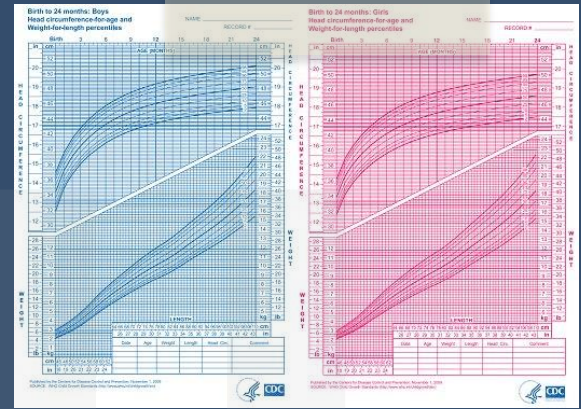# Short Stature Referrals: What to Do When They're Off the Charts!

19TH Annual Doernbecher Pediatric Review
Rachel Palting, DO
10/24/2025
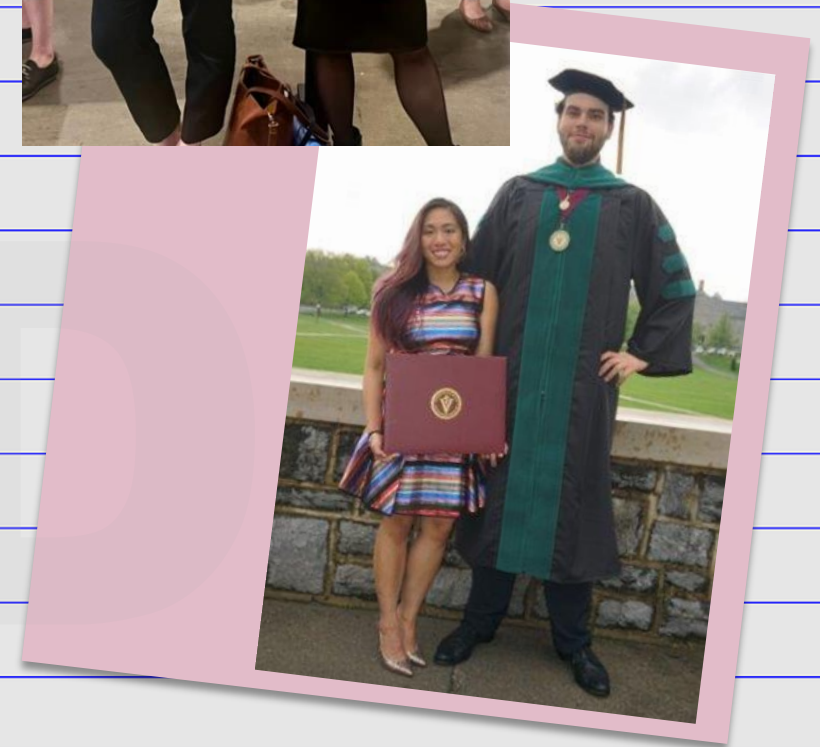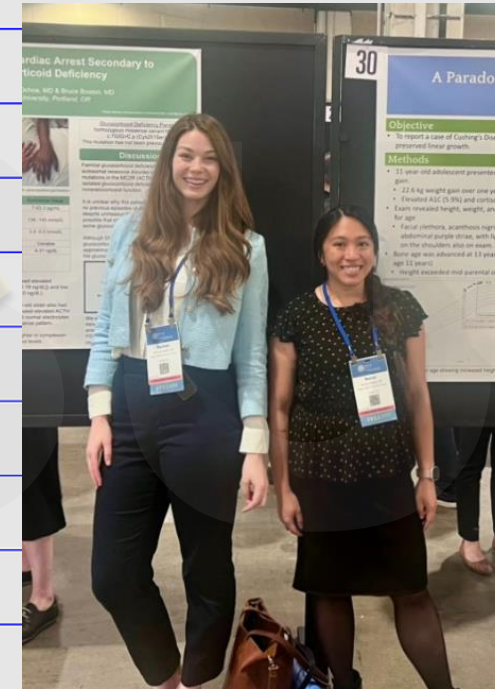
RANDALL CHILDREN'S HOSPITAL
LEGACY EMANUEL

DOERNBECHER CHILDREN'S Hospital
OHSU

Objectives

- Empower general practitioners to accurately and efficiently distinguish between normal variants of short stature and pathological causes.

- Review high-yield work up to determine which children require prompt referral to pediatric endocrinology.

Phases of Linear Growth: Intrauterine

STAGES OF DEVELOPMENT

- Most rapid growth during lifetime (100 cm/year)
- **Nutrition** and **maternal/fetal health** are key
  - Maternal factors: weight gain, systemic illness, medications, drugs(tobacco/alcohol)
  - Placental factors: twinning/infection
  - Fetal factors: **syndromes, chromosomal abnormalities**
  - Insulin is the most important hormone
  - Poorly controlled gestational diabetes => LGA
- Paternally expressed **IGF-2** in the fetus/placenta are both important in fetal growth
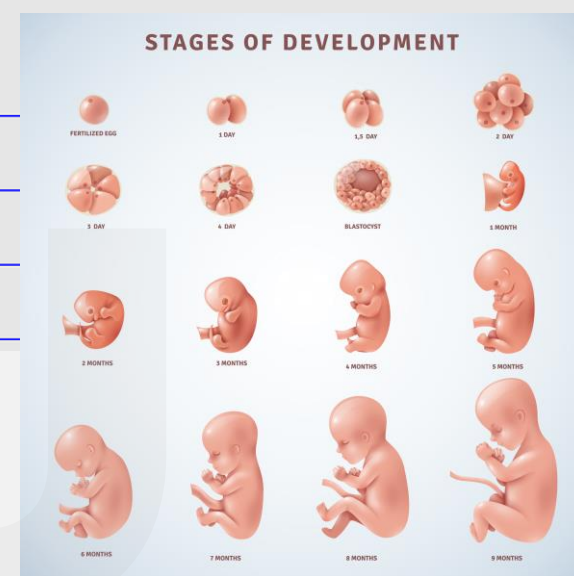
Infancy (birth to age 2)

- Growth remains rapid (25-50 cm/year)
- **Nutrition** still important from 6-9 months of life

  - Then **GH becomes important**
- **Crossing height percentiles is normal** during transition from prenatal to postnatal growth
- Growth faltering during this period can be an early sign of **constitutional delay of growth**

$1 + 2 = 3$

Childhood

- Slowest and longest period of growth (5 cm/year)
- Growth hormone is the primary driver
- Shifting percentiles is *abnormal* during this phase

$1 + 2 = 3$

Adolescence

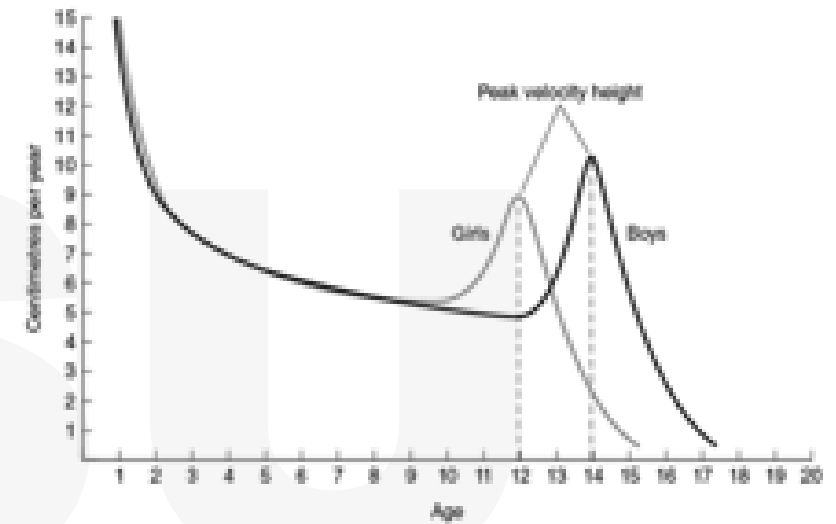**Final 15% of growth (8-10 cm/year)**

Girls
- Accelerate at 10 years
- Peak of 9 cm/year at 11.5 years
- Average growth of 7.5 cm growth post menarche

Boys
- Accelerate at 12 years
- Peak 10 cm/year at 13.5 years
- 97% height attained at bone age of 15 years

**Growth hormone secretion is increased by sex steroids**

Figure 8.1 Peak velocity height curve for girls and boys showing the increase in stretch stature (height) expressed in units of centimetres per year.
From http://www.brianmac.co.uk/Itad.htm

Definitions/Clarifications

- Short stature: height < - 2.0 SD (~3%tile for age and sex)

- Growth deceleration: crossing $\geq$ 2 major percentile lines or growth velocity below normal

- Projected height >2 SD below MPH suggests pathology

- Severe short stature: < - 3.0 SD = refer
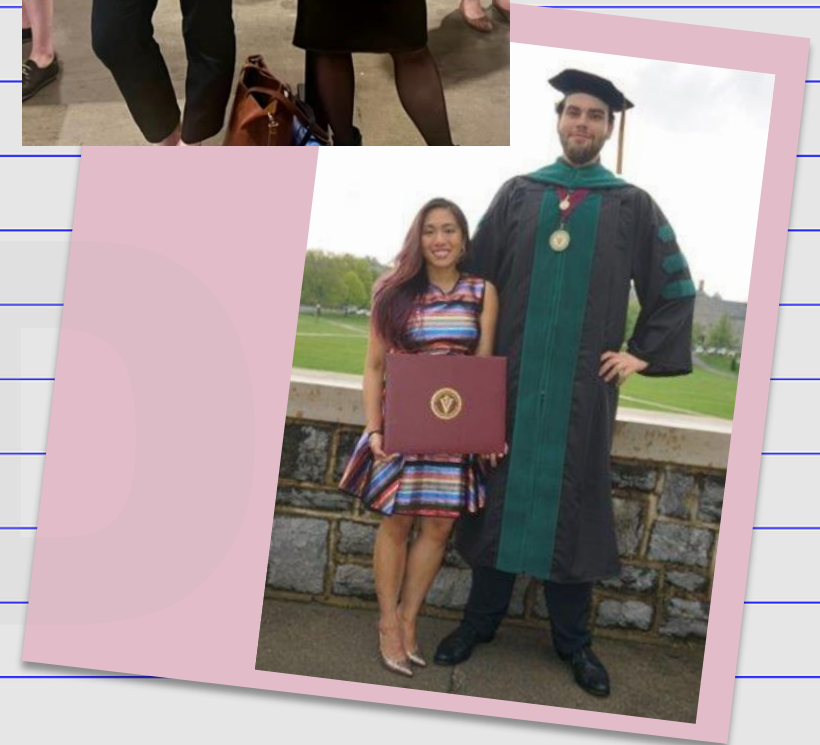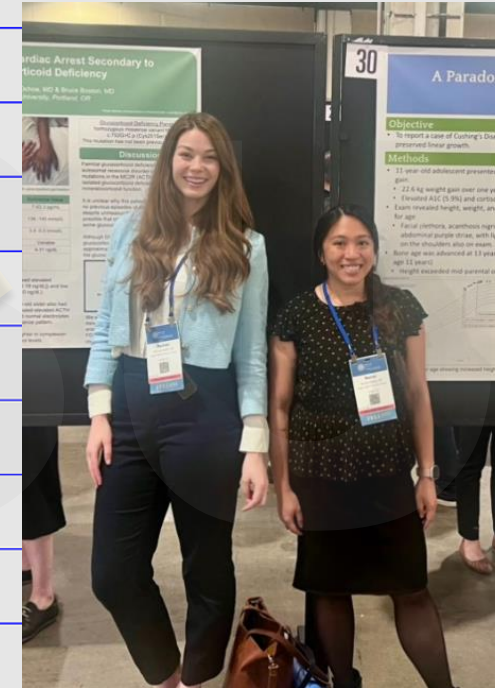
Length Measurement

Birth – 24 months:
Supine measurement

2-3 years and older:
Statiometer

- Shoes off
- Back of heels to wall
- Looking straight ahead

WHO (2006) Birth – 24 mos

- recumbent length
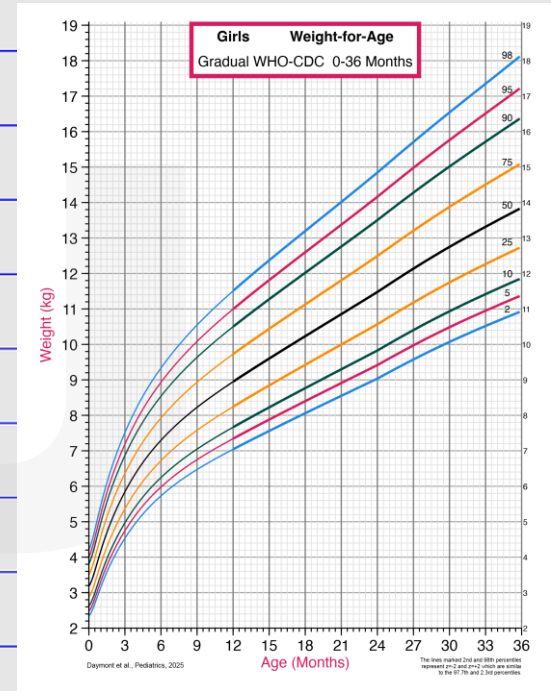- longitudinal data across 6 diverse countries
- **identify how children should growth when provided optimal conditions**
- better description of physiological growth in infancy

CDC (2000) 2-19 YEARS OLD
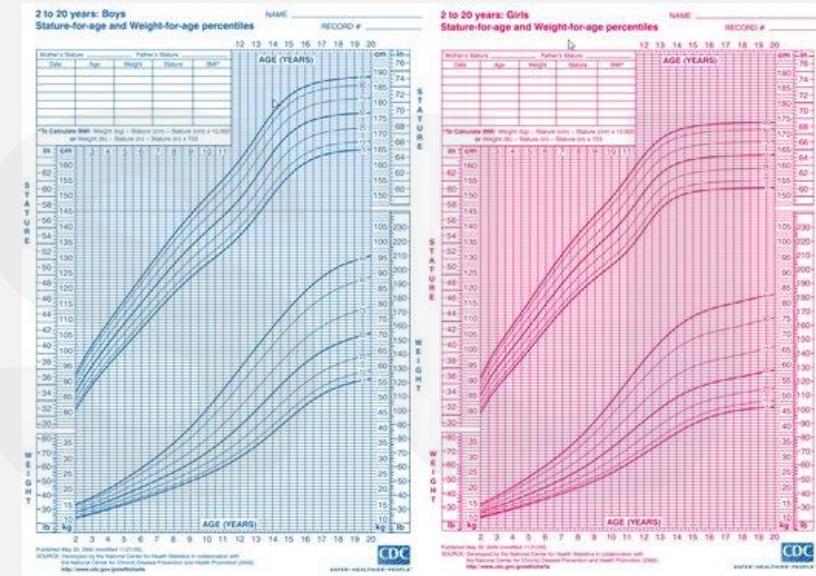
- standing height >2 years
- **cross-sectional data from the US, reference population from national surveys from 1963-1980**
- observationally describes how children in the population grow

WHO -> CDC

Pt tracking just below the CDC weight-for-age 2.3rd percentile

Boys   Weight-for-Age
Gradual WHO-CDC 0-36 Months

Girls   Weight-for-Age
Gradual WHO-CDC 0-36 Months
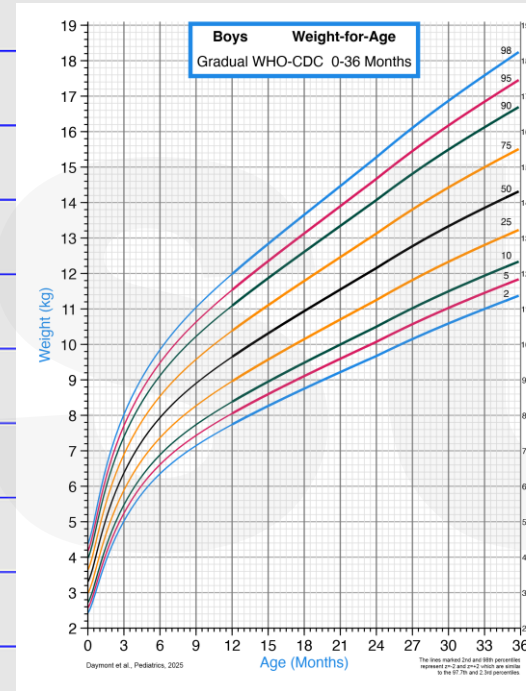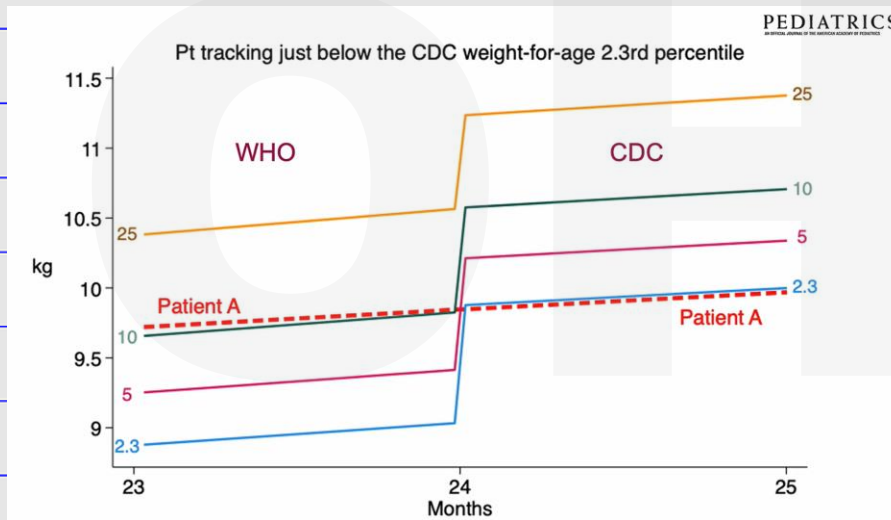
- There is a significant discontinuity between these growth charts at this age (10%tile to <2%tile).
- Researchers at Penn State have created growth charts that make the transition from WHO to CDC gradually and smoothly from 2 to 5 years (single center, n=>7000).
- Just published last month (Sept 2025)

A little bit about physiology...
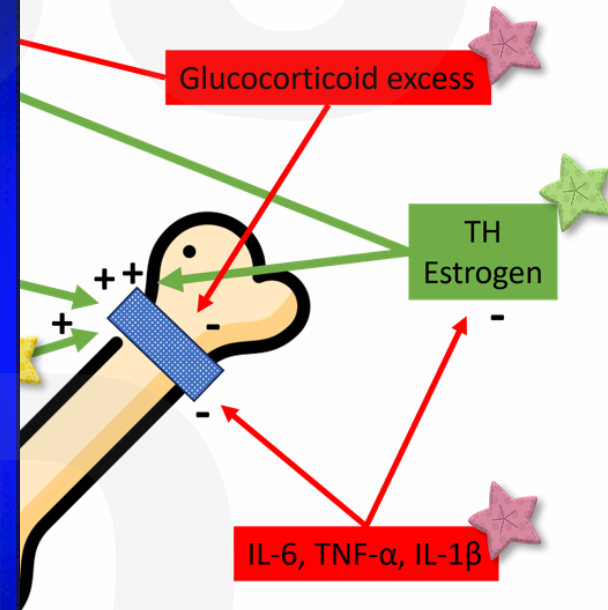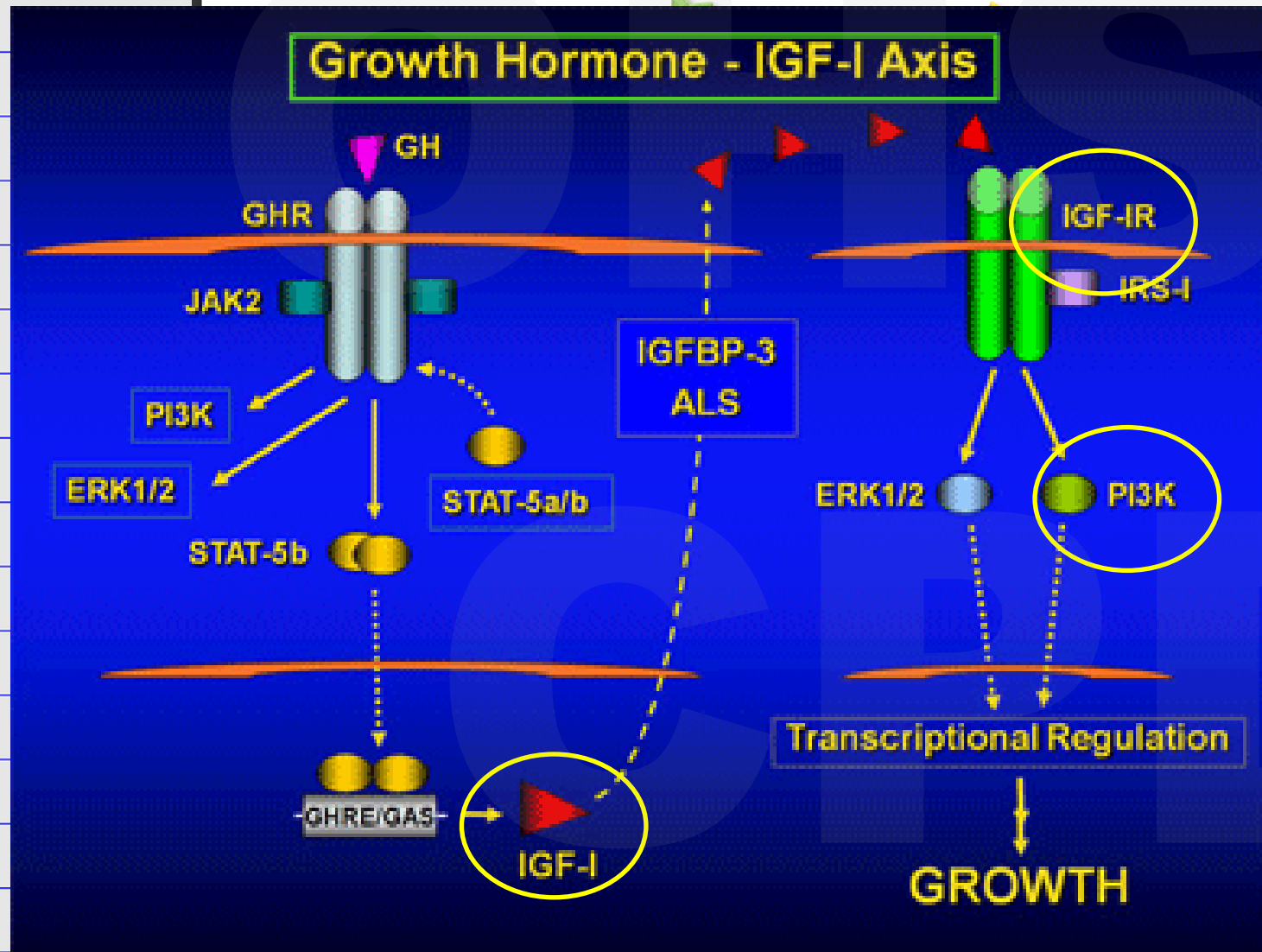
Dr. Susie Cabrerra from Medical College Wisconsin

Summary so far!

- Phases of growth
  - Intrauterine
  - Infancy
  - Childhood
  - Adolescence
- Length measurements
- Growth charts
- Physiology

Approaches to short stature

- How tall is the child expected to be?

- When did growth deviate?

- Is growth velocity continuing to increase?

- Does the child have normal weight gain?

History!

Birth history
- **Weight/length** (SGA?)
- Complications
- Maternal factors (FAS?)
- **Hypoglycemia** (GH deficiency)
- **Jaundice** (Hypothyroidism?)

Chronic illness
- TNF α, IL-1β, IL-6 act **inhibit chondrocytes**
- Malnutrition → reduced **IGF-1 levels**
- Require **glucocorticoid** therapy
- Relative GH resistance, possibly due to **downregulation of JAK2 signaling**

Head trauma
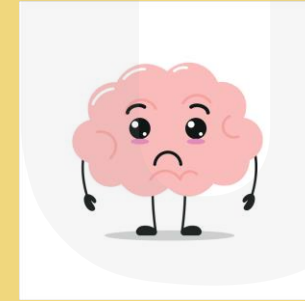
Medications
- Steroids
- Stimulants (delayed height velocity)
- Chemotherapy

Family
- Parental heights
- Parental growth patterns (CDGP?)
- Pubertal timing

Social environment
- Psychosocial short stature I – before age 2
- Psychoscial short stature II – after age 3

Prediction of Adult height

- Least accurate!
- Mid parental height assumes that height is inherited in a polygenic fashion
- Some parents don't know their height **(guys will say they're 6'0" when they're 5'10")**
- MPH is +/- 2-2.5 inches (could be up to 4"!)

For boys: [mother's height + 5 inches] + father's height / 2
For girls: [father's height – 5 inches] + mother's height / 2

Physical exam – upper segment to lower segment ratio

Upper segment
Pubic symphysis
Lower segment
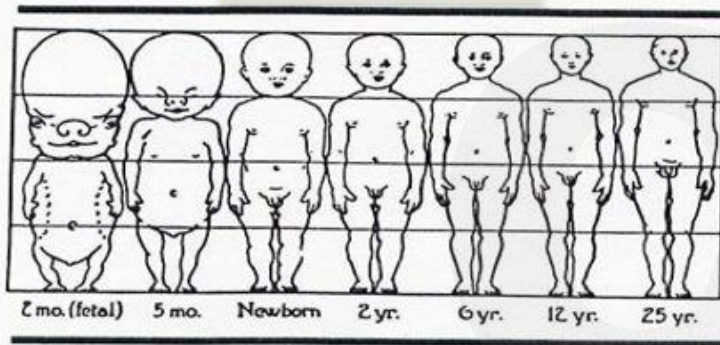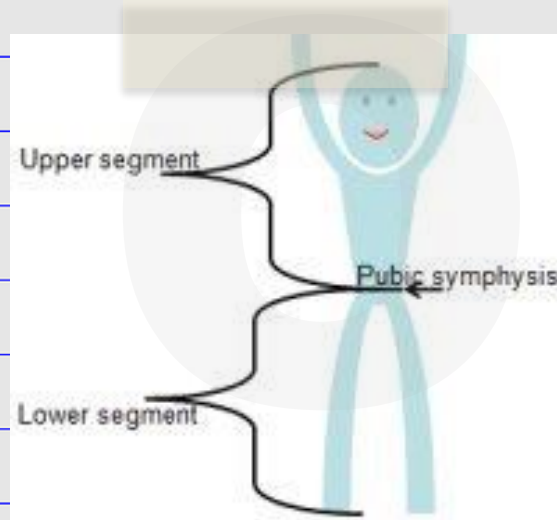
Figure 1–15. Changes in body proportions from second fetal month to adulthood. (From Robbins WJ, et al: Growth. New Haven, CT, Yale University Press, 1928, by permission of the publisher.)

2 mo.(fetal)   5 mo.   Newborn   2 yr.   6 yr.   12 yr.   25 yr.

U/L BODY RATIO — AGE (YEARS)

Males ——
Females ·······
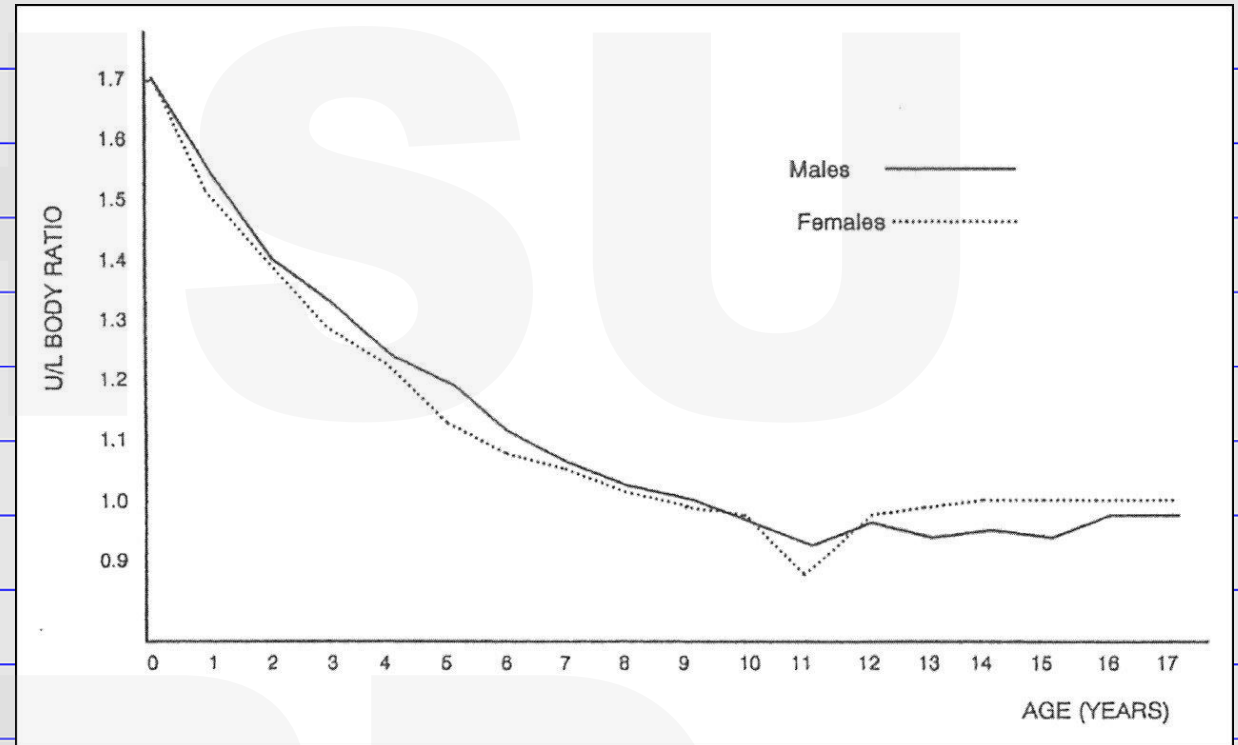
- US:LS
- Birth 1.70 (Greatest ratio)
- Postpuberty ~1.0

Bone Age X-Ray

- Compares growth centers (epiphyses) with standards of same sex

- Boys grow until bone age of 18
- Girls grow until bone age of 15

Growth center

Carpal bones

Using the growth chart + bone age

Current height adjusted (horizontally) to bone age gives adult target height percentile.

- 6 yr 4 mo F

  - height = 105 cm

  - weight = 29 kg
- Bone age = 5 yr

2 to 20 years: Girls
Stature-for-age and Weight-for-age percentiles

NAME
RECORD #

*To Calculate BMI: Weight (kg) ÷ Stature (cm) ÷ Stature (cm) x 10,000
or Weight (lb) ÷ Stature (in) ÷ Stature (in) x 703

Published May 30, 2000 (modified 11/21/00).
SOURCE: Developed by the National Center for Health Statistics in collaboration with
the National Center for Chronic Disease Prevention and Health Promotion (2000).
http://www.cdc.gov/growthcharts

CDC
SAFER · HEALTHIER · PEOPLE™

SLIDESMANIA.COM

BoneXpert

Adult Height Predictor V3.1

Powered by www.BoneXpert.com

Name	Pikachu

⦿ Male ⦾ Female

Caucasian European North

Population Height 181.0 cm

Bone Age	9
Age	12
Height	145	cm
Father's Height	180	cm
Mother's Height	170	cm

☐ Show BHI/MCI

Automated bone age assessments

Did you know that bone age can be automatically measured from children's hand X-ray with BoneXpert?

[Contact BoneXpert] [Learn more]

Bone Age SDS	-2.74	
APHV	14.5 ± 0.9	y
AHP (x-ray)	180.0 ± 3.5	cm
AHP (parental)	181.8 ± 5.9	cm
AHP (x+p)	180.3 ± 3.1	cm

[User Manual] [Copy data into URL] [Save as PDF]

14.5 years

180.3 cm
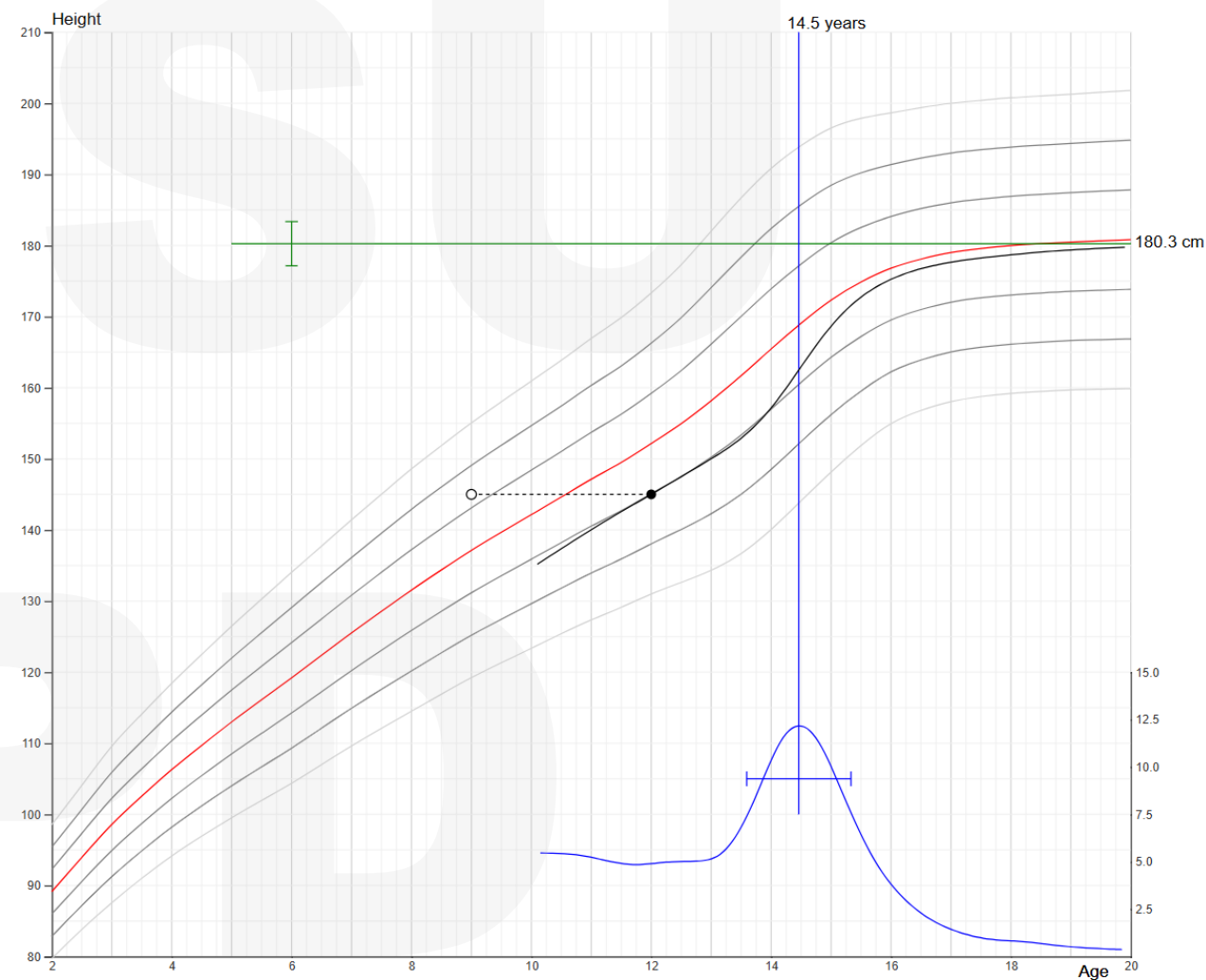
Physical exam

- Abnormal facies (frontal bossing, low set ears, micro/macrocephaly)
- Clinodactyly
- Shortened 4th metacarpal (AHO), café au lait spots (McCune Albright)
- Madelung deformity (SHOX deficiency, Turner syndrome)
- Body asymmetry + macrocephaly + triangular facies (Russell-Silver)
- Pubertal staging
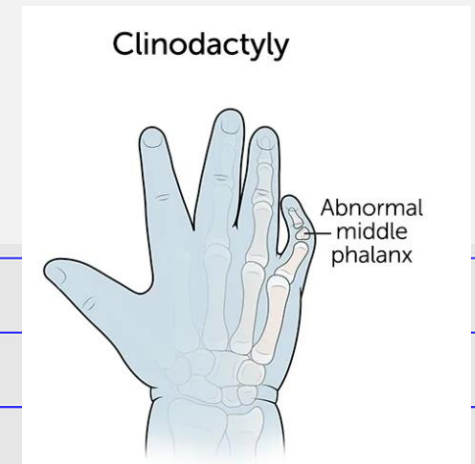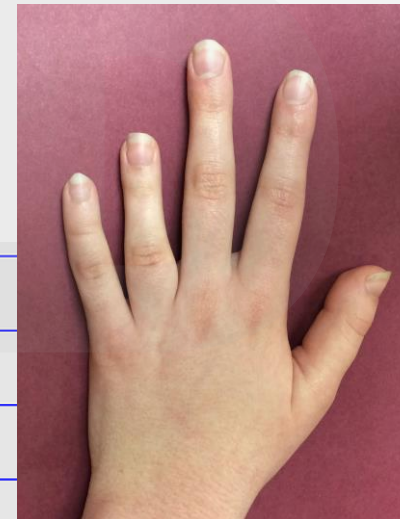
Summary part II

- Questions to ask on history
- The potential inaccuracy of MPH
- Physical exam findings
  - Upper segment:lower segment ratio
  - Physical exam clues
- Bone age
  - Growth chart + bone age
  - Bone Xpert
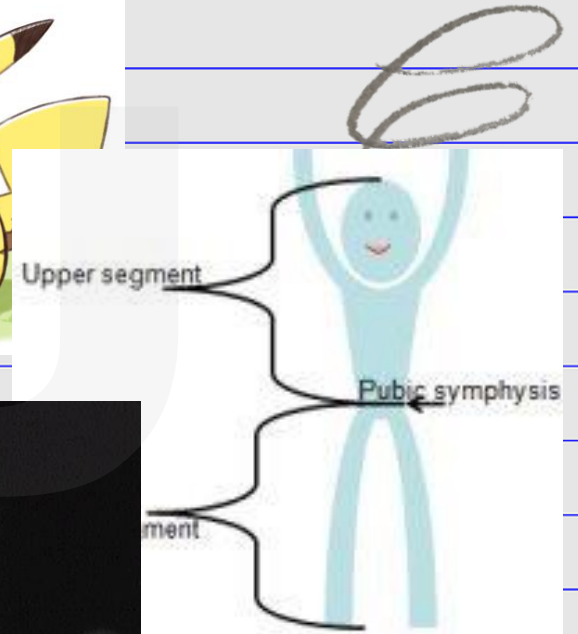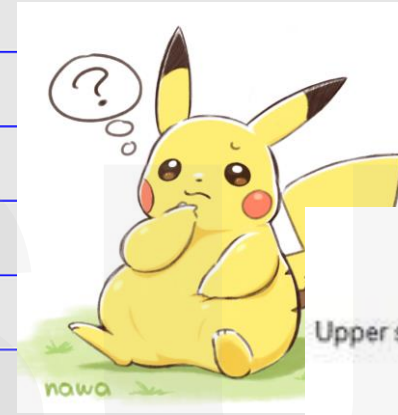
Differential diagnosis of short stature

Variations of normal
- Familial/genetic short stature
- Constitutional delay of growth and puberty

SGA
- SGA at birth without catch up growth by age 2

Chronic illness

Hormone disorder
- GH deficiency
- Hypothyroidism
- Cortisol excess

Medications
- Steroids
- Stimulants
- Cancer treatment

Chromosomal/syndrome association

Skeletal Dysplasia

Familial short stature

- Child of shorter than average parents
- Parallels the growth curve
- Height velocity and bone age are within the normal range for familial potential
- Bone age = chronologic age
- Final height expected to be below average
- Tx: Reassurance

BOYS: 2 TO 18 YEARS
PHYSICAL GROWTH
NCHS PERCENTILES*

Bone age

MPH

Susan R. Rose et al. Pediatrics in Review 2005;26:410-420
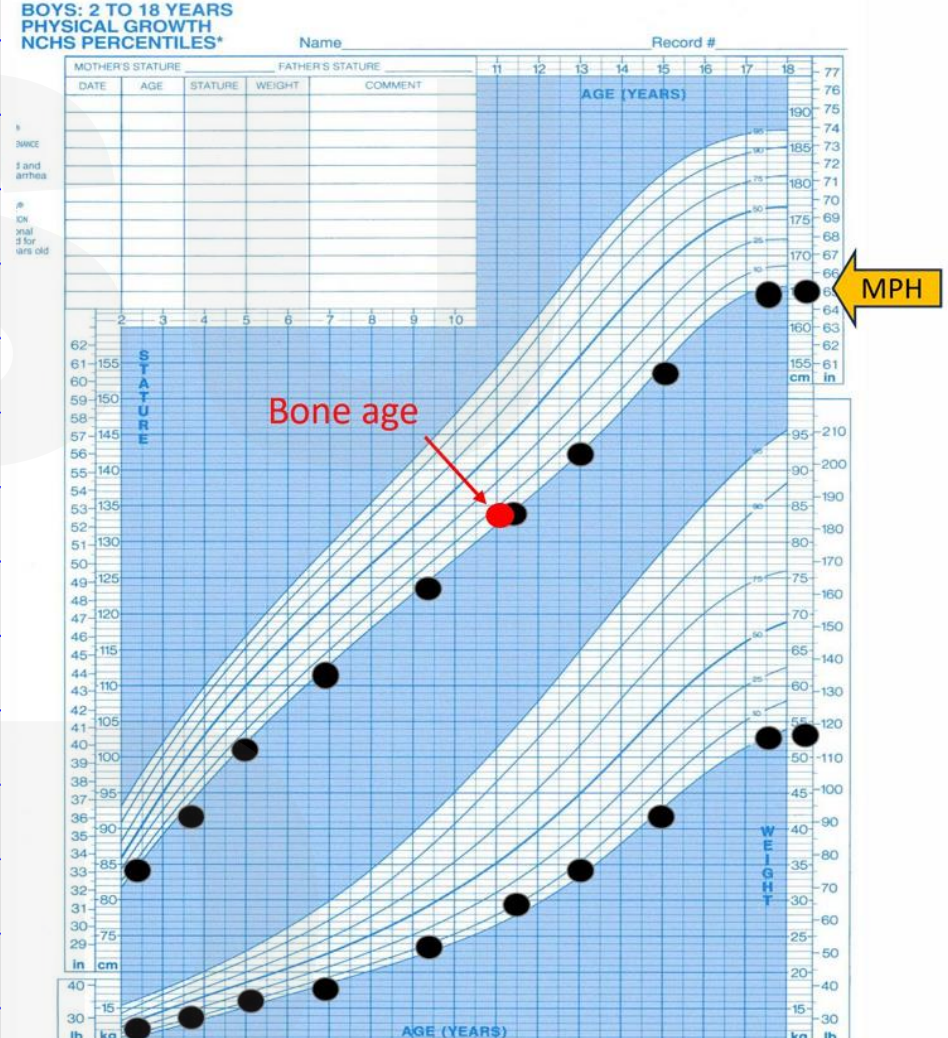
Constitutional Growth delay

- Hereditary growth variant
  - Male:Female 5:1

- Size at birth normal
- Growth slows between 12 - 24 months
- Growth velocity normal after 3 years

- Falls further away from curve at average time of puberty
  - Delayed pubertal changes

- Delayed bone age
  - Height for bone age is at the target height

- Consider course of testosterone or estrogen if puberty is delayed and there is increased psychosocial stress

BOYS: 2 TO 18 YEARS
PHYSICAL GROWTH
NCHS PERCENTILES*

Adjusted Height percentile based on bone age

MPH
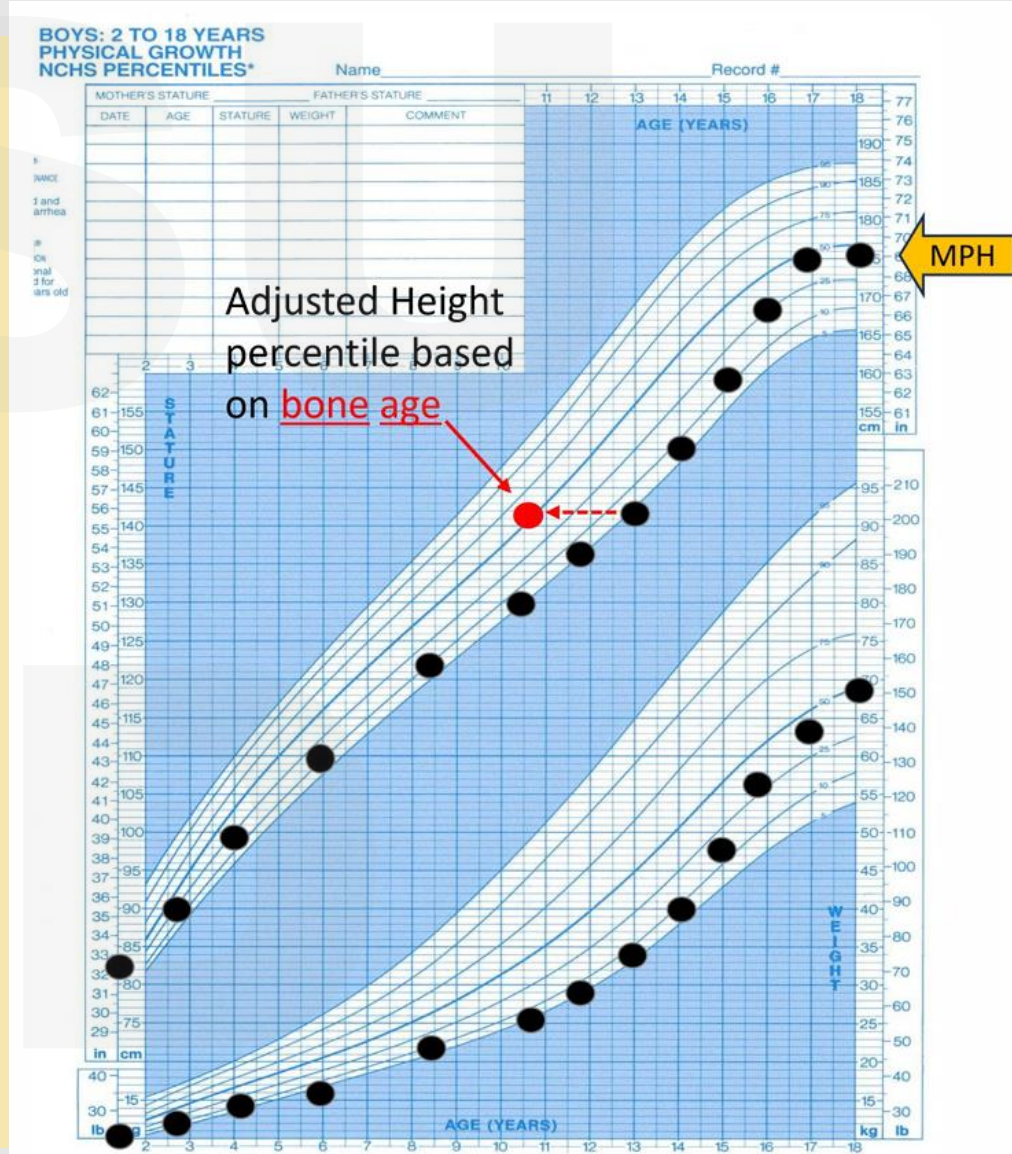
Small for Gestational Age

- Birth weight <10th percentile for gestational age <2.5kg for term baby

- Many syndromes encompass SGA in their features

- 85% of children with IUGR catch up in the first 6-12 months

- Can use growth hormone if child fails to have catch-up growth by age 2

Chronic Illness

XOXO
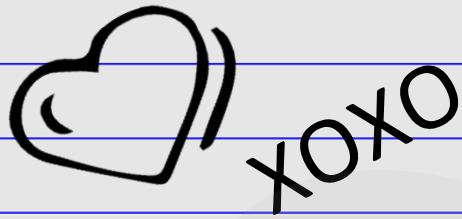
- **Cardiac**
- **Pulmonary**
  - CF, Asthma (steroid use)
- **GI -** Malabsorption, IBD
  - 50% of kids with Crohn Disease have decrease HV prior to symptoms
  - Celiac: can have short stature without obvious GI symptoms
- **Renal**
  - Chronic renal failure, renal tubular acidosis
- **Malnutrition/eating disorders**

- **Growth chart:** low weight for height/BMI
- **Bone age: delayed**

Primary nutritional deficiency
Severe chronic illness

STATURE

WEIGHT

AGE (YEARS)

Growth Hormone Deficiency

- **Congenital**: Normal size at birth, slowing in toddler age, slow growth velocity
  - Genetic, congenital malformations

- Bone age often 50% of the CA or less

- **Symptoms**
  - Hypoglycemia (newborn or fasting)
  - Micropenis

- **Associated physical features**
  - Cherubic, midface hypoplasia, midline facial defects, looks younger than real age

- **Acquired**
  - Head trauma, infection, tumor, radiation

Birth to 36 months: Girls
Length-for-age and Weight-for-age percentiles

OK13
5S05

GHR mutation =
Laron syndrome –
small face, saddle
nasal bridge, high
pitched voice
NORMAL BASAL GH!

Stat5B mutation
Severe postnatal
growth failure +
immune dysregulation
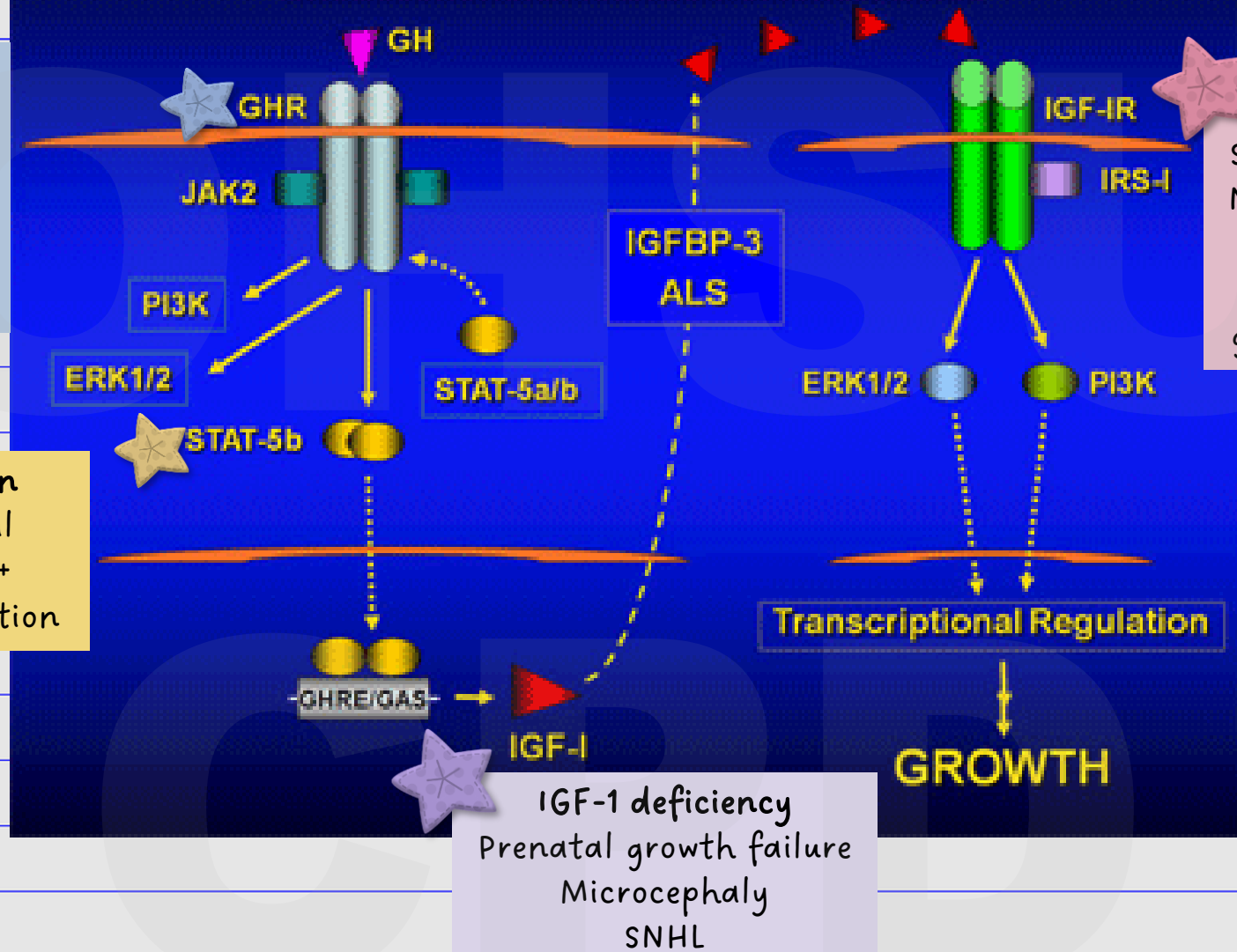
IGF-1 defect
SGA without catch up growth
Normal labs (IGF-1), IGF-BP3,
GH
Variable degree of
growth/delay in development

IGF-1 deficiency
Prenatal growth failure
Microcephaly
SNHL

Growth Hormone - IGF-I Axis

GH
GHR
JAK2
PI3K
ERK1/2
STAT-5a/b
STAT-5b
IGFBP-3
ALS
GHRE/GAS
IGF-I
IGF-IR
IRS-I
ERK1/2
PI3K
Transcriptional Regulation
GROWTH

Hypothyroidism

- ↓ growth velocity
- ↑ Weight for height/BMI
- Bone age delayed
- Symptoms
  - Fatigue
  - Late teeth
  - Constipation
  - Dry skin
  - High cholesterol
  - Delayed puberty

TRβ resistance

- FT4/FT3 high
- Normal TSH
- Hyperthyroid picture + growth failure

Trα resistance

- T4 low
- Borderline high T3
- Normal/high TSH
- Growth failure, delayed dentition

2 to 20 years: Boys
Stature-for-age and Weight-for-age percentiles
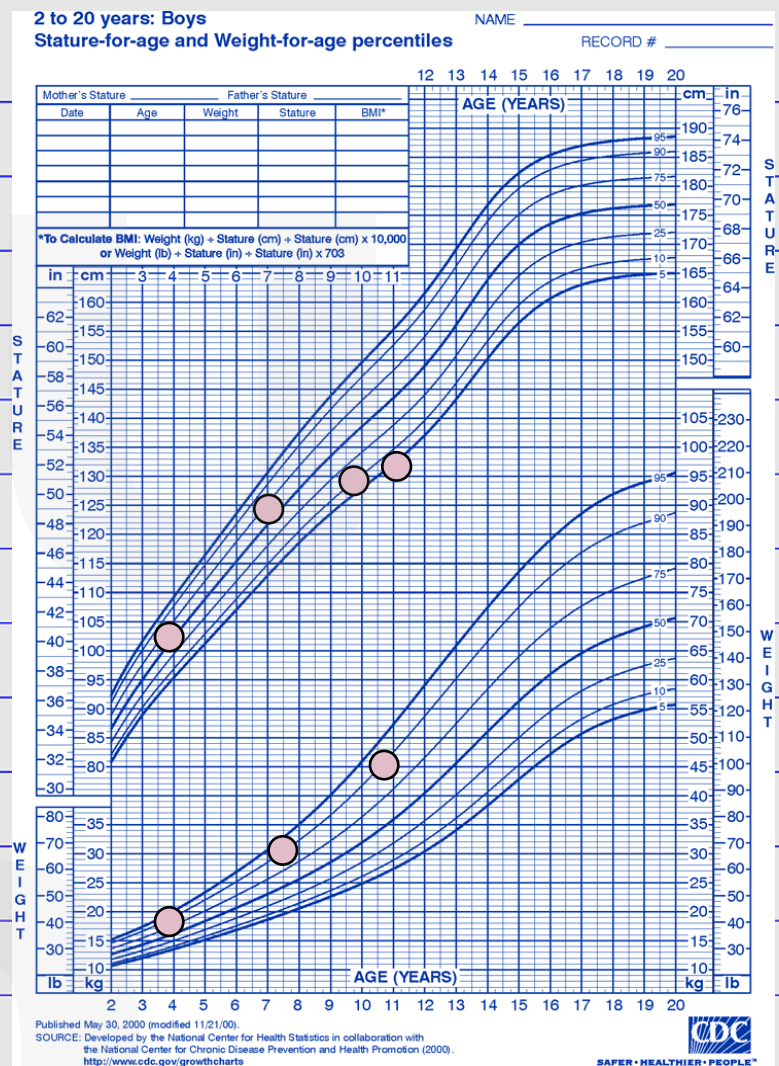
Cushing syndrome (cortisol excess)

- Adrenal or pituitary tumor
- Exogenous steroids
- Symptoms
  - Excess weight gain
  - Poor linear growth
  - Hypertension
  - Moon facies
  - Buffalo hump
  - Purple striae
  - Easy bruising
  - Delayed puberty
- **Linear growth deceleration + weight gain**

2 to 20 years: Boys
Stature-for-age and Weight-for-age percentiles
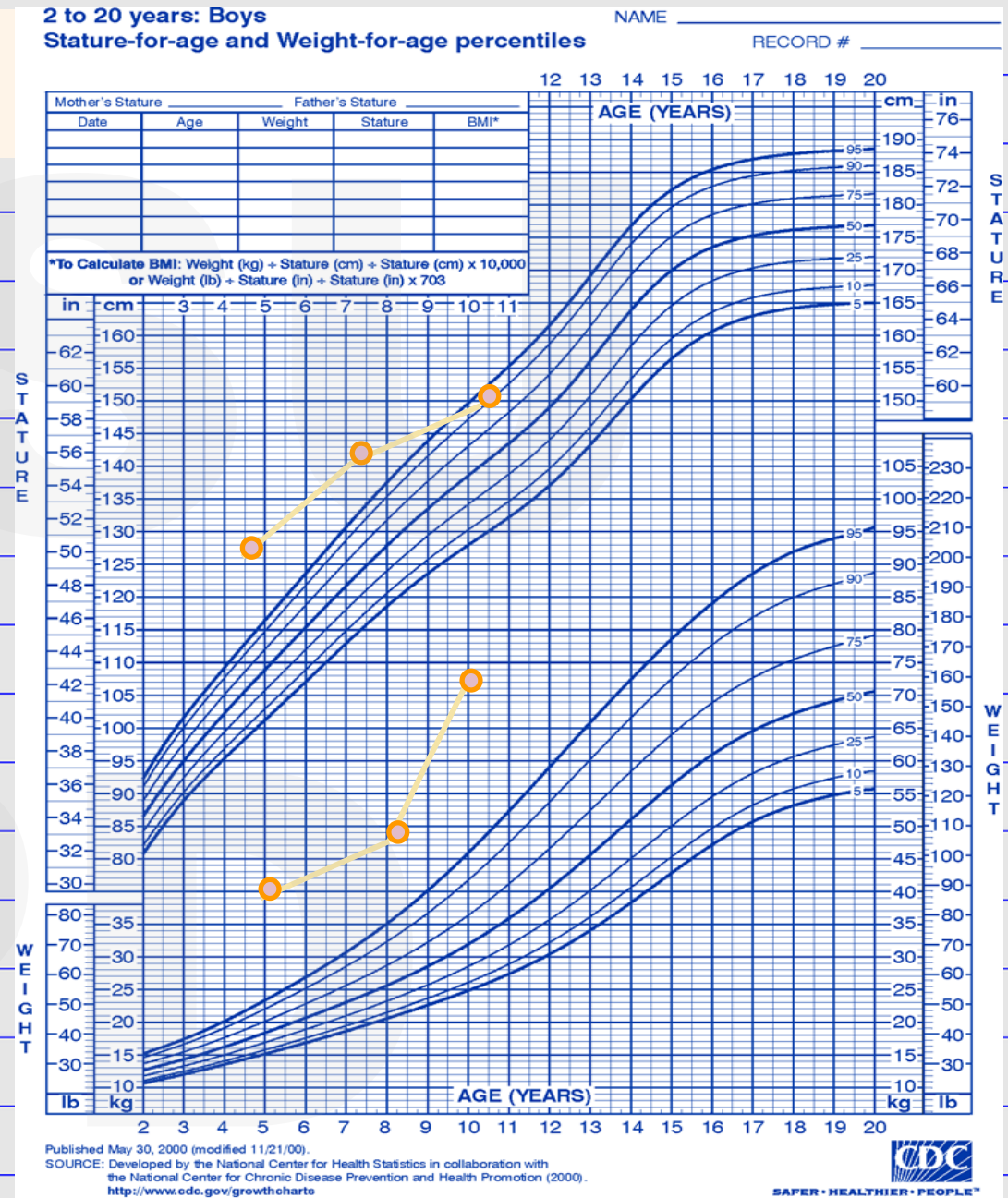
Skeletal Dysplasia

- Skeletal abnormality associated with disproportionate growth

  - Shorter limbs

  - ↑Upper to lower segment ratio

- May not show up in infancy
- Bone age congruent with chronologic age
- Growth hormone beneficial in some conditions
- New therapies on the horizon for achondroplasia
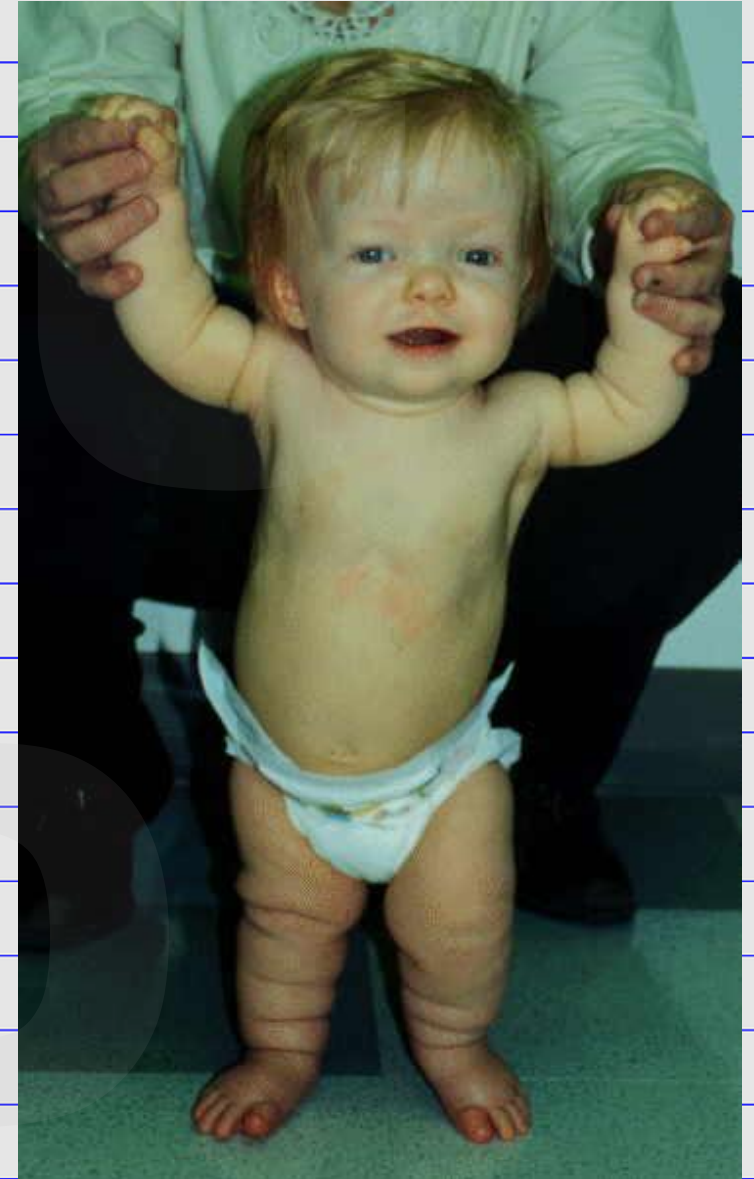
(Not so) Common syndromes
(that would take multiple lectures to cover)

- Turner syndrome
- Russell Silver syndrome
- Noonan syndrome
- Prader-Willi syndrome
- Pseudohypoparathyroidism/Albright hereditary osteodystrophy
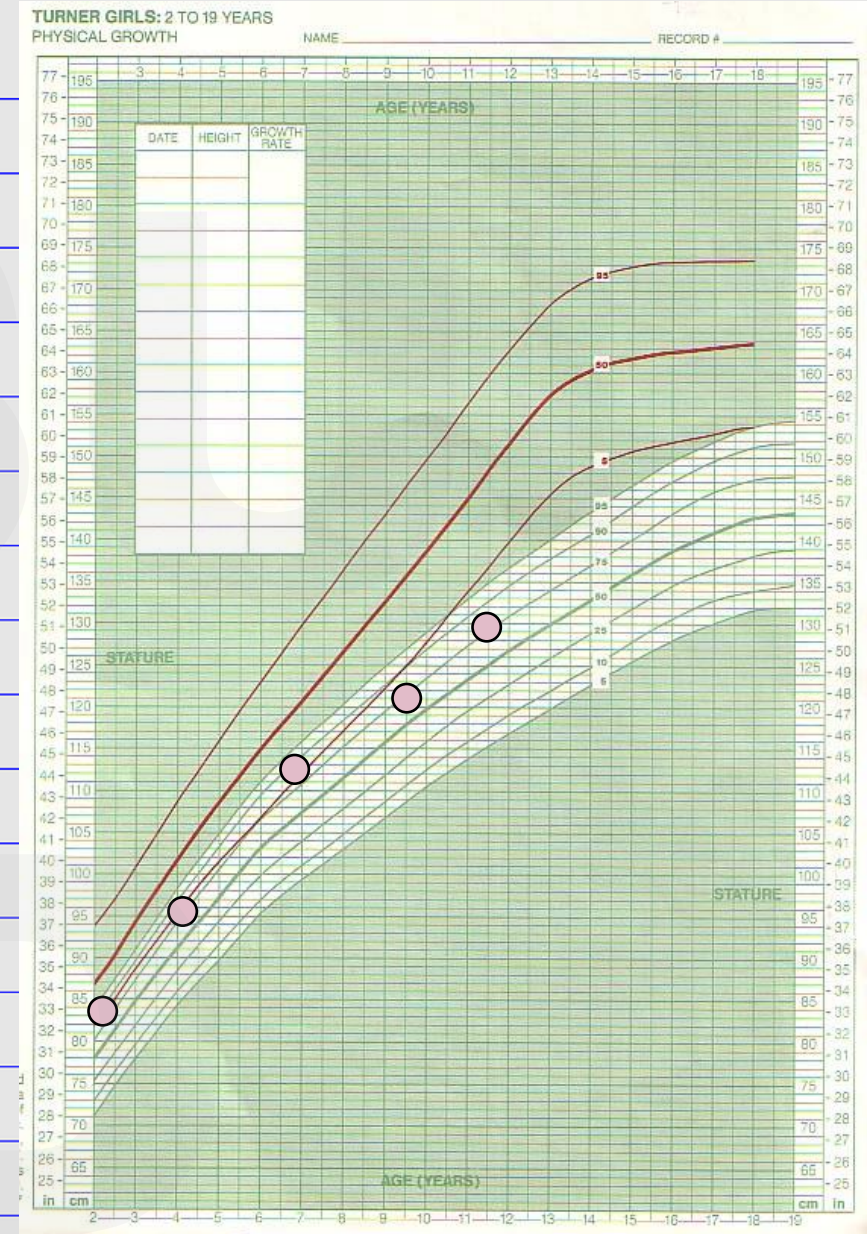
FDA Approved Indications for GH Treatment

Growth hormone deficiency

Pituitary GH Deficiency in adults

Turner Syndrome

Growth delay associated with Chronic Renal Insufficiency

SGA

Prader Willi syndrome

Idiopathic Short Stature

When to suspect pathologic short stature

- Disproportionate growth (skeletal dysplasia)
- Downward crossing of height percentile after 2 years of age
- Growth velocity below the 3rd percentile (-2 SDS) for at least 1 year
- Height percentile less than 3rd percentile (-2 SDS), especially if height %tile is less than MPH
- SGA without catch up growth by age 2-4
- **Any** girl with unexplained short stature (possible Turner)

EVALUATION

- Verify measurements, calculate GV
- Calculate MPH and compare projected height
- Bone age (we'll read it!)
- Labs:

  - Karyotype if female

  - TSH, Free T4 (not reflex!)

  - Growth factors (IGF-1, IGF-BP3)

  - Screening for chronic illness: Celiac (IgA, Ttg-IGA), Renal (BMP), IBD (ESR)

Summary

- Variations of normal – Familial/Genetic short stature, CDGP
- SGA without catch up growth
- Chronic illness
- Endocrine specials – GH deficiency, resistance, hypothyroidism, cortisol excess
- Skeletal dysplasia
- Common syndromes – Turner, Russell-Silver, Noonan, Prader-Willi, AHO

Referral Algorithm: Short Stature Criteria for Patients 2 Years and Older

Less than 3 percentile for height?
OR
Decrease in growth velocity less than 4 cm growth for greater than 1 year?
OR
Greater than or equal to 3 standard deviations below expected height based on mid-parental height?*

→ **YES** →

Boys aged greater than 14 years OR girls aged greater than 12 years

→ **YES** →

Bone age required (completed within the past 6 months)
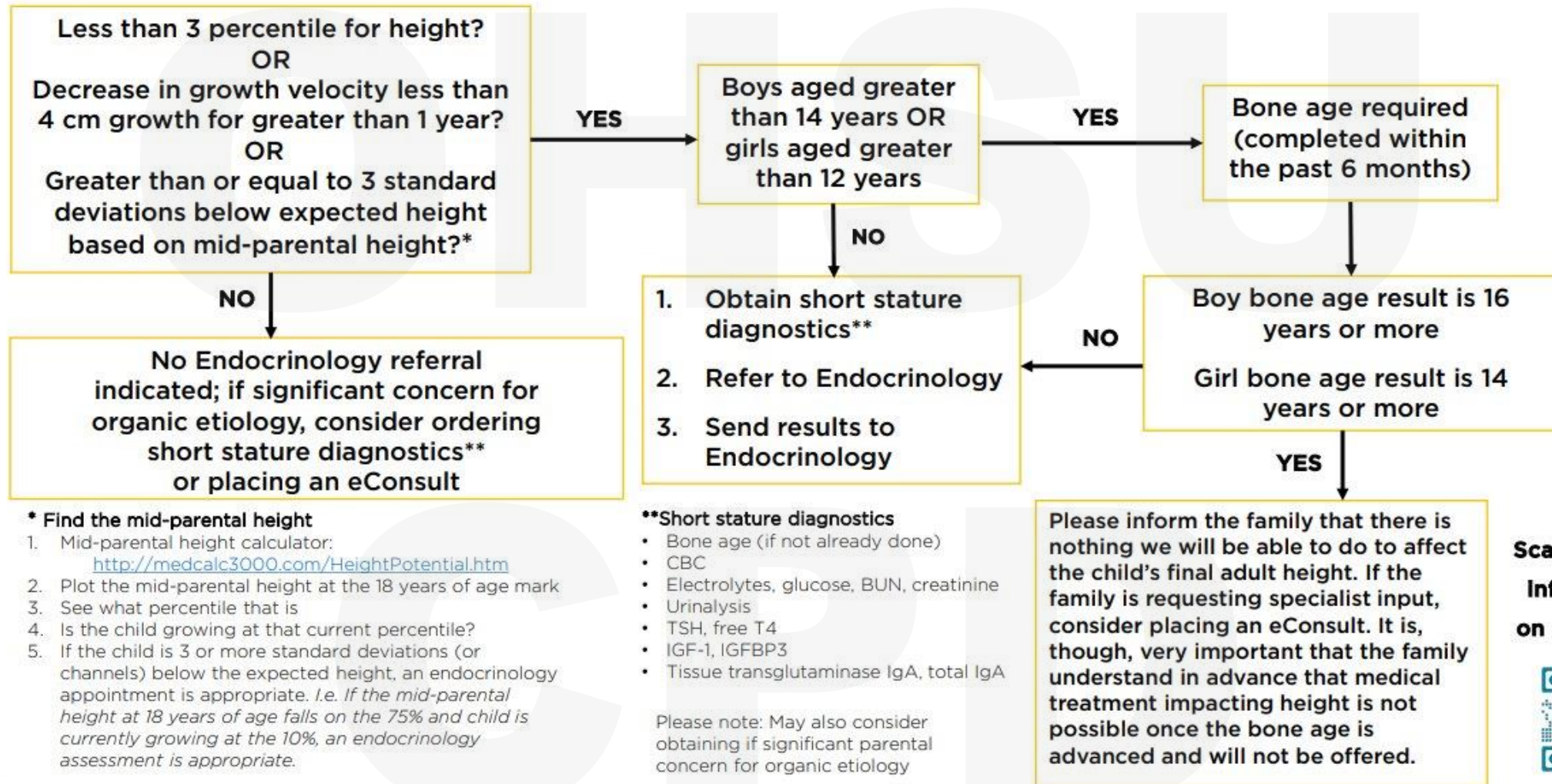
NO ↓ (from first box)

No Endocrinology referral indicated; if significant concern for organic etiology, consider ordering short stature diagnostics or placing an eConsult**

NO ↓ (from Boys aged box)

1. **Obtain short stature diagnostics****
2. **Refer to Endocrinology**
3. **Send results to Endocrinology**

↓ (from Bone age required)

Boy bone age result is 16 years or more

Girl bone age result is 14 years or more

← **NO** (to diagnostics box)

↓ **YES**

Please inform the family that there is nothing we will be able to do to affect the child's final adult height. If the family is requesting specialist input, consider placing an eConsult. It is, though, very important that the family understand in advance that medical treatment impacting height is not possible once the bone age is advanced and will not be offered.

---

* Find the mid-parental height
1. Mid-parental height calculator:
   http://medcalc3000.com/HeightPotential.htm
2. Plot the mid-parental height at the 18 years of age mark
3. See what percentile that is
4. Is the child growing at that current percentile?
5. If the child is 3 or more standard deviations (or channels) below the expected height, an endocrinology appointment is appropriate. *I.e. If the mid-parental height at 18 years of age falls on the 75% and child is currently growing at the 10%, an endocrinology assessment is appropriate.*

**Short stature diagnostics
- Bone age (if not already done)
- CBC
- Electrolytes, glucose, BUN, creatinine
- Urinalysis
- TSH, free T4
- IGF-1, IGFBP3
- Tissue transglutaminase IgA, total IgA

Please note: May also consider obtaining if significant parental concern for organic etiology

Scan for more Information on eConsults.

Seattle Children's
HOSPITAL · RESEARCH · FOUNDATION

Endocrine Referral: Short Stature Criteria for Patients ≥2 Years
www.seattlechildrens.org/clinics/endocrinology/refer-a-patient

Revised 04 2024

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