

Understanding Growth: Normal vs. Abnormal Patterns

Facilitator's Guide

Case Author:

Laurie E. Cohen, MD
Harvard Medical School
Children's Hospital, Boston

Case Advisors:

S. Jean Emans, MD
John R. Knight, MD
Harvard Medical School
Children's Hospital, Boston

Topic: Understanding Growth

Abstract:

Growth problems are common in children and adolescents. Every child should have his/her height and weight plotted on an appropriate growth chart as part of routine medical care. Growth abnormalities will often present first to the primary care clinician. Therefore, clinicians must know how to plot growth, be able to discriminate normal from pathological growth, and know when referral to an endocrinologist is warranted. This educational exercise includes a series of brief patient vignettes with corresponding growth charts. Each vignette will prompt a discussion of the likely diagnosis and the next step in patient management.

Goal:

To improve clinical skills in recognizing and evaluating children with growth abnormalities.

Objectives:

As a result of this training, clinicians will be able to:

1. To monitor and record growth data.
2. To recognize abnormal growth patterns.
3. To identify common etiologies of growth abnormalities.
4. To begin a diagnostic evaluation when a growth disorder is suspected.

Prerequisite Case: N/A

Related Case(s):

“Timmy and the ‘Big Kids’” (Constitutional Short Stature)
“The Shortest in the Class” (Turner’s Syndrome and Short Stature)
“Different From My Friends” (Turner’s Syndrome and Delayed Puberty)
“Will I Ever Get My Period?” (Growth and Chronic Disease)

Themes:

Growth in Children and Adolescents



Supported by a grant from *The Genentech Foundation for Growth and Development*. These materials may be freely reproduced, but may not be modified without written consent of the authors.

Key Words:

Bone age, malnutrition, growth hormone, hypothyroidism, short stature

Bright Futures Core Concepts:

While all of the Core Concepts are included in each case, this particular case can be used to highlight communication, advocacy, and prevention/health promotion.

Materials Provided:

- Facilitator's Guide
- 10 plotted growth charts with brief patient vignette
- Handout on Systemic Disorders That Affect Growth (for Cases 4 & 7)

Facilitator Preparation:

Facilitators should thoroughly review this guide and the other materials provided. Prepare enough photocopies of the case vignettes and accompanying growth charts for your group of learners. You may wish to create overheads of all growth charts used.

Suggested Format for a One Hour Session:

We anticipate that case facilitators will modify implementation of the case session to best fit their educational setting and learners. Facilitators should decide how many of the 10 case scenarios they wish to present in their allotted time. They may distribute the cases before the teaching session, and ask the learners to select particular cases for discussion. If all 10 cases are planned for discussion, an additional one-hour session may be required. For detailed recommendations on case facilitation, please see the previous chapter entitled, "A Brief Guide to Facilitating Case Discussion."

Open the Discussion: Introduce the session goal. Explain that this will be an interactive case discussion and not a lecture. Ask participants "What do you know about growth rates in children?" After several minutes of discussion, introduce an overview on Plotting Growth.

Introduction: Overview on Plotting Growth

Primary care pediatricians should record growth information on every child. The most commonly used growth charts are from the National Center for Health Statistics (NCHS) and are age and gender specific (<http://www.cdc.gov/growthcharts/>):

1) Birth to 36 Months

- a) Derived from a small sample of predominantly white, middle-class children (these percentiles may not be valid for other ethnic groups, but growth patterns should be similar)
- b) Infants are measured supine

c) There is an overlap between these charts and the *2 to 20 Years* growth charts; however, there is a small loss in height when a child is measured in a standing position, so height may not plot to the same percentile level on both charts.

2) *2-20 years*

Separate NCHS charts, based on a large cross-sectional sampling of North American children, have been created to track growth in boys and girls that provide the normative curves ± 2 SD for both height and weight parameters.

To ensure accuracy and reliability, clinicians should:

- Use proper equipment (e.g., stadiometer) to facilitate more accurate measurements (the floppy arm scales are inherently variable and can yield inaccurate results).
- Obtain 2-3 measurements
- Check the child's position before each measurement
- Plot correctly on appropriate growth chart

Warning signals of subnormal growth:

- Abnormally slow growth rate
 - Ages 3 years to puberty, less than 2 inches/year (5 cm/year) with downward crossing of centile channels on growth chart after age of 18 months (just prior to the onset of puberty, the growth rate may dip to 4 cm/year)
- Height below the 3rd percentile
- Height significantly below genetic potential, i.e., >2 SD below mid-parental height

Note:

- Underweight for height may indicate a systemic disease with decreased nutritional intake, malabsorption, or increased energy requirements (e.g., cardiac or respiratory disease). Overweight for height may indicate endocrine disorders (e.g., growth hormone deficiency, hypothyroidism, or cortisol excess.)

Mid-parental Height: This calculation provides a target mean and range for the genetic potential of a child based upon the biologic parents' heights. This calculation *alone* is not sufficient to predict final height; it only calculates a *reference* range for assessing growth.

mid-parental height = $\frac{(\text{father's height} - 5 \text{ in.}) + (\text{mother's height})}{2}$
for girls (inches)

mid-parental height = $\frac{(\text{mother's height} + 5 \text{ in.}) + (\text{father's height})}{2}$
for boys (inches)

Target height = mid-parental height ± 2 SD (1 SD = 2 in.)

Short Stature: What is the normal growth rate during childhood? Most children establish a pattern of growth by 3 years of age and do not deviate from this pattern until the onset of puberty. During this time, the normal growth rate is 2-2.5 inches/year (5-6.5 cm/year). When

patients in this age group cross over or change growth channels, this may signal a growth problem and should be evaluated further.

When further evaluation is necessary, it is important to determine whether a patient's height is caused by constitutional growth delay and/or familial short stature. Is the child healthy and on track for attaining adequate adult height? Or is his shortness within normal limits when considering his parents' heights? If neither of these scenarios is the case, then the clinician must consider the possible pathologic origins of short stature and poor growth.

The term "short stature" has been defined as height below the 3rd percentile. "Extreme short stature" is defined as height more than 3 standard deviations from the mean.

Ask the participants "*What would you like to focus on during our discussion today?*" List agenda items on a blackboard or flipchart.

Distribute the first growth chart and ask one of the participants to read the patient vignette aloud. Following this reading, ask all participants, "*What do you think about this child?*" Remember that the key to successfully leading a small group is facilitation of the discussion rather than lecture. Draw as many participants as possible into the discussion. As you ask additional questions, allow silences while group members consider their answers/comments. You should further develop discussion by asking, "*What is the next step in clinical management?*" and "*What is the most likely diagnosis?*"

Follow the same procedure for additional cases.

Review/Conclude. You may elect to give participants copies of the discussion guide or copies of other materials such as journal articles. Ask the group how further information might be obtained, reviewing the reference list and other sources of information.

Understanding Growth: Normal vs. Abnormal Patterns

Case 1 Facilitator's Guide

J.G. is an 11 year old girl who has always been “short for her age.” Her mother is 5’0”, her father is 5’5”. Her physical exam is normal, and her breasts are Tanner II, pubic hair is Tanner II.

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart

Answer: (a) Calculate mid-parental height.

Key Teaching Points: Pediatricians should know how to calculate **mid-parental height** and **target height** for boys and girls. Target height for this patient is 5’0”.

2. The most likely diagnosis is (select one answer):
 - a) familial short stature
 - b) constitutional delay
 - c) Turner’s Syndrome
 - d) Down Syndrome

Answer: (a) Familial short stature. This is not constitutional delay because there is not a history of delayed puberty.

Key Teaching Points: Familial (or genetic) short stature is characterized by:

- Family history of short stature
- Birth weight > 2.5 kg
- Height < 3rd percentile for chronologic age
- Growth curve **parallel** but at or below 3rd percentile
- Predicted adult height < 3rd percentile
- No organic or emotional cause for growth failure
- Normal annual growth rate and bone age
- Normal pubertal onset and maturation

Case 2 Facilitator's Guide

B.T. is a 12 year old boy who has always been shorter than his peers. His mother is 5'1", and his father is 5'6". His mother had menarche at age 15 years; his father had late pubertal development. His physical examination is unremarkable, with pubertal development Tanner I.

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart

Answers: (a), (b), and (d)

Key Teaching Points:

- (a) Calculate mid-parental height (Facilitator Introduction).
His mid-parental height is 5'6".
 - (b) Obtain bone age (a radiograph of the left wrist and hand)
 - Bone age is a measurement of epiphyseal ossification of the bones in the hand and wrist, including appearance and progression of size and shape.
 - Comparison to the standards of Greulich and Pyle or the Tanner-Whitehouse scoring system is used for each bone. Experience in determination is essential; not all radiologists may have adequate expertise in assessing bone age.
 - Many etiologies of short stature are associated with a delayed bone age, in which the bone age lags behind chronologic age (e.g., constitutional delay, malnutrition, hypothyroidism, growth hormone deficiency).
 - (d) **Flip now to longitudinal growth chart.** Replot on a syndrome-specialized growth chart (i.e., Bayer-Bayley or Tanner and Davies).
 - The NCHS growth charts are derived from **cross-sectional** data and tend to flatten out the variability of the pubertal growth spurt
 - Often used by pediatric endocrinologists, these **longitudinal** growth charts are derived from **longitudinal** data and contain curves for early and late developers and, therefore, are more useful than the NCHS charts for tracking pubertal development.
2. The most likely diagnosis is (select one answer):
 - a) skeletal dysplasia
 - b) constitutional delay
 - c) growth hormone deficiency
 - d) Turner's Syndrome
 - e) chronic disease

Answer: (b) Constitutional delay.

Key Teaching Points: Constitutional delay is characterized by:

- Family history of similar pattern of growth and puberty
- Height at or below 3rd percentile for age, but normal annual growth rate

- Delayed puberty
- Delayed bone age, appropriate for height age
- Normal predicted adult height in context of family pattern
- No organic or emotional cause for growth failure
- More common in boys

Case 3 Facilitator's Guide

S.T. is an 11 year old girl with short stature and history of recurrent otitis media. Her mother is 5'4", and her father is 5'9". Her physical exam is remarkable for multiple nevi, low posterior hairline, webbed neck, widely spaced nipples, and increased carrying angle. Her breast and pubic hair development are Tanner I.

1. What should you do next? (select as many as apply)

- a) calculate mid-parental height
- b) obtain bone age
- c) laboratory screening
- d) re-plot on a specialized growth chart

Answer: (a) Calculate mid-parental height, (b) Bone age, (c) Laboratory screening and (d) Re-plot on a specialized growth chart.

Key Teaching Points:

- Females who present with unexplained short stature (and no history of familial short stature or an ethnic background associated with shorter stature than captured by U.S. growth chart) should have a chromosomal karyotype performed.
- **Show Turner's syndrome growth chart after learners have made diagnosis.** A number of specialty growth charts have been created for tracking specific syndromes (e.g., Down syndrome, Turner's syndrome, and Noonan syndrome).
- Consider obtaining FSH level if patient is over 11 years old to assess for primary ovarian failure.
- Consider TSH level, since Turner's Syndrome is associated with an increased risk of primary hypothyroidism

2. The most likely diagnosis is (select one answer):

- a) skeletal dysplasia
- b) constitutional delay
- c) growth hormone deficiency
- d) Turner's Syndrome
- e) chronic disease

Answer: (d) Turner's syndrome.

Key Teaching Points:

- Consider Turner's syndrome in any girl who presents with unexplained short stature
- Characteristic phenotypic features (e.g., webbed neck, low posterior hairline, high arched palate, short fourth and fifth metacarpals, increased carrying angles, broad chest, and nevi) may **not** be present

Case 4 Facilitator's Guide

B.H. is an 8 year old boy who has always been shorter than his peers. His review of systems is negative. He has been generally healthy. His mother is 5'4", his father is 5'9". On physical exam, he has a "cherubic" appearance. His phallus is 4.5 cm (<10th percentile), and his upper to lower segment ratio is 1.0. His physical exam is otherwise unremarkable.

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart

Answers: (a), (b), and (c)

Key Teaching Points:

- (a) Calculate mid-parental height (Facilitator Introduction).
The mid-parental height is 5'9".
 - (b) Obtain bone age (a radiograph of the left wrist and hand).
 - Bone age is a measurement of epiphyseal ossification of the bones in the hands and the wrist, including appearance and progression of size and shape.
 - Comparison to the standards of Greulich and Pyle or the Tanner-Whitehouse scoring system is used for each bone. Experience in determination is essential; not all radiologists may have adequate expertise in assessing bone age.
 - Many etiologies of short stature are associated with a delayed bone age, where the bone age lags behind chronologic age (e.g., constitutional delay, malnutrition, hypothyroidism, growth hormone deficiency).
 - (c) Laboratory screening
 - Rule out disorders affecting growth (**Distribute Handout on Systemic Disorders That Affect Growth**).
 - Rule out growth hormone deficiency using IGF-1 and IGFBP-3 levels:
 - Concentrations parallel the secretion of growth hormone, which cannot be easily assessed without stimulation test
 - Low levels in GH deficiency
 - Low levels of IGF-1 may also be seen in malnutrition, hypothyroidism, renal failure, and diabetes.
2. The most likely diagnosis is (select one answer):
 - a) skeletal dysplasia
 - b) constitutional delay
 - c) growth hormone deficiency
 - d) Turner's Syndrome

e) chronic disease

Answer: (c) Growth hormone deficiency.

Key Teaching Points: A diagnosis of growth hormone deficiency or inadequacy is characterized by the following:

- Results from damage to or malformation of the hypothalamus or pituitary
- May exist as an isolated deficiency or in combination with other pituitary deficiencies
- Other systemic causes of short stature ruled out
- If present at birth, may cause hypoglycemia, seizures, prolonged direct hyperbilirubinemia; and micropenis in males
- Birth weight and growth during infancy are often normal
- After 3 years of age, subnormal growth rate, i.e., usually less than 2 inches/year (5 cm/year)
- Height progressively declines to a lower percentile
- As weight increases with chronological age, the height curve falls off progressively
- Delayed bone age
- **Facilitator's Note: Distribute Growth Chart 4b.** Once treatment with recombinant human growth hormone is initiated (represented by the arrows on chart 4b) there is a rapid increase in growth velocity.

Case 5 Facilitator's Guide

Preliminary Discussion: *What is the normal growth rate for an infant?*

- Normal growth rate during neonatal period (birth to 12 months) is 9-11 inches/year (23-28 cm/year).
- Normal growth rate during infancy (12-36 months) is 3-5 inches/year (7.5-13 cm/year).

B.B. is a 30-month-old male whose percentile for length is decreasing. He was the 8 lb. and 20-1/2 in. product of a full-term gestation delivered vaginally without complications. His past medical history is significant for a few upper respiratory infections, but he has been healthy otherwise. His mother is 63", his father is 68".

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart

Answer: (a) Calculate mid-parental height

Key Teaching Points: (Facilitator Introduction) calculation of mid-parental height and target height will assess genetic potential.

2. The most likely diagnosis is (select one answer):
 - a) constitutional delay
 - b) hypothyroidism
 - c) non-organic failure to thrive
 - d) channeling (i.e., normal variant)
 - e) skeletal dysplasia

Answer: (d) Channeling (i.e., normal variant)

Key Teaching Points:

- Infant growth rate is determined more by perinatal factors, such as maternal nutrition, maternal substance abuse, congenital infections, and placental sufficiency.
- Frequent crossing of centiles as prenatal influences diminish, known as "channeling up" or "channeling down," lead to large variations in growth velocity with "catch up" and "catch down" growth.
- Growth pattern/velocity is established by 36 months of age.

Case 6 Facilitator's Guide

G.C. is an 11 year old girl who has always been short and is developmentally delayed. Her past medical history is notable for a ventricular septal defect and recurrent otitis media. Her mother is 5'5", her father is 5'10". Her physical exam is notable for abnormal palpebral fissures and palmar creases, a protruding tongue, and a short neck. Her breast and pubic hair development are Tanner II.

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart

Answer: (d) Re-plot on a specialized growth chart. Another possible answer is (c) laboratory screening, including a chromosome analysis if not already done to confirm diagnosis and TSH level because there is an increased incidence of primary hypothyroidism in Down syndrome.

Key Teaching Points: Distribute Down syndrome growth chart. A number of specialty growth charts have been created for tracking specific syndromes (e.g., Down syndrome, Turner's syndrome, and Noonan syndrome).

2. The most likely diagnosis is (select one answer):
 - a) familial short stature
 - b) constitutional delay
 - c) Turner's Syndrome
 - d) Down Syndrome

Answer: (d) Down syndrome.

Key Teaching Points: Congenital disorders are commonly associated with short stature. These disorders include:

- Genetic syndromes
- Chromosomal abnormalities
- Skeletal dysplasias
- IUGR (Intrauterine Growth Retardation)

Case 7 Facilitator's Guide

K.A. is a 13 year old boy with short stature and pubertal delay. His past medical history is significant for a seizure disorder and developmental delay. His medications include Depakote, Phenobarbital, Neurontin, and Diamox. His review of systems is positive for a restricted diet; he likes only potato chips. He denies abdominal pain or diarrhea. His mother is 5'5", his father is 5'10". His physical exam is notable for a gaunt appearance. He has 5 cc testes and Tanner II pubic hair.

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart
 - e) other

Answers: (b), (c), and (e)

Key Teaching Points:

- (b) Obtain bone age (a radiograph of the left wrist and hand).
 - Bone age is a measurement of epiphyseal ossification of the bones in the hands and the wrist, including appearance and progression of size and shape.
 - This is compared with the standards of Greulich and Pyle or the Tanner-Whitehouse scoring system is used for each bone. Experience in determination is essential; not all radiologists may have adequate expertise in assessing bone age.
 - Many etiologies of short stature are associated with a delayed bone age, where the bone age lags behind chronologic age (e.g., constitutional delay, malnutrition, hypothyroidism, growth hormone deficiency).
- (c) Laboratory screening to rule out chronic disease
 - Complete blood cell count (CBC)
Screen for infection, anemia, other hematologic abnormalities
 - Erythrocyte sedimentation rate (ESR)
Screen for evidence of chronic inflammation, e.g., inflammatory bowel disease
 - Electrolytes and chemistry panel
Screen for abnormalities of the kidneys, liver, bones, and adrenal glands
 - Urinalysis
Screen for kidney disease, renal tubular acidosis in infants
 - Anti-endomysial antibodies, Celiac panel
Screen for celiac disease
 - Thyroxine (T4), thyrotropin stimulating hormone (TSH)
Screen for hypothyroidism
- (e) Other: Calorie count

2. The most likely diagnosis is (select one answer):

- a) constitutional delay
- b) hypothyroidism
- c) malnutrition
- d) channeling (i.e., normal variant)
- e) skeletal dysplasia

Answer: (c) Malnutrition

Key Teaching Points: Distribute Handout on Systemic Disorders That Affect Growth.

These are:

- Malnutrition
- Renal disease
 - Growth failure secondary to rickets, acidosis, and nutritional failure
 - Resistance to GH
- Diabetes
 - Poor control, with significant acidosis, will result in significant growth retardation
- Cardiac
 - Growth failure may be due to cyanosis and hypoxia
 - Other unclear underlying mechanisms
- Hematologic disease
 - Chronic anemias
- Gastrointestinal disorders
 - Inflammatory bowel disease
 - Chronic liver disease
 - Celiac disease
 - Other causes of malabsorption
- Respiratory disease
 - Cystic fibrosis
 - Asthma
- Endocrine disorders
 - Hypothyroidism
 - Growth hormone deficiency/inadequacy
 - Cortisol excess
- Congenital Disorders
 - Intrauterine growth retardation
 - Skeletal dysplasia
 - Other genetic syndromes (e.g., Turner's Syndrome)

Case 8 Facilitator's Guide

K.R. is a 6 and 1/2 year old girl presenting with fatigue. Her review of systems is positive for cold intolerance, dry skin, and constipation. Her physical exam is remarkable for a sallow appearance, waxy dry skin, and coarse hair. Her mother is 5'2" and her father is 5'7".

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart

Answer: (c) Laboratory screening

Key Teaching Point: Thyroid function tests will confirm the diagnosis.

2. The most likely diagnosis is (select one answer):
 - a) constitutional delay
 - b) hypothyroidism
 - c) non-organic failure to thrive
 - d) channeling (i.e., normal variant)
 - e) skeletal dysplasia

Answer: (b) Hypothyroidism.

Key Teaching Points: *Primary Hypothyroidism*

- Onset of symptoms and signs (including cold intolerance, myxedema, and delayed deep tendon reflexes) is **subtle**. Enlarged thyroid gland may not be present.
- Growth rate may drop to as little as 1 cm/year.
- **Facilitator's Note: Distribute Growth Chart 8b.** Once treatment with L-thyroxine is initiated (represented by the arrow), there is a rapid increase in growth velocity with catch-up growth.

Case 9 Facilitator's Guide

G.F. is a 17 year old girl who has been overweight “*for as long as I can remember.*” Her family history is positive for obesity on both the paternal and maternal sides of the family. Her dietary history is notable for erratic eating habits and skipping meals; she has a high intake of fat and concentrated sweets. She has regular menses. Her breast and pubic hair development are Tanner V.

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart
 - e) other

Answer: (c) Consider laboratory screening, with thyroid function tests. (e) Other: Refer for nutritional assessment and counseling.

Key Teaching Point: Patients with hypothyroidism may be overweight for height, have subtle symptoms and signs, and the neck exam may be difficult in an obese patient. However, her longstanding overweight status makes hypothyroidism unlikely, but some families and patients need reassurance before embarking on a nutritional intervention.

2. The most likely diagnosis is (select one answer):
 - a) precocious puberty
 - b) growth hormone excess
 - c) obesity
 - d) Cushing's syndrome

Answer: (c) Obesity.

Key Teaching Points:

- Body weight for height in excess of 120% defines obesity.
- If mental retardation is also present, consider genetic syndromes (e.g., Prader-Willi, Laurence-Moon-Biedl, Cohen, Carpenter's, Alstrom's) and pseudohypoparathyroidism.
- In absence of mental retardation, consider endocrine causes, but note that these are associated with **poor linear growth** if the girl is still growing. Normal height virtually eliminates endocrine causes for obesity in the growing younger child which include:
 - hypothyroidism
 - Cushing's syndrome (hypercortisolism): signs include truncal obesity, decreased muscle mass, striae, easy bruising, thin skin, and irregular menses
- In this girl, no signs or symptoms suggests an endocrine disorder

Case 10 Facilitator's Guide

Preliminary Discussion: *What are the characteristics of normal pubertal growth?*

- Growth rate is rapid and highly variable due to increased production of adrenal and gonadal hormones
- In girls, an acceleration in growth is usually seen at the onset of puberty; whereas in boys, onset of growth spurt follows onset of puberty and is often preceded by a measurable decline in growth rate.

A.B. is a 4 and 9/12 year old girl who developed breast buds at age 3 and 10/12 years. Height acceleration was noted from the age of 4 years. Pubic hair development and apocrine axillary odor were noted at age 4 and 6/12 years.

1. What should you do next? (select as many as apply)
 - a) calculate mid-parental height
 - b) obtain bone age
 - c) laboratory screening
 - d) re-plot on a specialized growth chart

Answer: (b) Obtain bone age.

Key Teaching Points:

- Bone age is generally advanced relative to chronologic age in precocious puberty (may be delayed if the cause of early sexual maturation is hypothyroidism).
- **No** screening laboratory tests need to be performed if the primary care clinician suspects **central** precocious puberty. Screening tests are not helpful because gonadotropins and sex steroids are secreted in a pulsatile manner with circadian variation, and therefore, spot samples may be misleading during early pubertal onset.
- A GnRH stimulation test should be performed in consultation with a pediatric endocrinologist in girls who appear clinically to have precocious pubertal development, have a height spurt, and an advanced bone age.
- If central precocious puberty is confirmed, a cranial MRI should be performed to rule out an intracranial lesion.
- If central precocious puberty is not diagnosed, a pelvic ultrasound should be obtained to rule out an ovarian tumor or cyst; although a cyst has often resolved by the time a patient is seen for evaluation.

2. The most likely diagnosis is (select one answer):
 - a) tall stature
 - b) precocious puberty
 - c) growth hormone excess
 - d) obesity
 - e) Cushing's syndrome

Answer: (b) Precocious puberty.

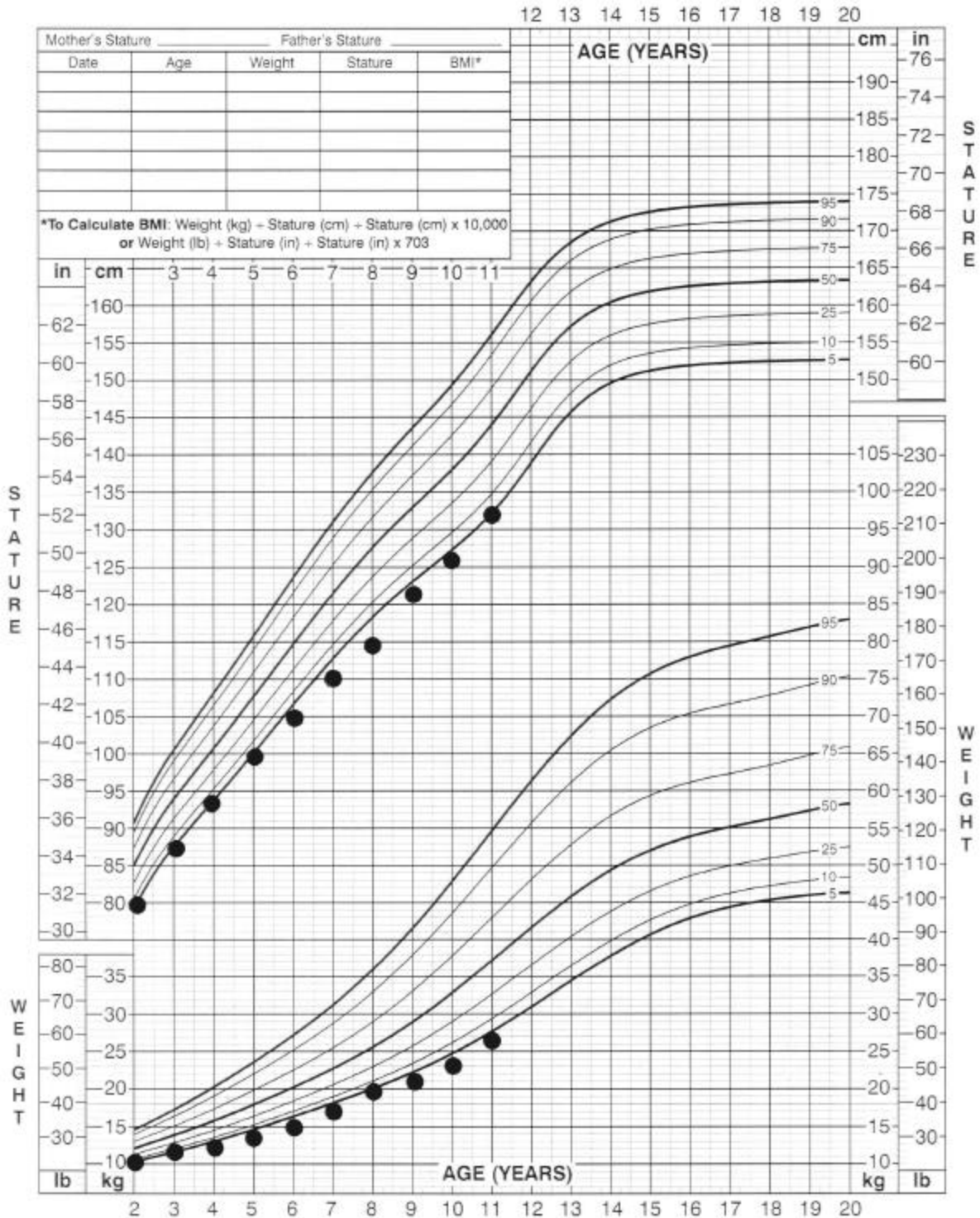
Key Teaching Points:

- Appearance of secondary sexual characteristics in girls before 8 years of age, and in boys before 9 years of age, has been considered “precocious”. Some normal girls may start pubertal development at age 7-8, especially those who are black and Hispanic, and thus age 7 may be more appropriately termed “precocious” for girls.
- Once begun, there is a normal temporal relationship between development of the various physical features of puberty

Case 1

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

NAME J.G.
RECORD # case 1



Revised and corrected November 28, 2000.
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>



Case 1—J.G. is an 11 year old girl who has always been “short for her age.” Her mother is 5’0”, her father is 5’5”. Her physical exam is normal, and her breasts are Tanner II, pubic hair is Tanner II.

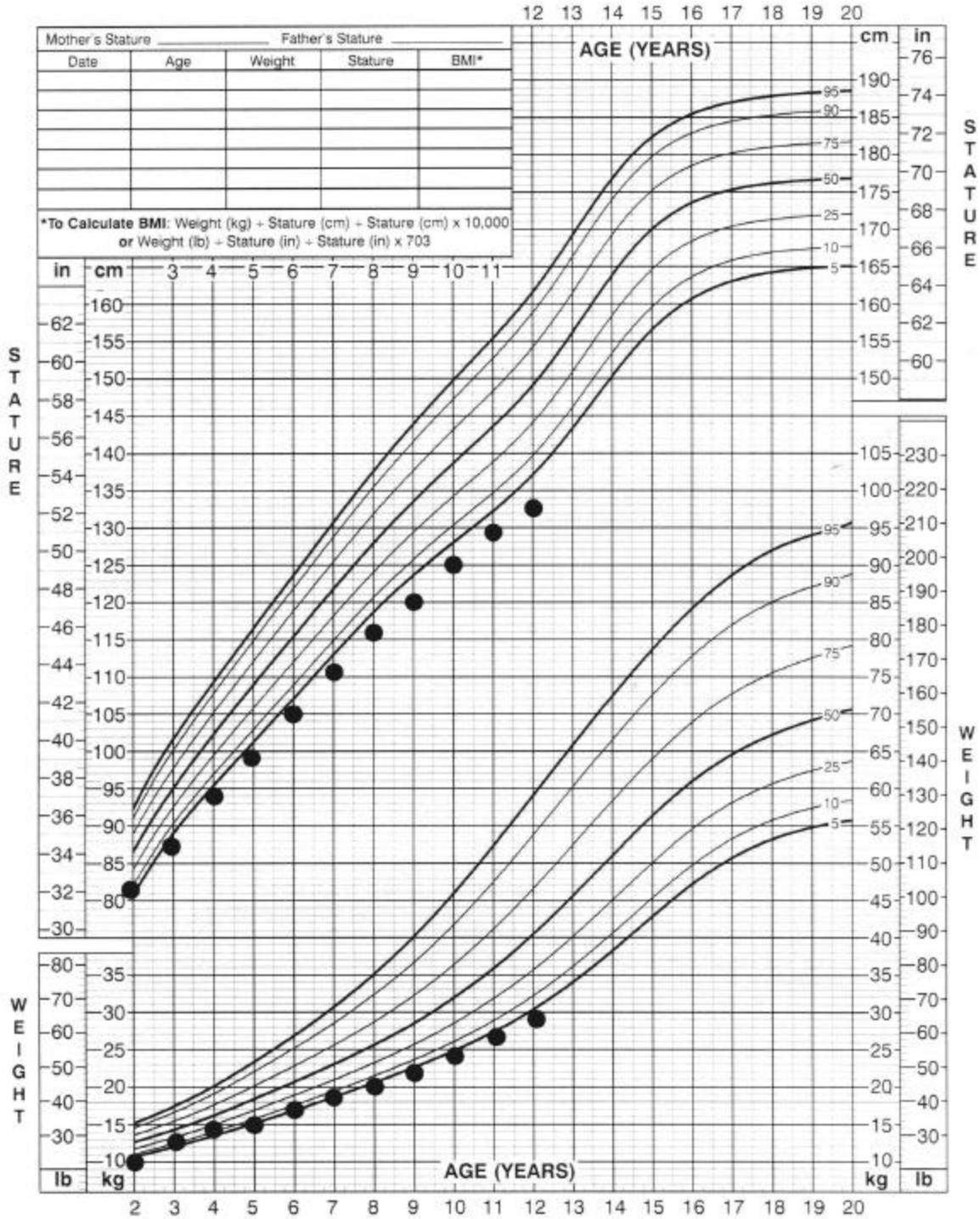
1. What should you do next? (Select as many as apply.)
 - e) calculate mid-parental height
 - f) obtain bone age
 - g) laboratory screening
 - h) re-plot on a specialized growth chart

2. The most likely diagnosis is (select one answer):
 - e) familial short stature
 - f) constitutional delay
 - g) Turner Syndrome
 - h) Down Syndrome

Case 2a

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

NAME B.T.
RECORD # Case 2a

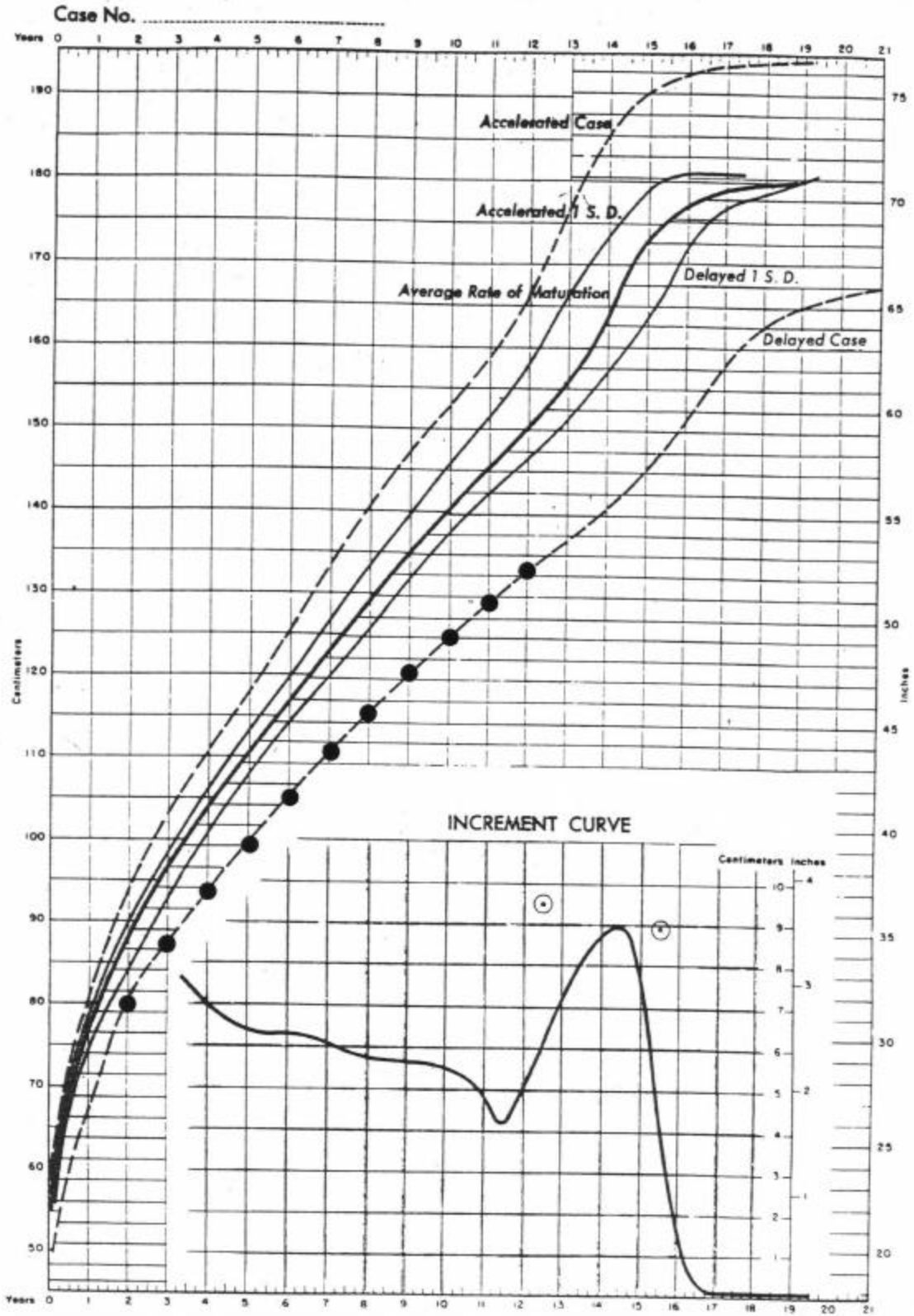


Revised and corrected November 28, 2000.
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).
<http://www.cdc.gov/growthcharts>



Case 2b

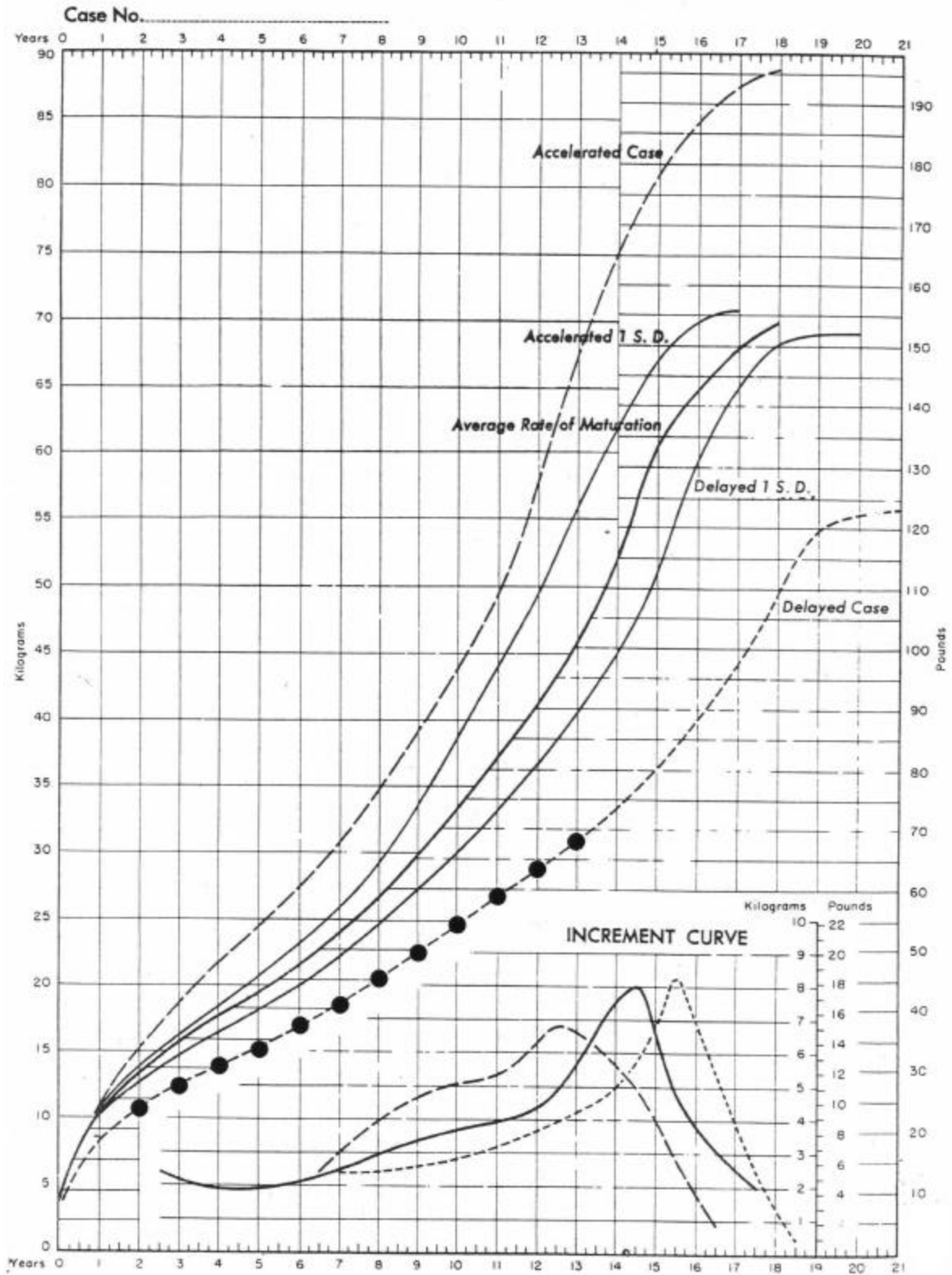
GROWTH CURVES OF HEIGHT BY AGE FOR BOYS
(Average, Accelerated, and Retarded Rates of Maturation)



Case 2c

GROWTH CURVES OF WEIGHT BY AGE FOR BOYS

(Average, Accelerated, and Retarded Rates of Maturation)



Case 2—B.T. is a 12 year old boy who has always been shorter than his peers. His mother is 5'1", and his father is 5'6". His mother had menarche at age 15 years; his father had late pubertal development. His physical examination is unremarkable, with pubertal development Tanner I.

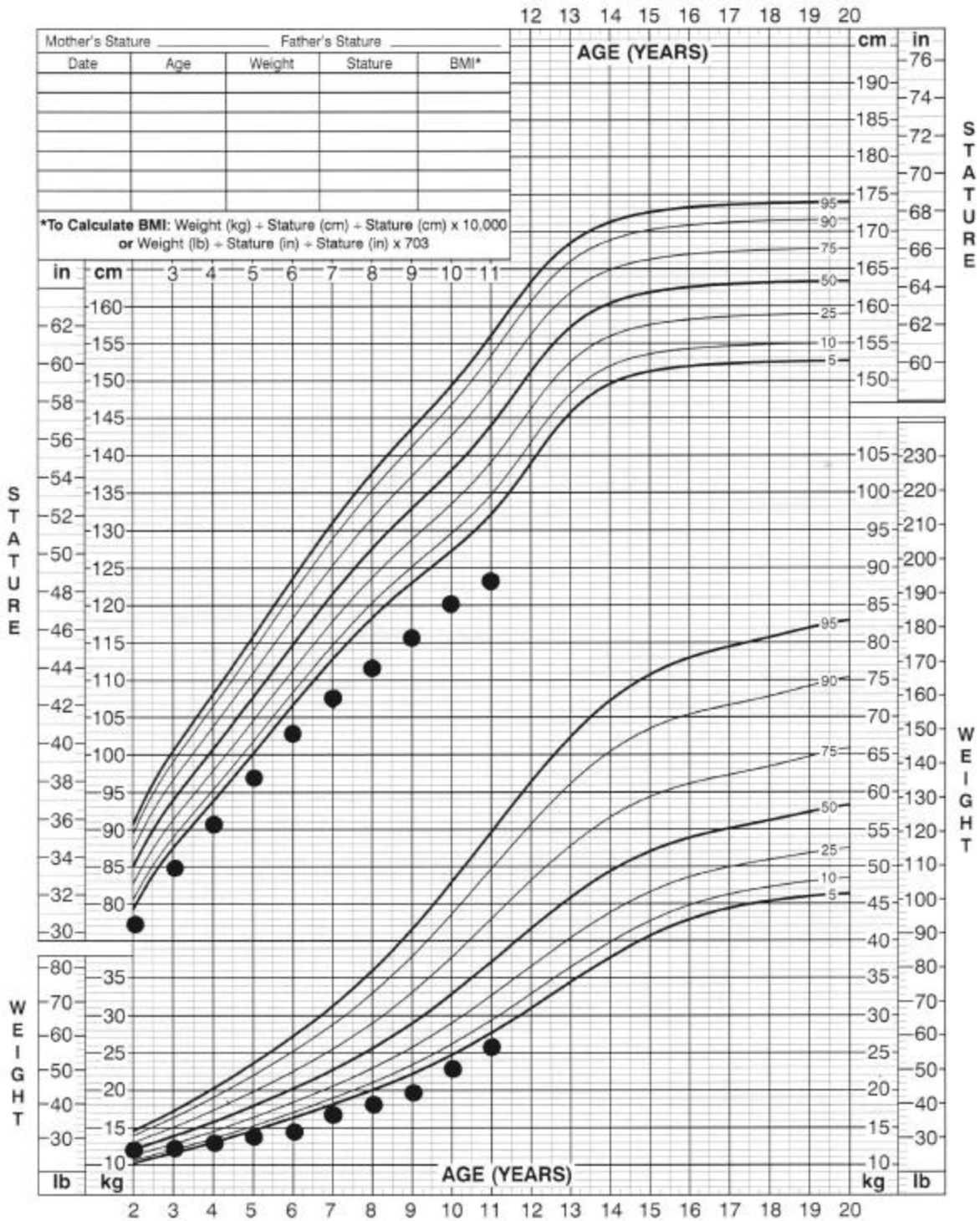
1. What should you do next? (Select as many as apply.)
 - e) calculate mid-parental height
 - f) obtain bone age
 - g) laboratory screening
 - h) re-plot on a specialized growth chart

2. The most likely diagnosis is (select one answer):
 - f) skeletal dysplasia
 - g) constitutional delay
 - h) growth hormone deficiency
 - i) Turner Syndrome
 - j) chronic disease

Case 3a

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

NAME S.T.
RECORD # case 3a



Revised and corrected November 28, 2000.
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>



Case 3—S.T. is an 11 year old girl with short stature and history of recurrent otitis media. Her mother is 5'4", and her father is 5'9". Her physical exam is remarkable for multiple nevi, low posterior hairline, webbed neck, widely spaced nipples, and increased carrying angle. Her breast and pubic hair development are Tanner I.

1. What should you do next? (Select as many as apply.)
 - e) calculate mid-parental height
 - f) obtain bone age
 - g) laboratory screening
 - h) re-plot on a specialized growth chart

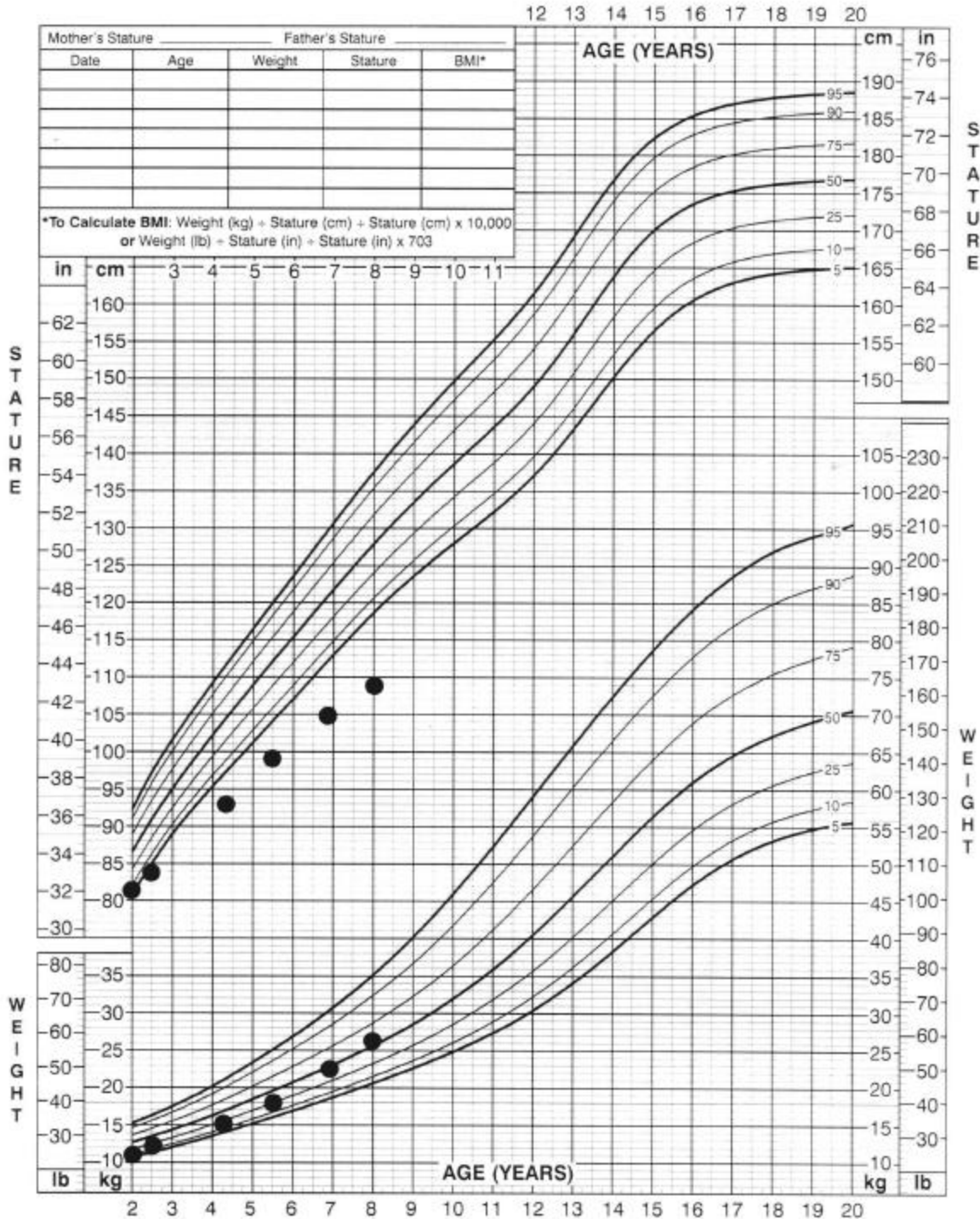
2. The most likely diagnosis is (select one answer):
 - f) skeletal dysplasia
 - g) constitutional delay
 - h) growth hormone deficiency
 - i) Turner Syndrome
 - j) chronic disease

Case 4a

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

NAME B.H.

RECORD # case 4a



Revised and corrected November 28, 2000.
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>



Case 4—B.H. is an 8 year old boy who has always been shorter than his peers. His review of systems is negative. He has been generally healthy. His mother is 5'4", his father is 5'9". On physical exam, he has a "cherubic" appearance. His phallus is 4.5 cm (<10th percentile), and his upper to lower segment ratio is 1.0. His physical exam is otherwise unremarkable.

1. What should you do next? (Select as many as apply.)

- e) calculate mid-parental height
- f) obtain bone age
- g) laboratory screening
- h) re-plot on a specialized growth chart

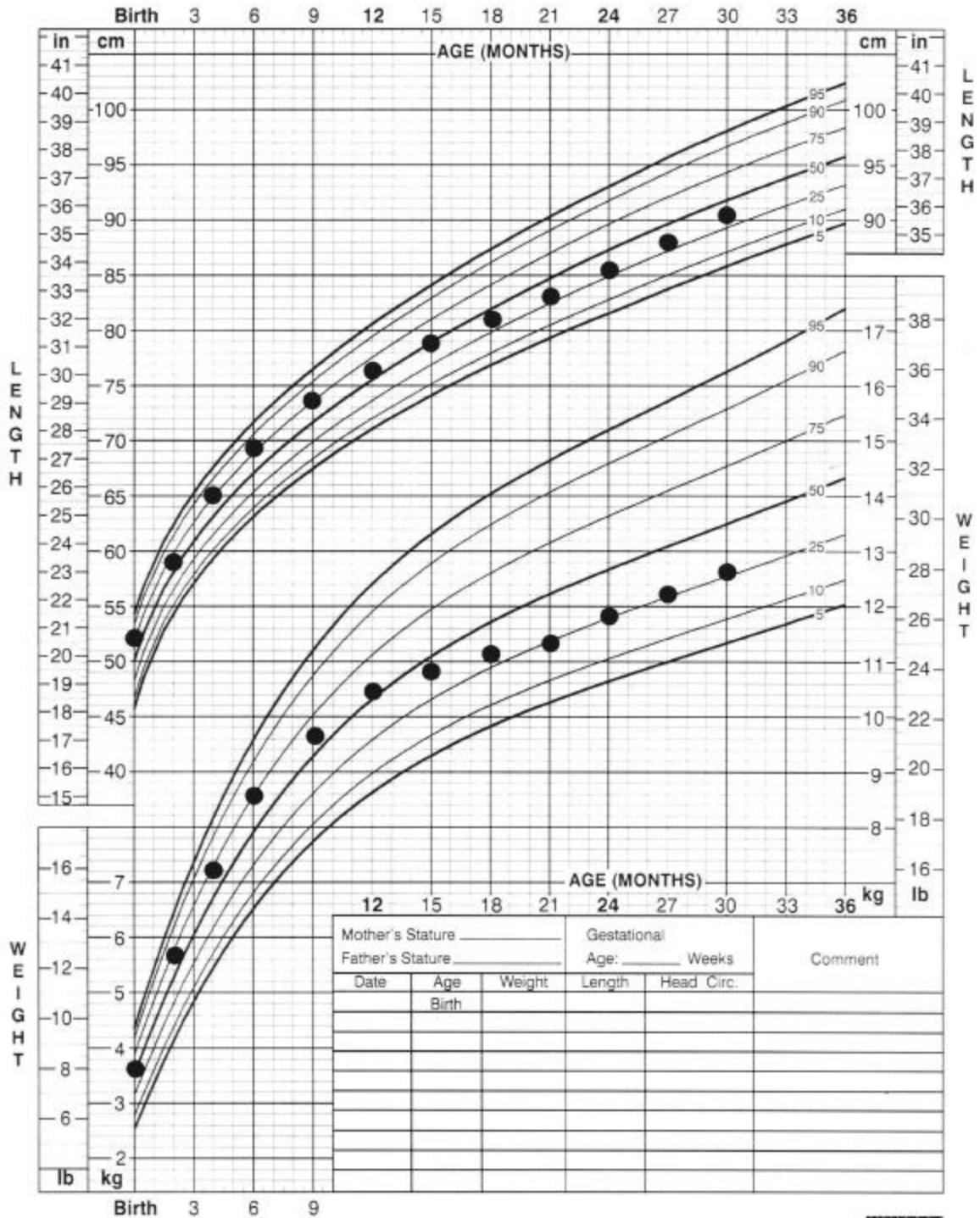
2. The most likely diagnosis is (select one answer):

- f) skeletal dysplasia
- g) constitutional delay
- h) growth hormone deficiency
- i) Turner Syndrome
- j) chronic disease

Case 5a

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

NAME B.B.
 RECORD # Case 5a



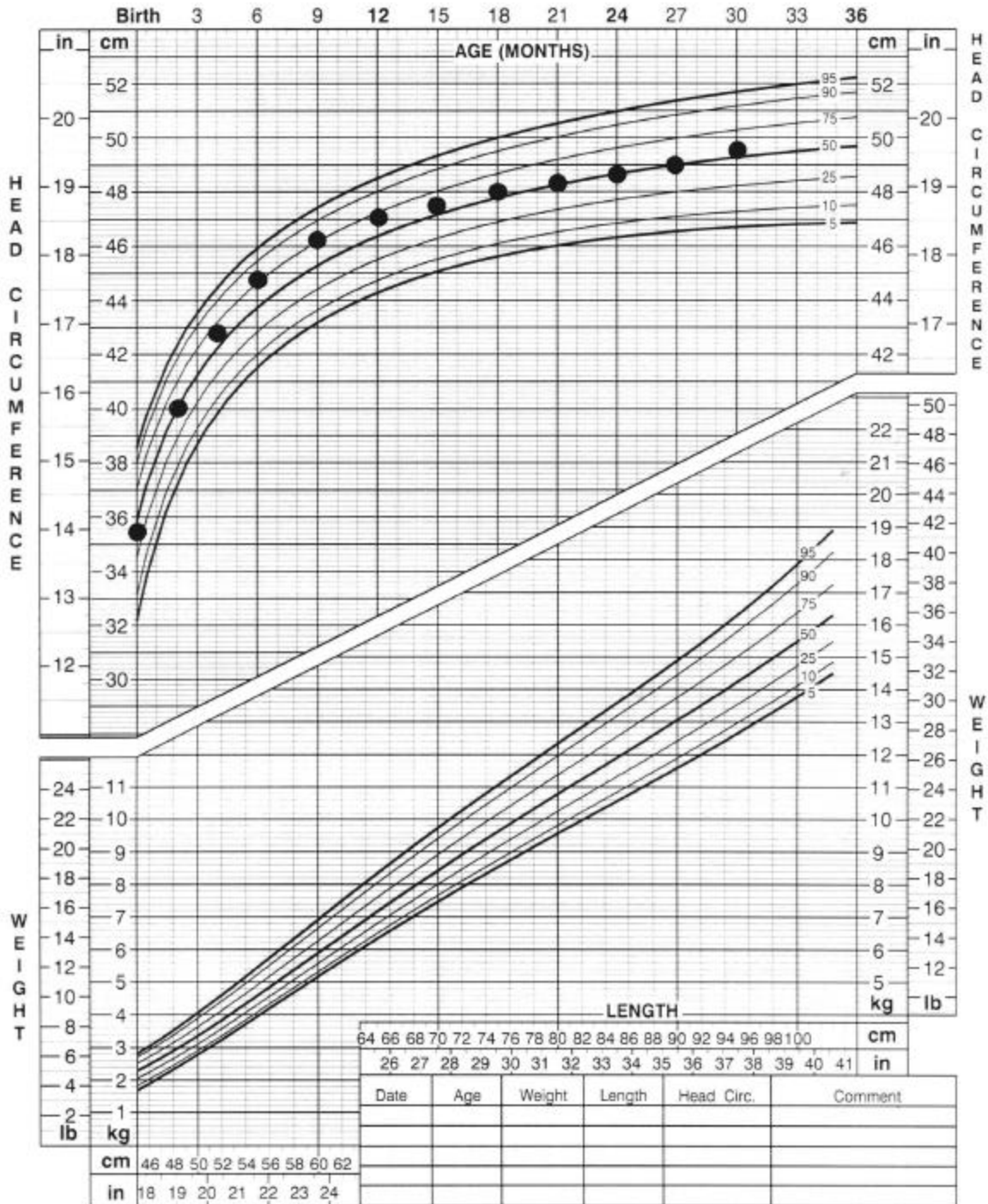
Revised November 28, 2000.
 SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).
<http://www.cdc.gov/growthcharts>



Case 5b

Birth to 36 months: Boys
 Head circumference-for-age and
 Weight-for-length percentiles

NAME B.B.
 RECORD # case 5b



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>



Case 5—B.B. is a 30 month old male whose length percentile is decreasing. He was the 8 lb. 20½ inch product of a full-term gestation delivered vaginally without complications. His past medical history is significant for a few upper respiratory infections, but he has been otherwise healthy. His mother is 63”, his father is 68”.

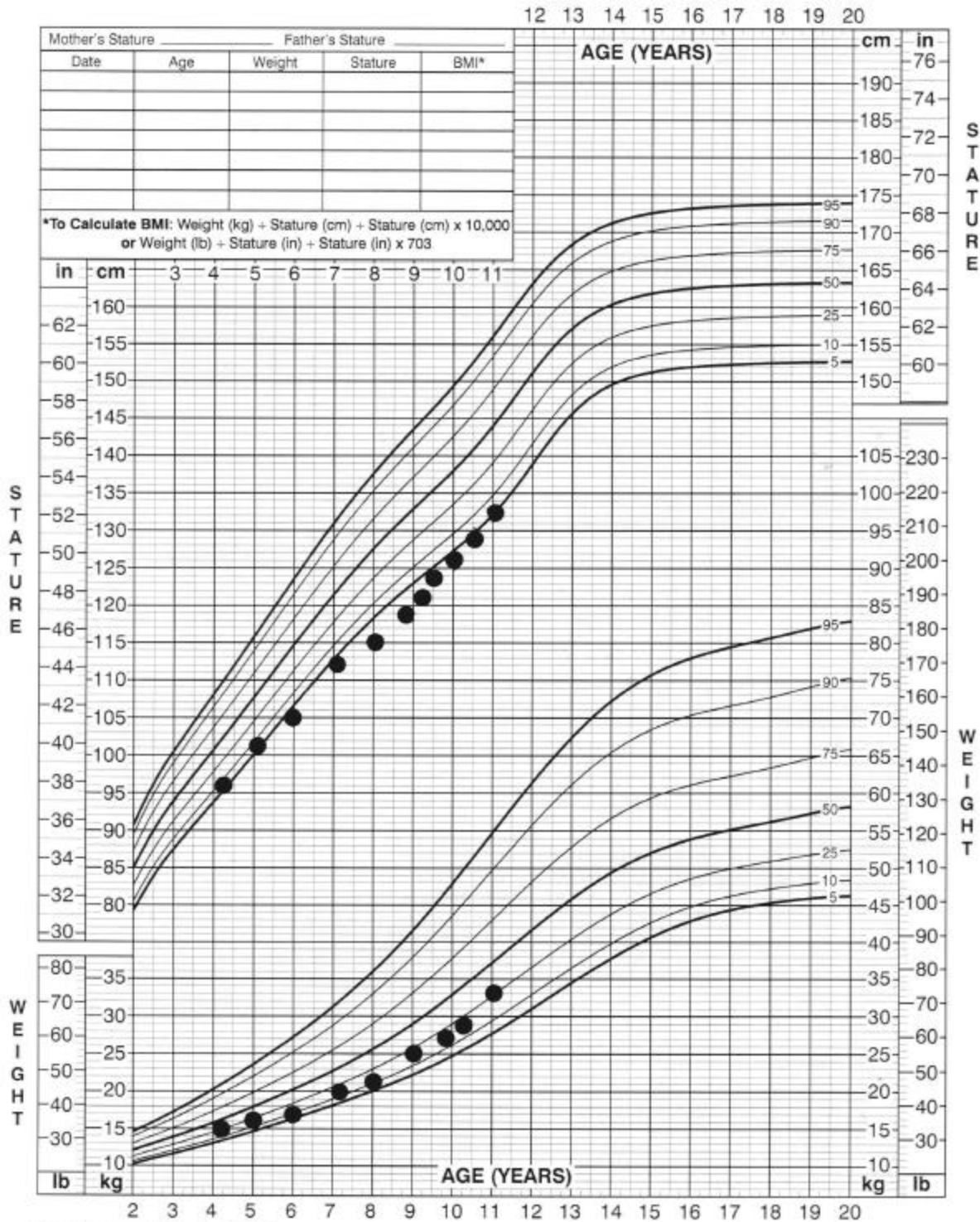
1. What should you do next? (Select as many as apply.)
 - e) calculate mid-parental height
 - f) obtain bone age
 - g) laboratory screening
 - h) re-plot on a specialized growth chart

2. The most likely diagnosis is (select one answer):
 - f) constitutional delay
 - g) hypothyroidism
 - h) non-organic failure to thrive
 - i) channeling (i.e., normal variant)
 - j) skeletal dysplasia

Case 6a

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

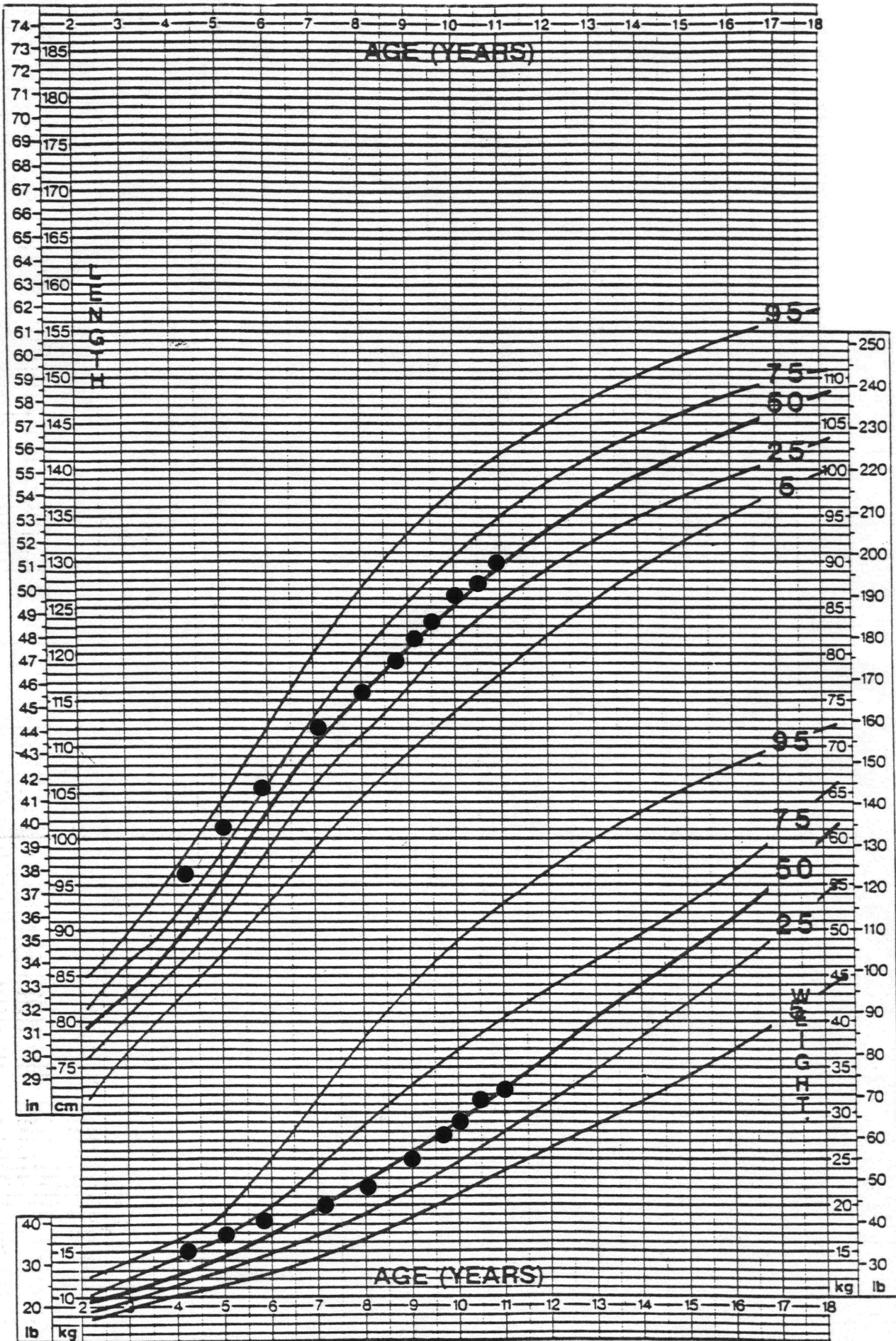
NAME G.C.
RECORD # case 6a



Revised and corrected November 28, 2000.
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>



Case 6b-Girls with Down Syndrome



Case 6—G.C. is an 11 year old girl who has always been short and is developmentally delayed. Her past medical history is notable for a ventricular septal defect and recurrent otitis media. Her mother is 5'5", her father is 5'10". Her physical exam is notable for abnormal palpebral fissures and palmar creases, a protruding tongue, and a short neck. Her breast and pubic hair development are Tanner II.

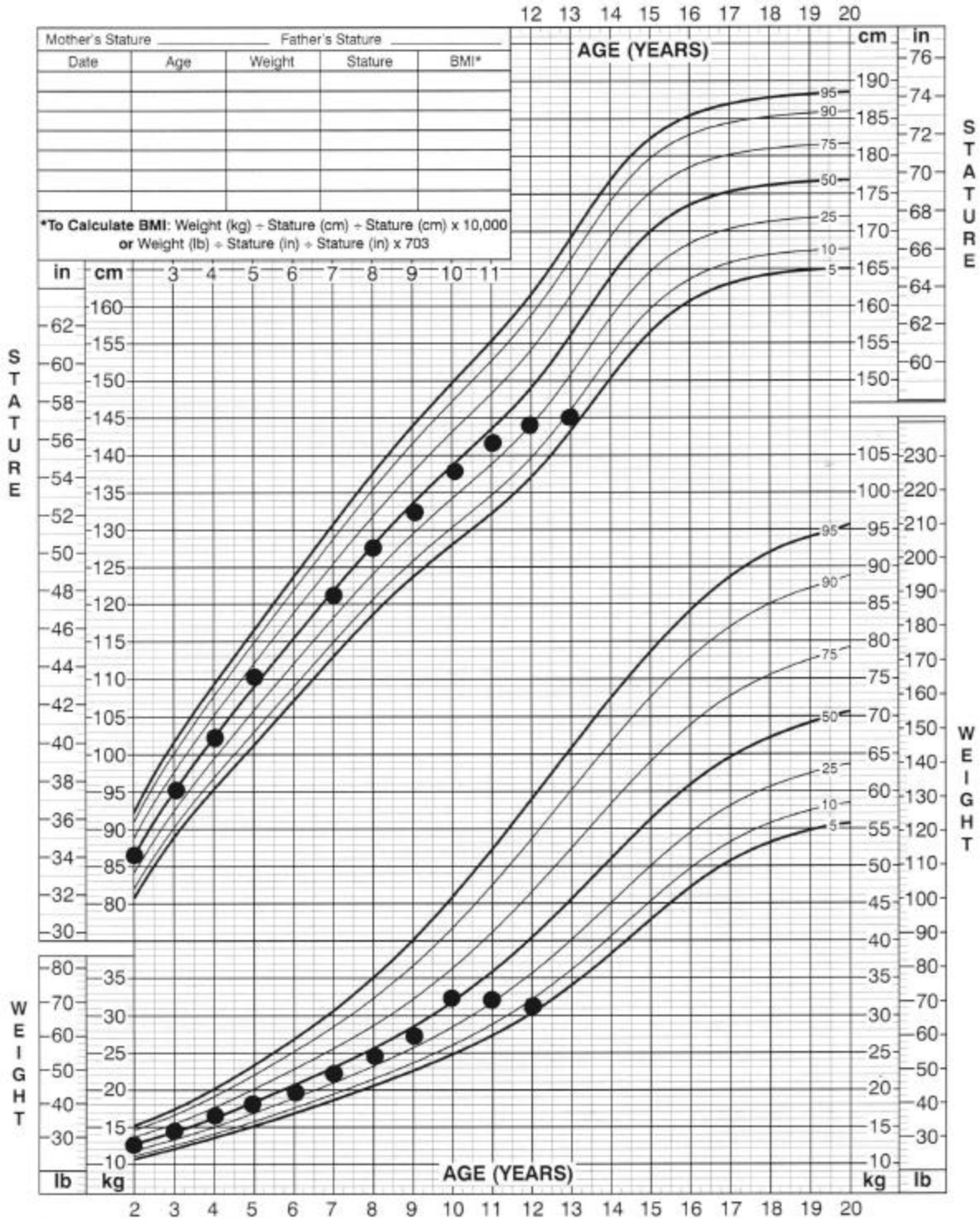
1. What should you do next? (Select as many as apply.)
 - e) calculate mid-parental height
 - f) obtain bone age
 - g) laboratory screening
 - h) re-plot on a specialized growth chart

2. The most likely diagnosis is (select one answer):
 - e) familial short stature
 - f) constitutional delay
 - g) Turner Syndrome
 - h) Down Syndrome

Case 7

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

NAME K.A.
RECORD # case 7



Revised and corrected November 28, 2000.
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>



Case 7—K.A. is a 13 year old boy with short stature and pubertal delay. His past medical history is significant for a seizure disorder and developmental delay. His medications include Depakote, Phenobarbital, Neurontin, and Diamox. His review of systems is positive for a restricted diet; he likes only potato chips. He denies abdominal pain or diarrhea. His mother is 5'5", his father is 5'10". His physical exam is notable for a gaunt appearance. He has 5 cc testes and Tanner II pubic hair.

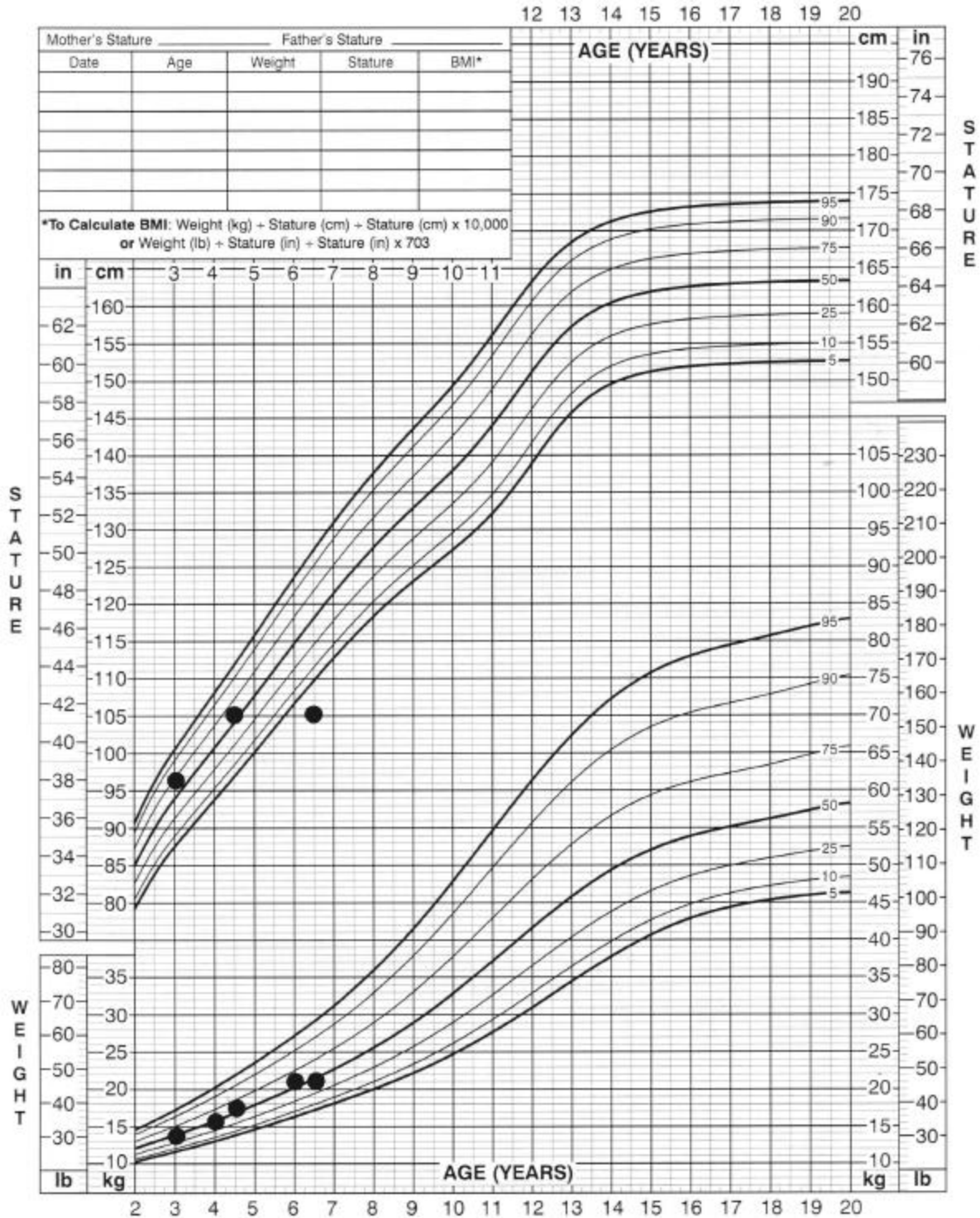
1. What should you do next? (Select as many as apply.)
 - f) calculate mid-parental height
 - g) obtain bone age
 - h) laboratory screening
 - i) re-plot on a specialized growth chart
 - j) other

2. The most likely diagnosis is (select one answer):
 - e) constitutional delay
 - f) hypothyroidism
 - g) malnutrition
 - h) channeling (i.e., normal variant)
 - i) skeletal dysplasia

Case 8a

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

NAME K.R.
RECORD # Case 8a



Revised and corrected November 28, 2000.
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>



Case 8—K.R. is a 6 and 1/2 year old girl presenting with fatigue. Her review of systems is positive for cold intolerance, dry skin, and constipation. Her physical exam is remarkable for a sallow appearance, waxy dry skin, and coarse hair. Her mother is 5'2" and her father is 5'7".

1. What should you do next? (Select as many as apply.)
 - e) calculate mid-parental height
 - f) obtain bone age
 - g) laboratory screening
 - h) re-plot on a specialized growth chart

2. The most likely diagnosis is (select one answer):
 - f) constitutional delay
 - g) hypothyroidism
 - h) non-organic failure to thrive
 - i) channeling (i.e., normal variant)
 - j) skeletal dysplasia

Case 9—G.F. is a 17 year old girl who has been overweight “*for as long as I can remember.*” Her family history is positive for obesity on both the paternal and maternal sides of the family. Her dietary history is notable for erratic eating habits and skipping meals; she has a high intake of fat and concentrated sweets. She has regular menses. Her breast and pubic hair development are Tanner V.

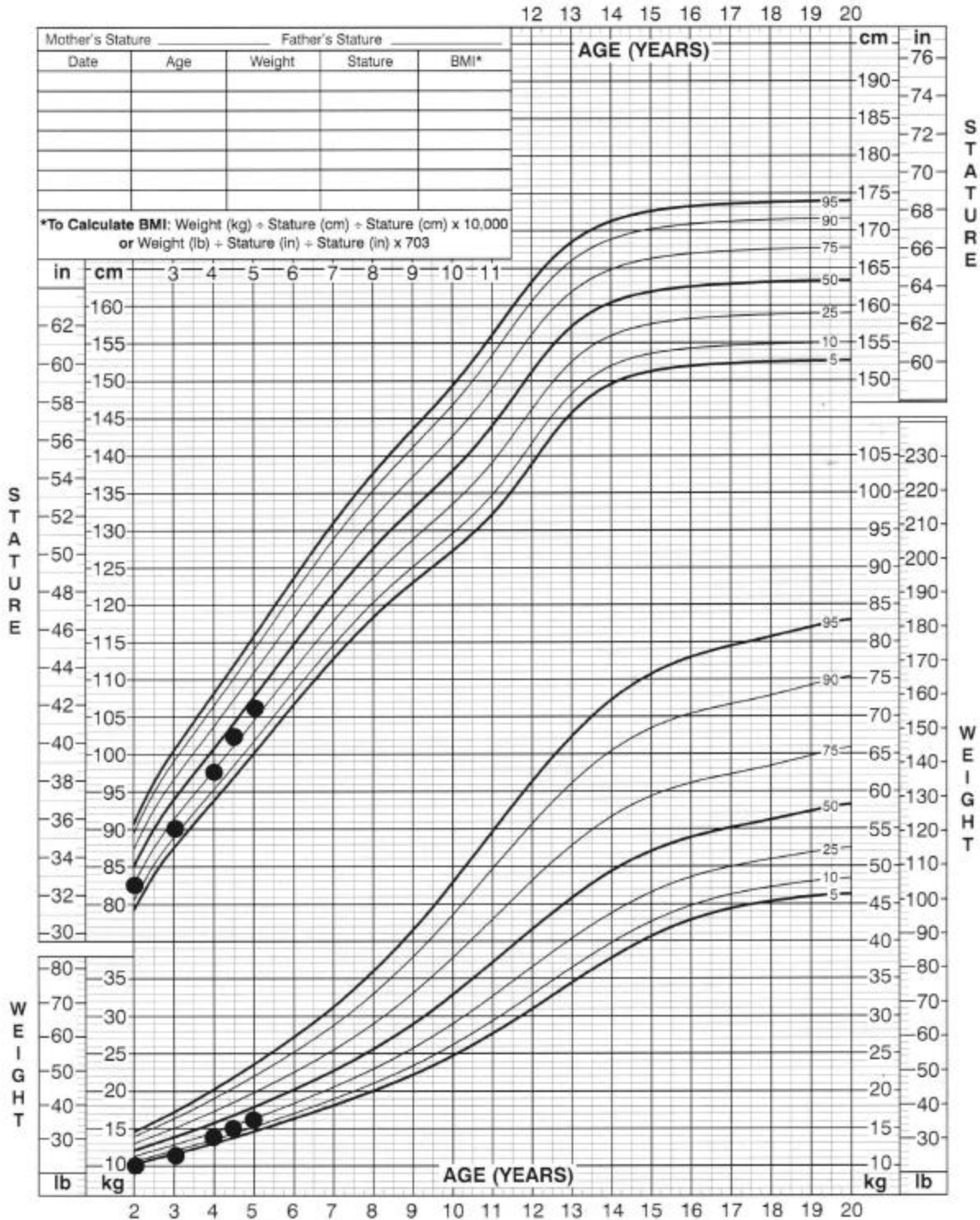
1. What should you do next? (Select as many as apply.)
 - f) calculate mid-parental height
 - g) obtain bone age
 - h) laboratory screening
 - i) re-plot on a specialized growth chart

2. The most likely diagnosis is (select one answer):
 - e) precocious puberty
 - f) growth hormone excess
 - g) obesity
 - h) Cushing’s syndrome

Case 10

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

NAME A.B.
RECORD # case 10



Revised and corrected November 28, 2000.
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>



Case 10—A.B. is a 4 and 9/12 year old girl who developed breast buds at age 3 and 10/12 years. Height acceleration was noted from the age of 4 years. Pubic hair development and apocrine odor were noted at age 4 and 6/12 years.

1. What should you do next? (Select as many as apply.)
 - e) calculate mid-parental height
 - f) obtain bone age
 - g) laboratory screening
 - h) re-plot on a specialized growth chart

2. The most likely diagnosis is (select one answer):
 - f) tall stature
 - g) precocious puberty
 - h) growth hormone excess
 - i) obesity
 - j) Cushing's syndrome

Understanding Growth: Normal vs. Abnormal Patterns **Handout for Cases 4 & 7**

Systemic Disorders That Affect Growth

- *Malnutrition*
- *Renal disease*
 - Growth failure secondary to rickets, acidosis, and nutritional failure
 - Resistance to GH
- *Diabetes*
 - Poor control, with significant acidosis, will result in significant growth retardation
- *Cardiac*
 - Growth failure may be due to cyanosis and hypoxia
 - Other unclear underlying mechanisms
- *Hematologic disease*
 - Chronic anemias
- *Gastrointestinal disorders*
 - Inflammatory bowel disease
 - Chronic liver disease
 - Celiac disease
 - Other causes of malabsorption
- *Respiratory disease*
 - Cystic fibrosis
 - Asthma
- *Endocrine disorders*
 - Hypothyroidism
 - Growth hormone deficiency/inadequacy
 - Cortisol excess
- **Congenital Disorders**
 - Intrauterine growth retardation
 - Skeletal dysplasia
 - Other genetic syndromes (e.g., Turner's Syndrome)

Understanding Growth: Normal vs. Abnormal Patterns

Bibliography:

Growth rates and monitoring growth

1. Monitoring and Assessment of Growth, The Primary Care Perspective [slide series]. Genentech, Inc.
2. Rosenfield RG. Skeletal Maturation (Bone Age). In: Sperling MA, editor. *Pediatric Endocrinology*. Philadelphia: W.B. Saunders Co; 1996. p.120-121.

Short stature

3. Cowell CT. Short Stature. In Brook CGD, editor. *Clinical Paediatric Endocrinology*. Oxford: Blackwell Science LTD.; 1995. pp. 136-172.
4. Linder B, Cassoria F. Short Stature, etiology, diagnosis, and treatment. *Journal of the American Medical Association* 1988; 260:3171-3175.
5. Mahoney CP. Evaluating the child with short stature. *Pediatric Clinics of North America* 1987; 34:825-849.

Hypothyroidism

6. Lafranchi S. Thyroiditis and acquired hypothyroidism. *Pediatric Annals* 1992;21:29-39.

Obesity

7. Arslanian S. Obesity. In: Sperling MA, editor. *Pediatric Endocrinology*. Philadelphia: W.B. Saunders Co; 1996. p. 535-543.

Precocious puberty

8. Bridges NA, Brook CGD. Sexual Precocity. In Brook CGD, editor. *Clinical Paediatric Endocrinology*. Oxford: Blackwell Science LTD; 1995, p. 253-262.

Suggested Reading (Annotated)

Mahoney CP. Evaluating the child with short stature. *Pediatric Clinics of North America* 1987; 34:825-849. A timeless review article, which describes normal growth patterns, the evaluation of short stature, and diseases causing short stature.

Shulman DI, Beru BB. Growth hormone therapy: An update. *Contemporary Pediatrics* 1998;15:95-110. An excellent review of the diagnosis and treatment of growth hormone deficiency and the evaluation of the short child in general.

Educational Resources on the World Wide Web

The National Center for Health Statistics

<http://www.cdc.gov/nchswww/> (Home page)

<http://www.cdc.gov/growthcharts/> (Growth charts)