have subtle signs/symptoms, less likely to have weight preserved, but still possible.
4. **Psychosocial —** could have subtle signs/symptoms; consider history & parent-child interaction.
5. **Environment —** possible, but exposures/medications would need to be long-standing.
6. **Nutritional intake —** weight is low for age, but following the growth curve.
7. **Variation of normal growth —** least likely, given the degree of growth failure.

CASE 1 — EXAM

Physical Exam

90/62	37°C	92/min	18/min	98%
BP	Temp	HR	RR	SaO_2

General

- Normal facies
- Increased truncal adiposity

Abdomen

- Soft, nontender, nondistended, no organomegaly

HEENT

- No midline palate abnormalities
- Optic disks sharp
- No thyromegaly or lymphadenopathy

Genitourinary

- Normal phallus, testes descended bilaterally, Tanner 1 pubic hair

Cardiopulmonary

- Heart RRR, no murmurs
- Lungs CTAB

Skin / Neuro / Extremities

- No abnormal hyperpigmentation or birth marks
- Neuro exam non-focal, no weakness
- No scoliosis, extremities normal

CASE 1 — WORKUP

Laboratory Workup

IGF-1	TSH	Free T4
Undetectable	**3.07**	**0.55**
(Ref range 31–214 ng/mL)	(Ref range 0.27–4.2 µIU/mL)	(Ref range 0.78–2.49 ng/dL)

Celiac screen negative. Comprehensive metabolic panel, CBC with differential: normal.

Q **What is your interpretation?**

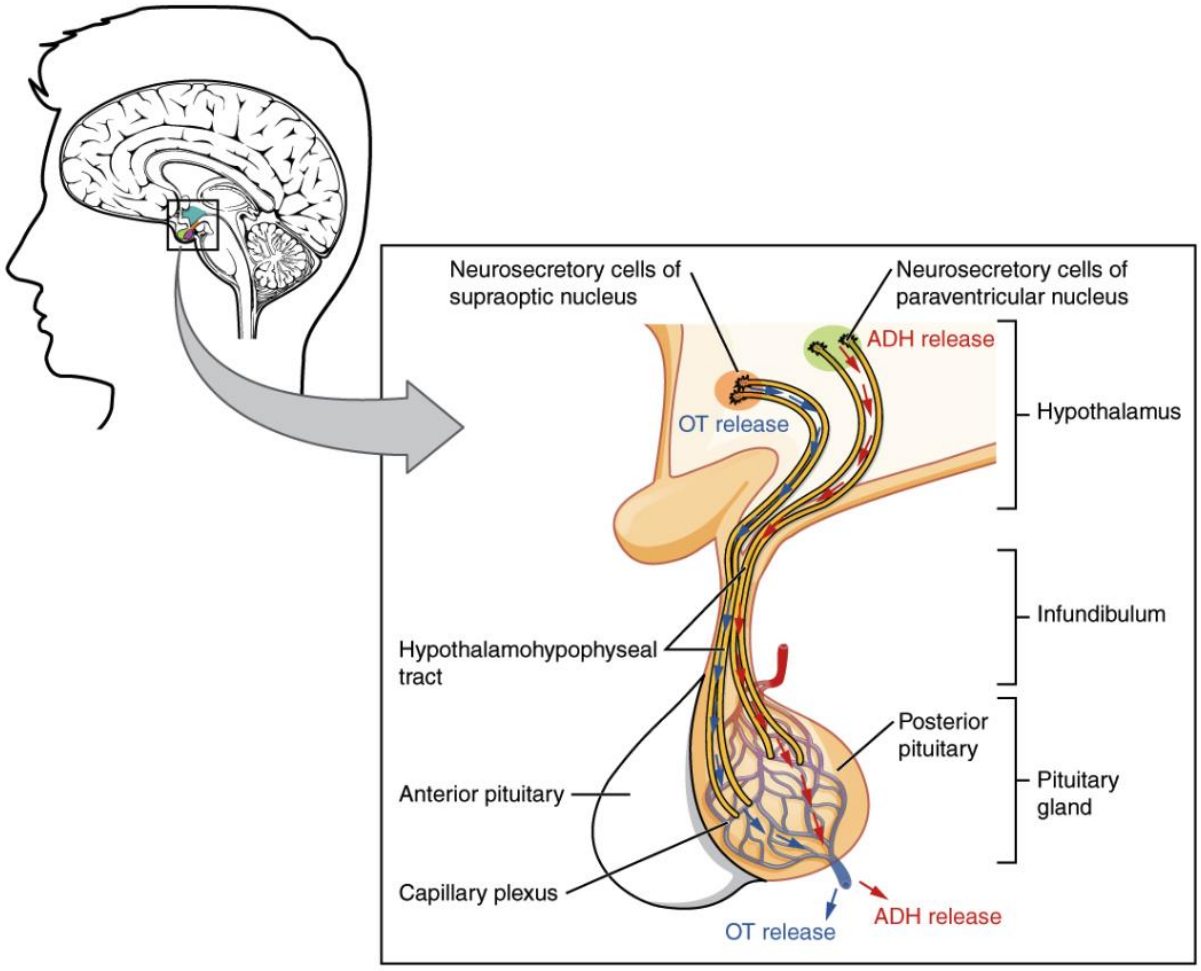
- ✓ Low IGF-1 with isolated worsening of height supports growth hormone deficiency.
- ✓ TSH is inappropriately normal for a low Free T4 — supports central hypothyroidism.

Q **What is your diagnosis?**

- ✓ Both raise concern for a congenital pituitary abnormality with multiple hormone deficiencies.

Anterior Pituitary (FLATPEG)

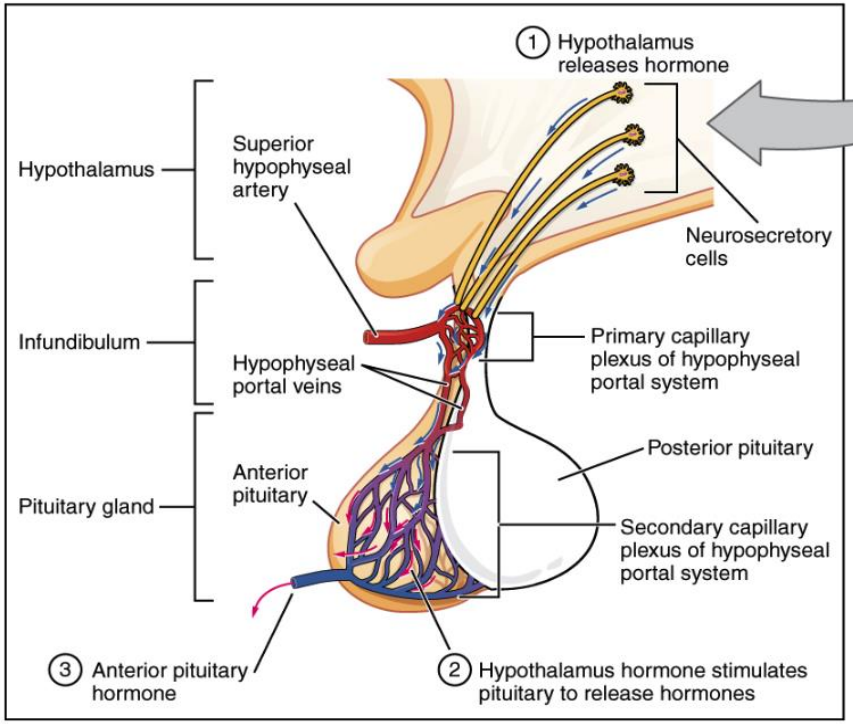
- FSH
- LH
- ACTH
- TSH
- Prolactin
- Endorphins
- Growth Hormone



OpenStax College. (2013). Anatomy & Physiology. Houston, TX: OpenStax CNX.

Posterior Pituitary

- Oxytocin
- Anti-Diuretic Hormone

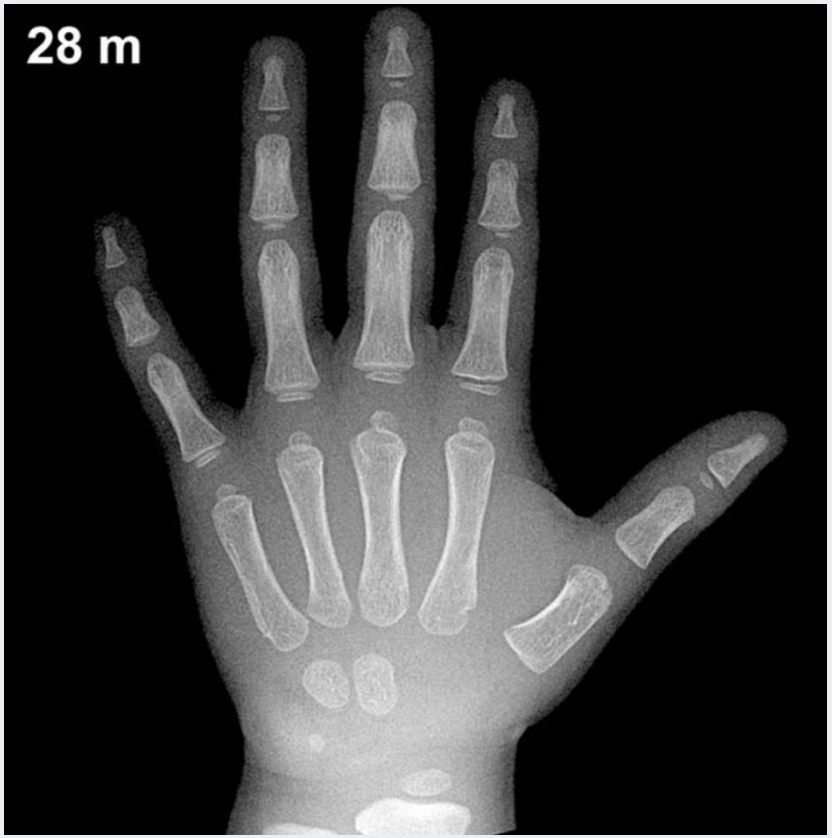


OpenStax College. (2013). Anatomy & Physiology. Houston, TX: OpenStax CNX.

CASE 1 — ADDITIONAL WORKUP

Bone Age vs. Chronological Age

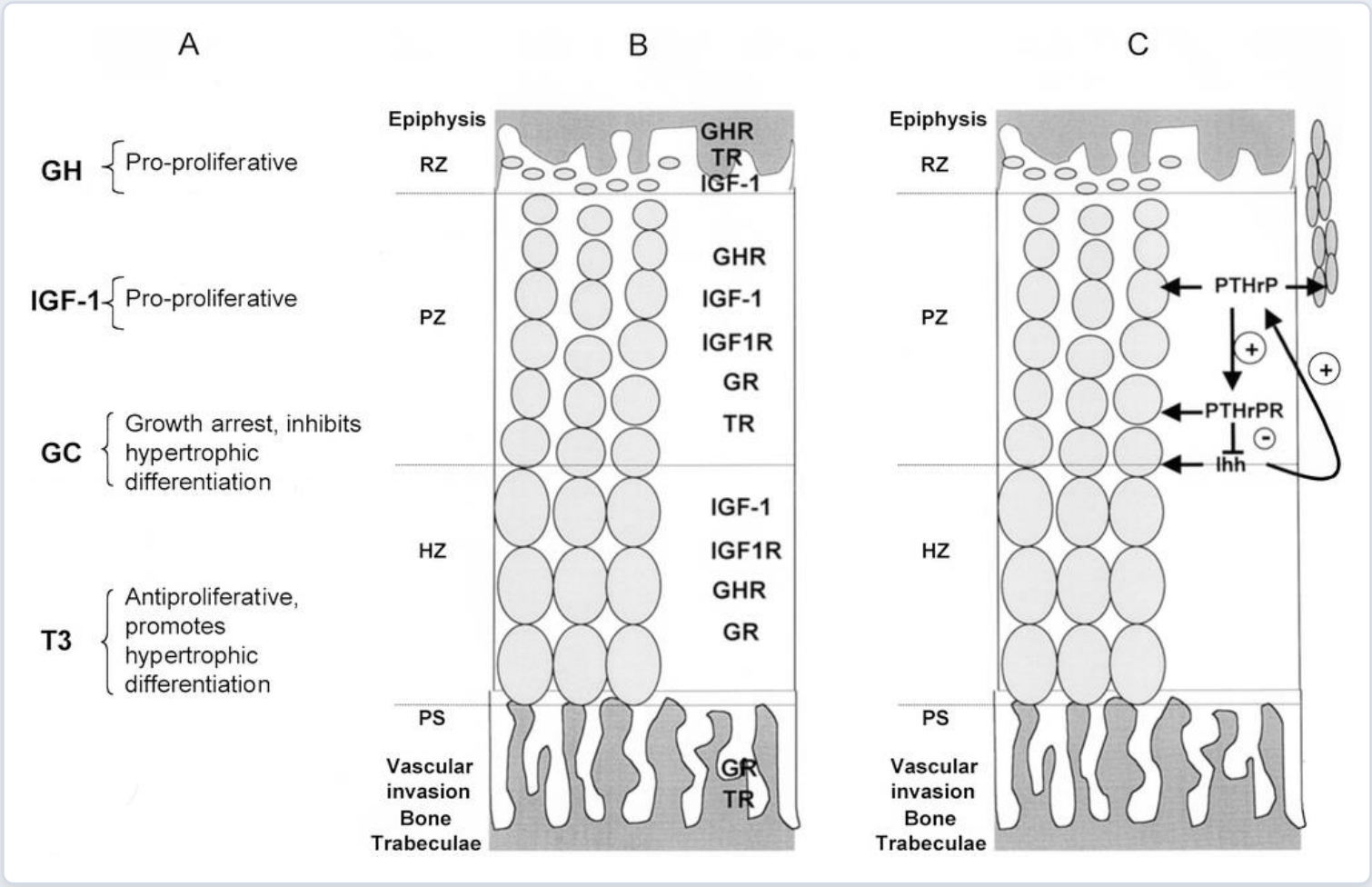
Bone Age



Chronological Age



Hormones & the Growth Plate

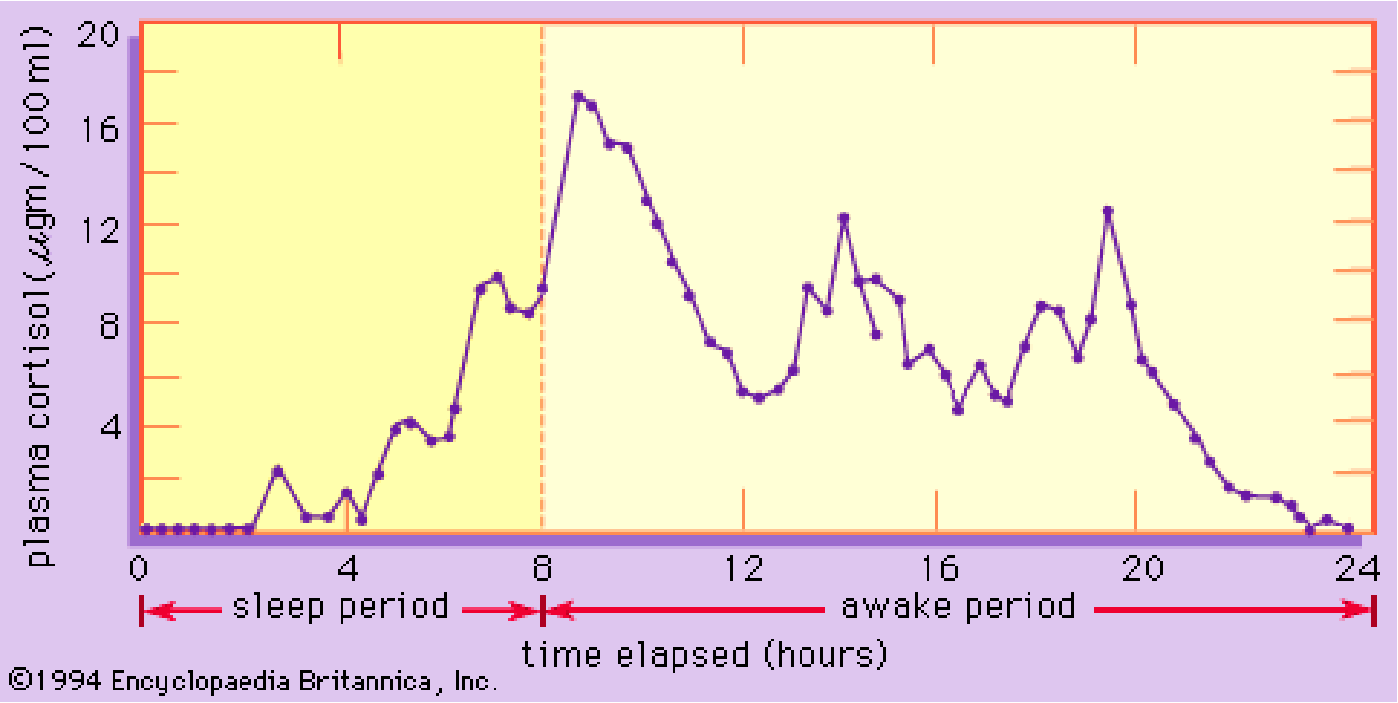


Thyroid hormone & growth hormone promote maturation at the growth plate.

Adrenal Gland Assessment

Adrenal insufficiency can be life-threatening. Check 8am ACTH & cortisol.

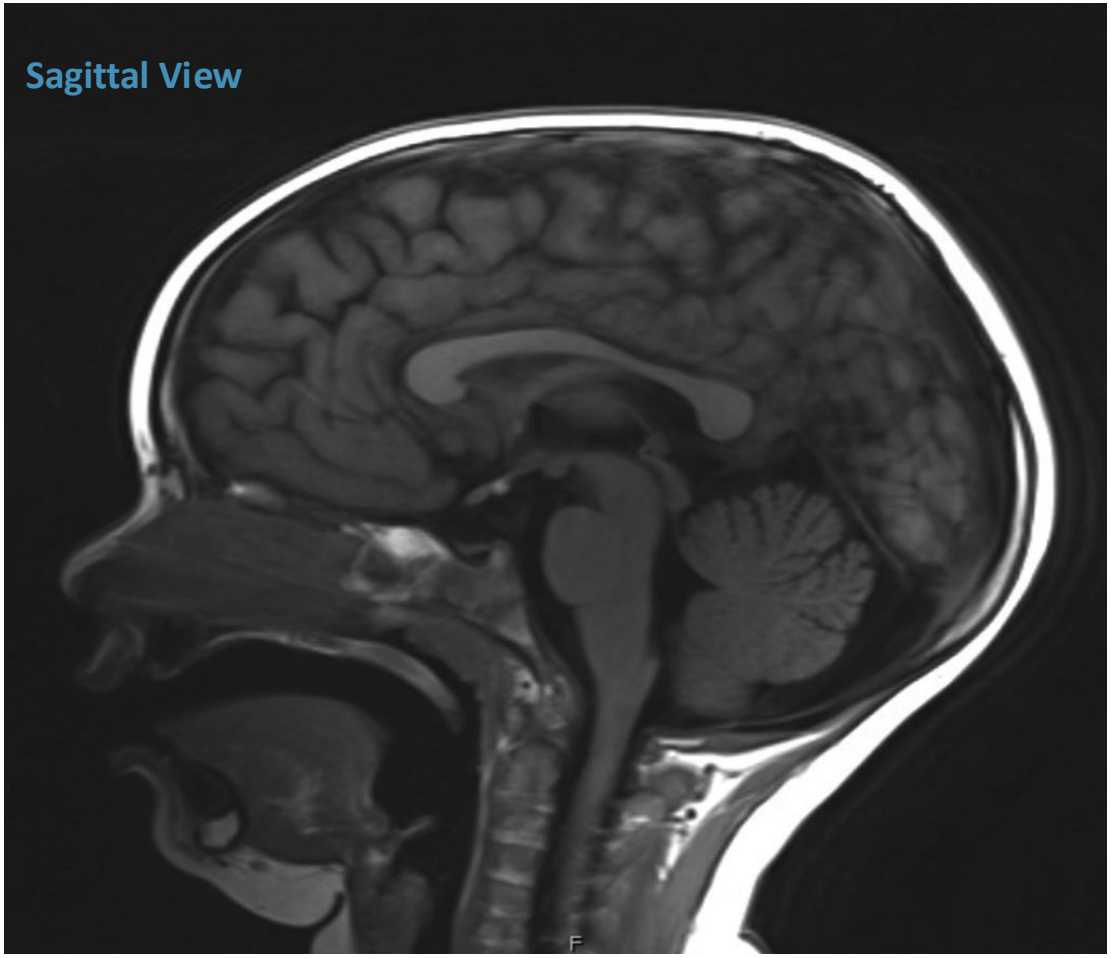
- 8am ACTH level 48 pg/mL (normal 9–57 pg/mL).
- 8am cortisol level 13.2 mcg/dL (normal 14–18 mcg/dL).
- ACTH stimulation test: normal results — appropriately able to mount a stress response.



Cortisol peaks 8–9am if circadian rhythm is intact — check adrenal function in the morning.

Brain MRI

Intracranial tumors can be life-threatening. MRI helps determine if a mass vs. malformed pituitary is the cause.



Findings

- Ectopic neurohypophysis (posterior pituitary, bright spot)
- Hypoplastic anterior pituitary gland
- Likely absent infundibulum

Integrating MRI findings

- MRI confirms the pituitary did not develop correctly.
- An intracranial mass compressing the pituitary has been ruled out.

CASE 1 — DIAGNOSIS

Features of Congenital Hypopituitarism

Central GH deficiency and hypothyroidism

ACTH/Cortisol axis intact

LH/FSH/Testosterone — to be assessed at puberty

Posterior pituitary not affected

What Should Be Monitored?

Height, weight, growth velocity, development every 6 months

Signs/symptoms of additional pituitary deficiencies.

Genetic evaluation for causes of hypopituitarism.

CASE 1 — FOLLOW UP

How Did This Patient Do?

After starting GH and thyroid hormone supplementation, he developed “catch-up growth” — growing at 12 cm/yr at 6 years 7 months.

IGF-1 and Free T4 normalized with treatment.

He retuned to clinic at 8 years old, noted to be increasingly tired compared to peers…

History at Follow Up

Nutrition

- 3 meals/day, not picky, no GI symptoms. Good calcium & vitamin D intake.

Hormonal

- Fatigued vs. peers. No polyuria/polydipsia. Compliant with medications.

Development

- Doing well in school, no physical delays.

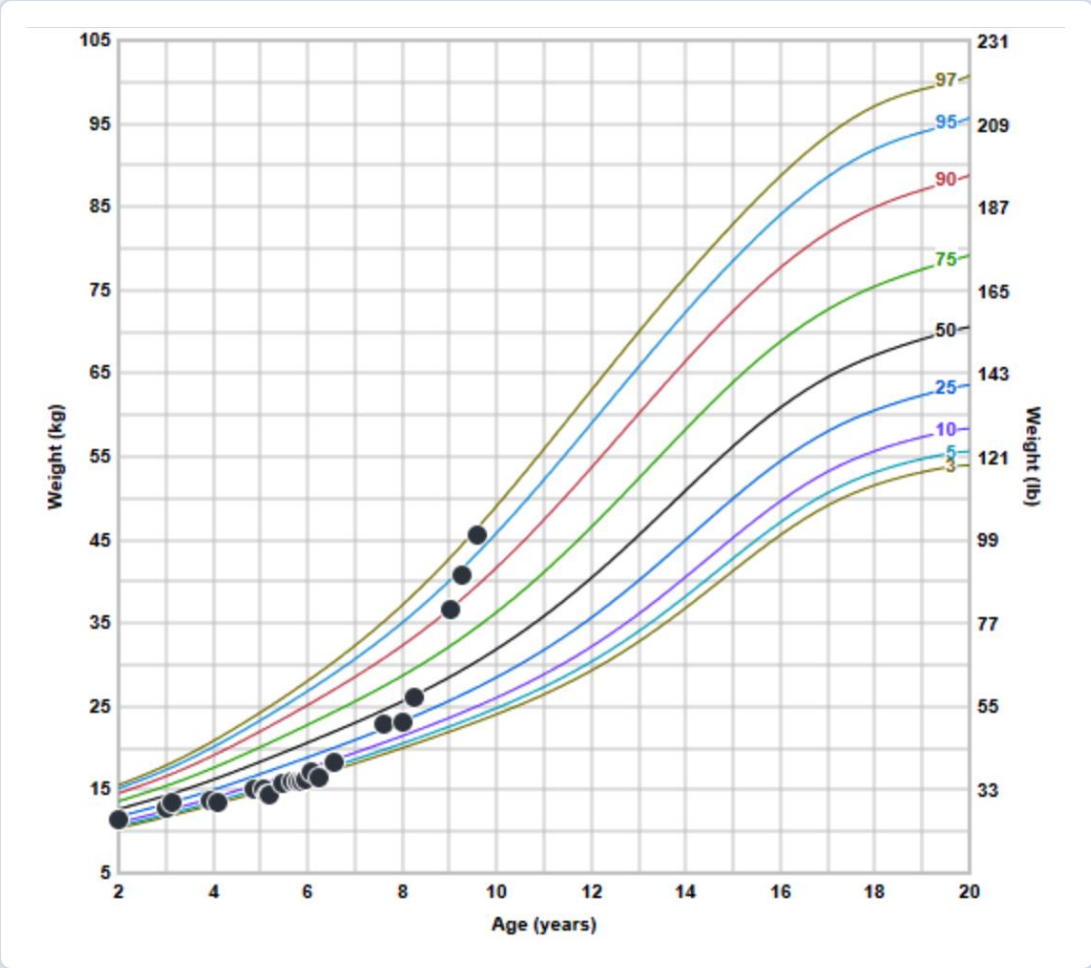
Genetics?

- Anything that could have been missed?

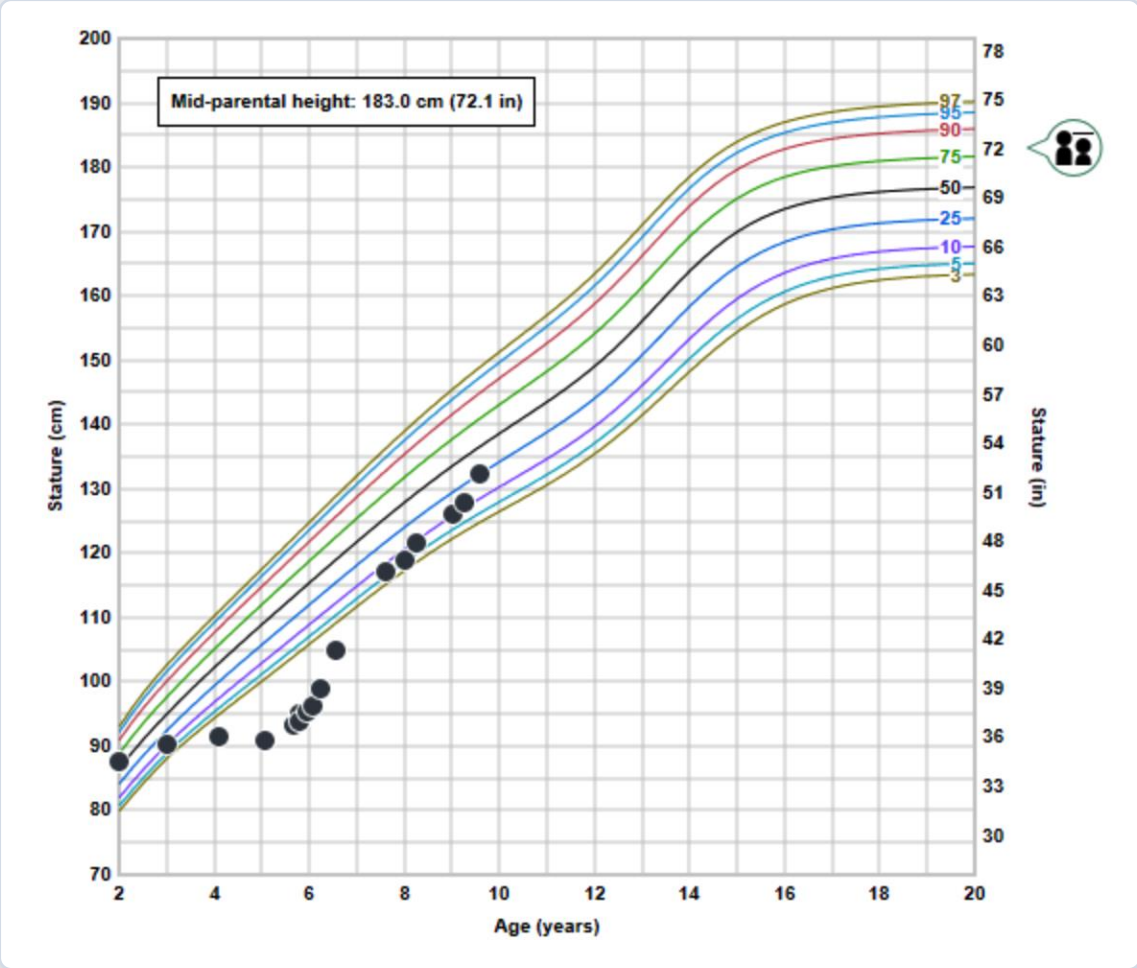
Psychosocial

- No major social changes or recent stressors.

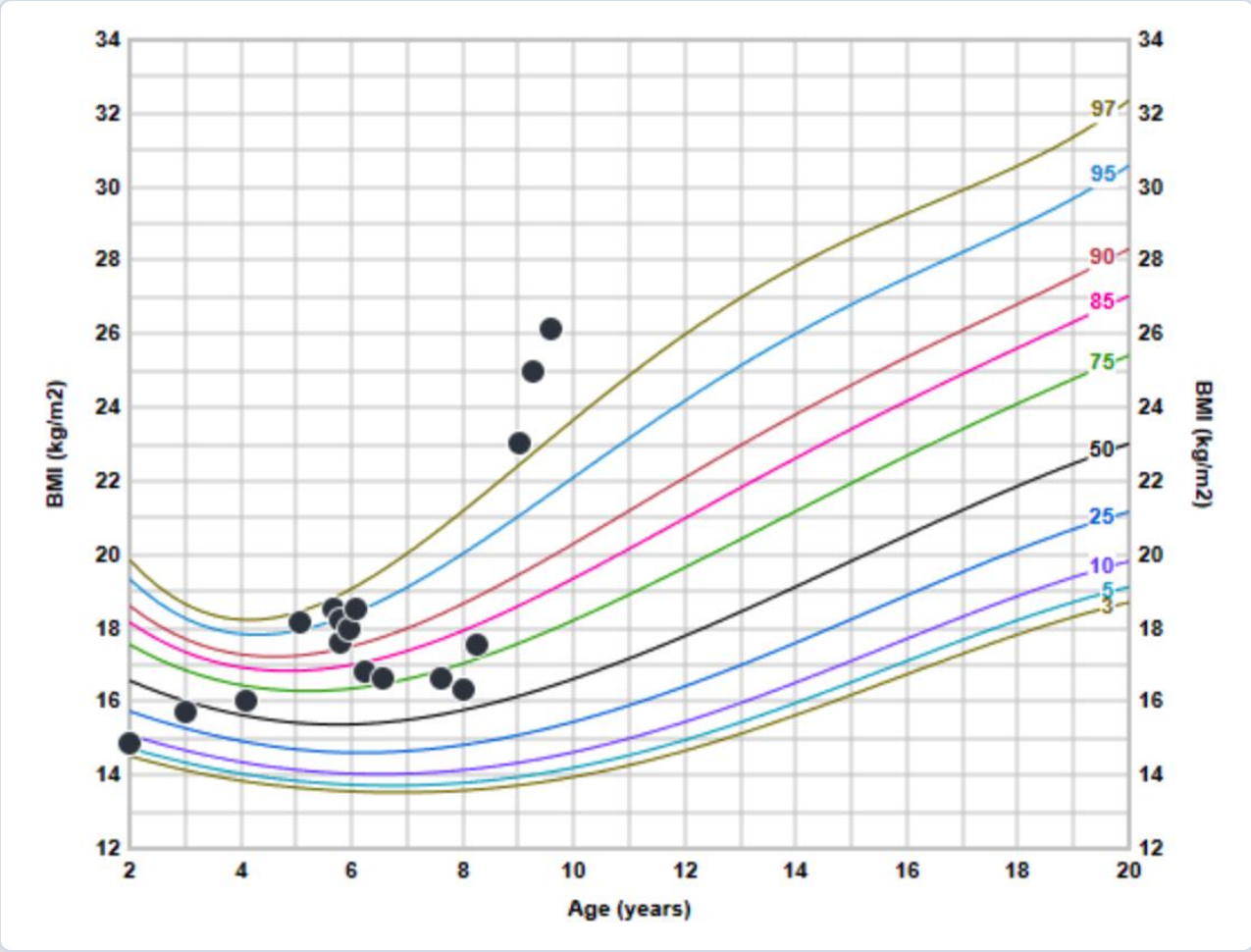
Weight Curve



Height Curve



BMI Curve


BMI (kg/m2)
Age (years)
34
32
30
28
26
24
22
20
18
16
14
12
2
4
6
8
10
12
14
16
18
20
97
95
90
85
75
50
25
10
5
3

What Are Your Next Steps?

Repeat 8am ACTH & cortisol levels to assess for central adrenal insufficiency.

Recheck Free T4 levels to assess compliance with thyroid hormone treatment.

Recheck IGF-1 level to assess compliance with growth hormone treatment.

1.0	**178**	**3.1**	**9**
Free T4 (normal 0.9–1.4)	**IGF-1** (normal 62–347)	**Cortisol** (normal 10–20)	**ACTH** (normal 9–54)

Cortisol is low and ACTH is low-normal.
If cortisol is low, ACTH should be higher.

What pattern is this?

Adrenal insufficiency.

CASE 1 — FOLLOW UP TREATMENT

Next Steps…

Began treatment with hydrocortisone replacement.

Physiologic daily dosing AND “stress dosing” — a higher dose for physiologic stress.

Physiologic stressors include fever, vomiting, fractures, anesthesia, or surgical procedures.

CASE 2

History of Present Illness

Esther, age 8, is brought in by her grandmother — who recently gained custody — for “always being small.” She was removed from her mother's home 8 months ago when her school district noticed she never attended first grade. Prior to that, Esther lived with her mother in a few different locations throughout CT and FL, and occasionally with extended family. Grandmother describes Maya as a “picky, anxious eater” who sometimes hoards food in her pockets at school.

Pre- & Perinatal History, Birth Measurements

- Grandmother thinks she was born at home, otherwise unknown

Developmental

- Struggles with a pencil, knife, and fork
- Bubbly personality, opened up a great deal over past 8 mos

Interpreting Developmental Information

- Fine motor delays
- Resilience

Clues Suggesting Thyroid, Pituitary, or Bone Disorders

Consider birth weight, length, and head circumference — congenital hypopituitarism can present with a large or normal birth size followed by growth failure.

Timing of Dental Eruption, Tooth Loss

Parallels skeletal maturity — delayed dentition can be another clue to a systemic growth or hormonal disorder.

CASE 2 — EXAM

Physical Exam

90/62	37°C	92/min	18/min	98%
BP	Temp	HR	RR	SaO_2

General
- Small for age, thin
- Appropriately portioned

HEENT
- No midline palate abnormalities
- Optic disks sharp
- No thyromegaly or lymphadenopathy

Cardiopulmonary
- Heart RRR, no murmurs
- Lungs CTAB

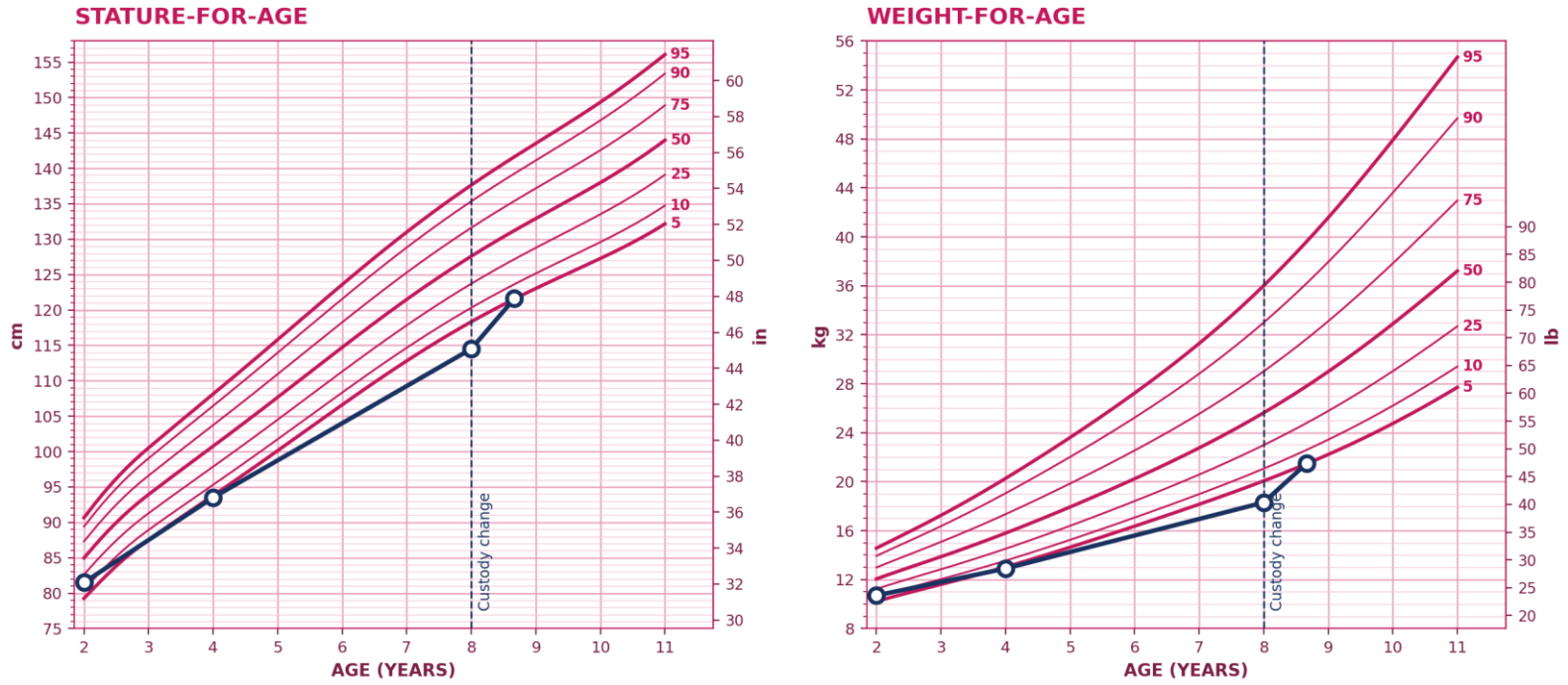
Abdomen
- Soft, nontender, nondistended, no organomegaly

Genitourinary
- Sexual Maturity Rating Stage 1

Skin / Neuro / Extremities
- No abnormal hyperpigmentation or birth marks
- Neuro exam non-focal, no weakness

Affect
- Withdrawn initially, then opens up

At Presentation…



2 to 20 years: Girls — percentile curves drawn from CDC/NCHS (2000) growth chart data (statage / wtage)

Height and weight are both tracking around the 1st percentile. Growth has improved in the 8 months since the custody change.

CASE 2 — WORKUP

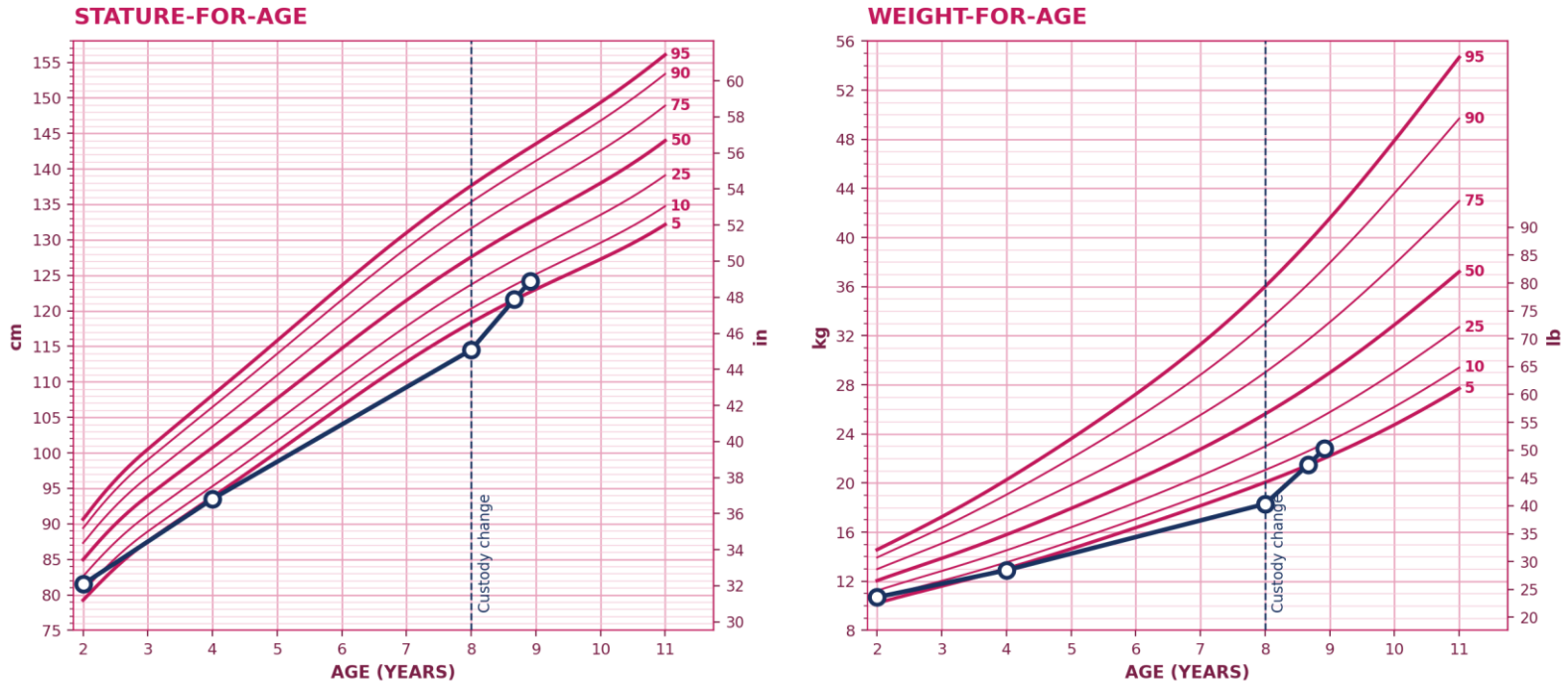
Initial Workup

Low	Blunted	Normal	Negative
IGF-1	GH stimulation test	TSH / Free T4	Celiac screen

The low IGF-1 and blunted GH response look like growth hormone deficiency — but the pattern doesn't fit a congenital process.

This is the classic biochemical signature of psychosocial short stature: emotional deprivation and chronic stress can functionally suppress the GH axis, producing labs that mimic true GH deficiency.

At Follow Up…



2 to 20 years: Girls — percentile curves drawn from CDC/NCHS (2000) growth chart data (statage / wtage)

Repeat IGF-1/GH testing 3 months later show improvement. “Catch-up growth” accompanies the lab normalization. This confirms the diagnosis retrospectively without a complex workup.