

# Pediatric Malnutrition: Under- and Over-weight in Children

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# Undernutrition: Global and Local



## Famine

- Political Instability
- Distribution of Resources
- Social Chaos
- Survival/Recovery

# Nutrient Deficiency



## Maternal-Child Dyad

- Maternal Nutrition/Health
- Intrauterine Onset
- Nursing insufficiency
- Weaning/transition

# Malabsorption



- Environmental Factors
- Infection: parasitosis
- Malabsorption → reduced intake
- Inflammation → increased energy needs

# Kwashiorkor



Displaced from nursing

Low protein alternatives

Endemic Infection

GI protein loss

Hypoalbuminemia → Edema

# Marasmus



Protein-Calorie Undernutrition

Fat and Muscle depletion

Preserved plasma proteins

Preserved homeostasis

# Failure to Thrive: Our world



Genetics

Prenatal environment

Behavioral factors

Psychosocial context

Disease factors

# To Thrive

- Homeostasis
- Full physiologic function
- Weight gain
- Linear growth
- Cranial growth
- Neurodevelopment
- Social integration

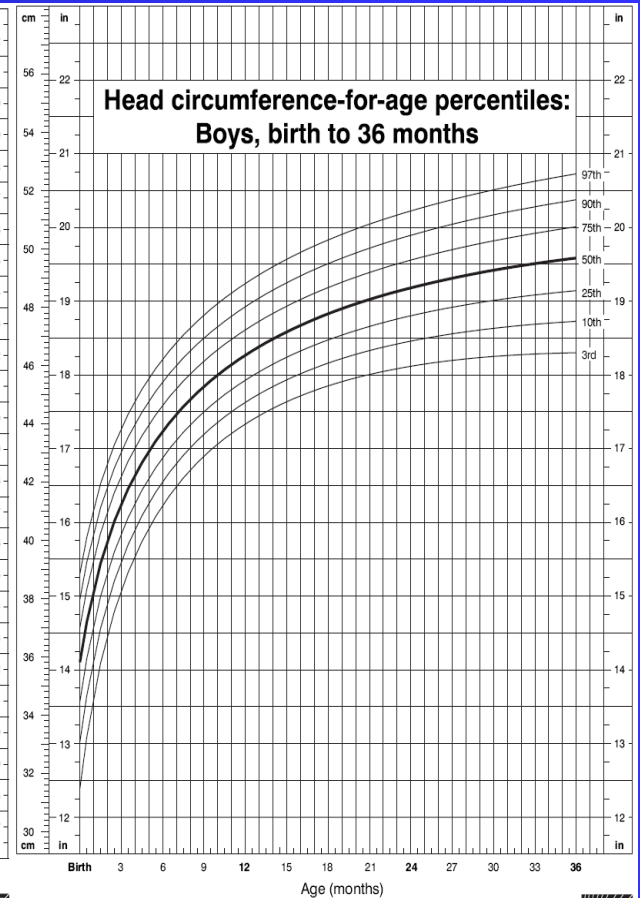
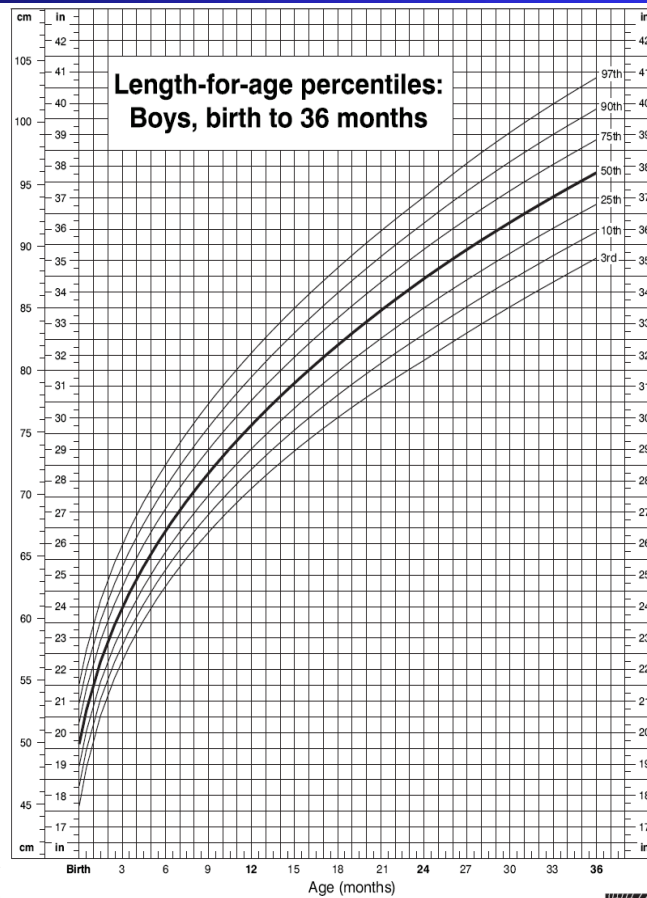
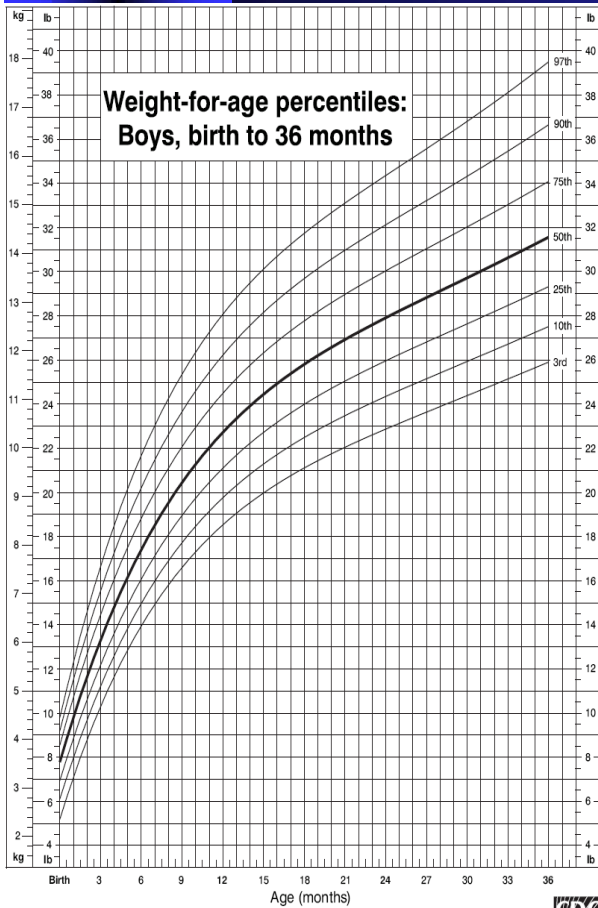


# Navigating The Growth Curve

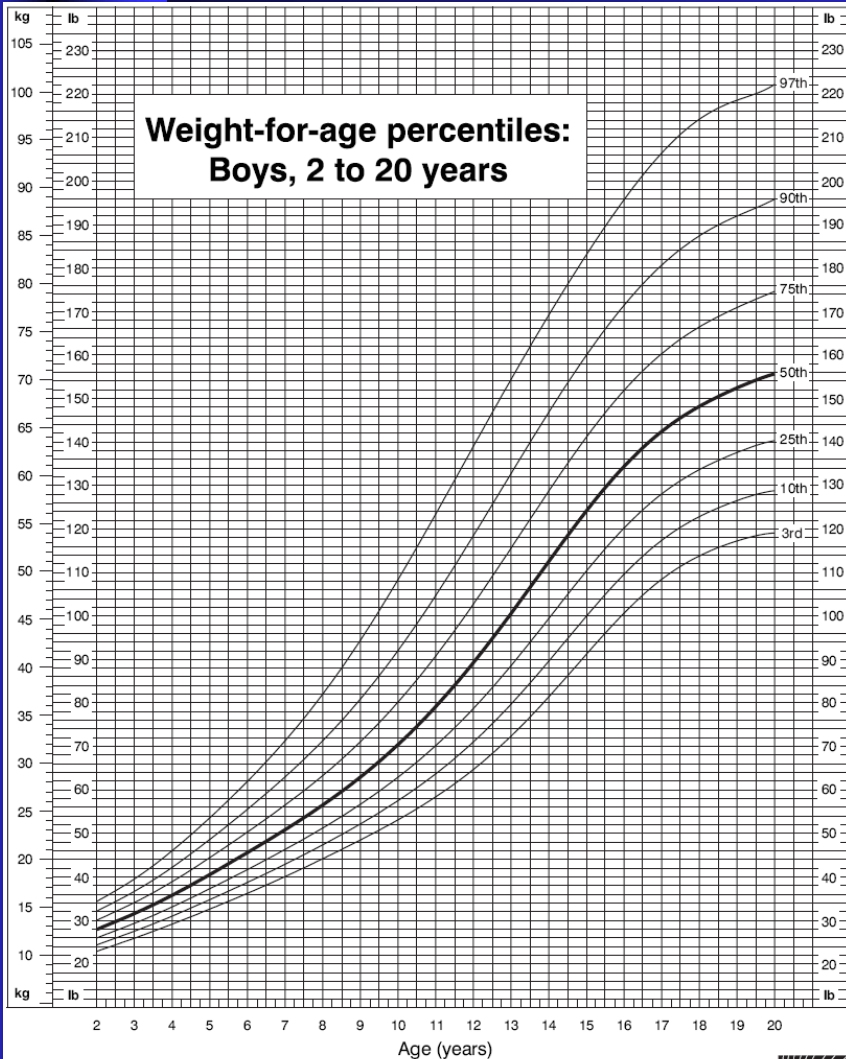
- Expectations
- Deviations
- Recovery
- Faltering
- Acute wasting
- Chronic stunting
- Cranial stasis



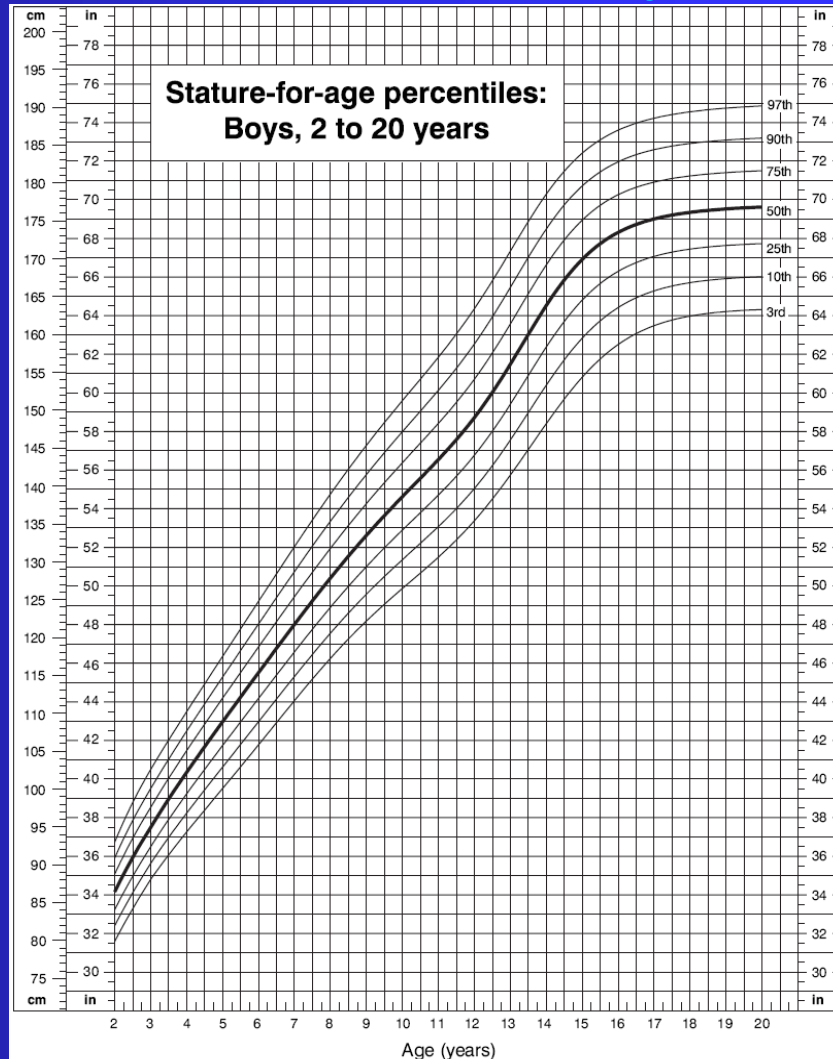
# CDC Growth Curves: 0-36 months



# CDC Growth Curves: 2-20 years



Published May 30, 2000.  
SOURCE: Developed by the National Center for Health Statistics in collaboration with  
the National Center for Chronic Disease Prevention and Health Promotion (2000).



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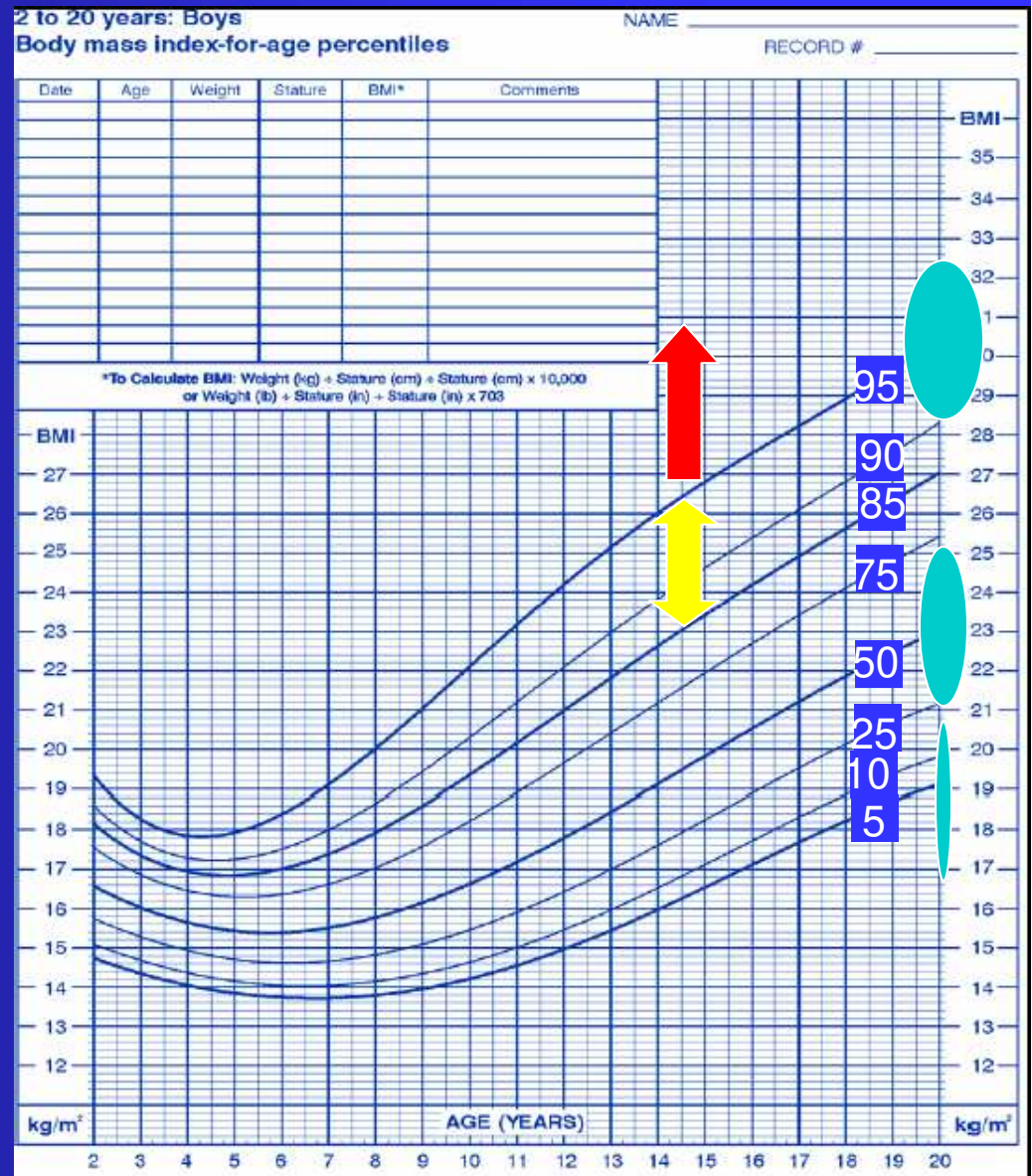
# Body Mass Index [BMI]: 2 years to 20 years

$$\text{BMI} = \text{weight (kg)} / \text{height}^2 (\text{m}^2)$$

**Extremely Obese:** BMI  $\geq$  99<sup>th</sup> %ile

**Obese:** BMI 95<sup>th</sup> to <99<sup>th</sup> %ile

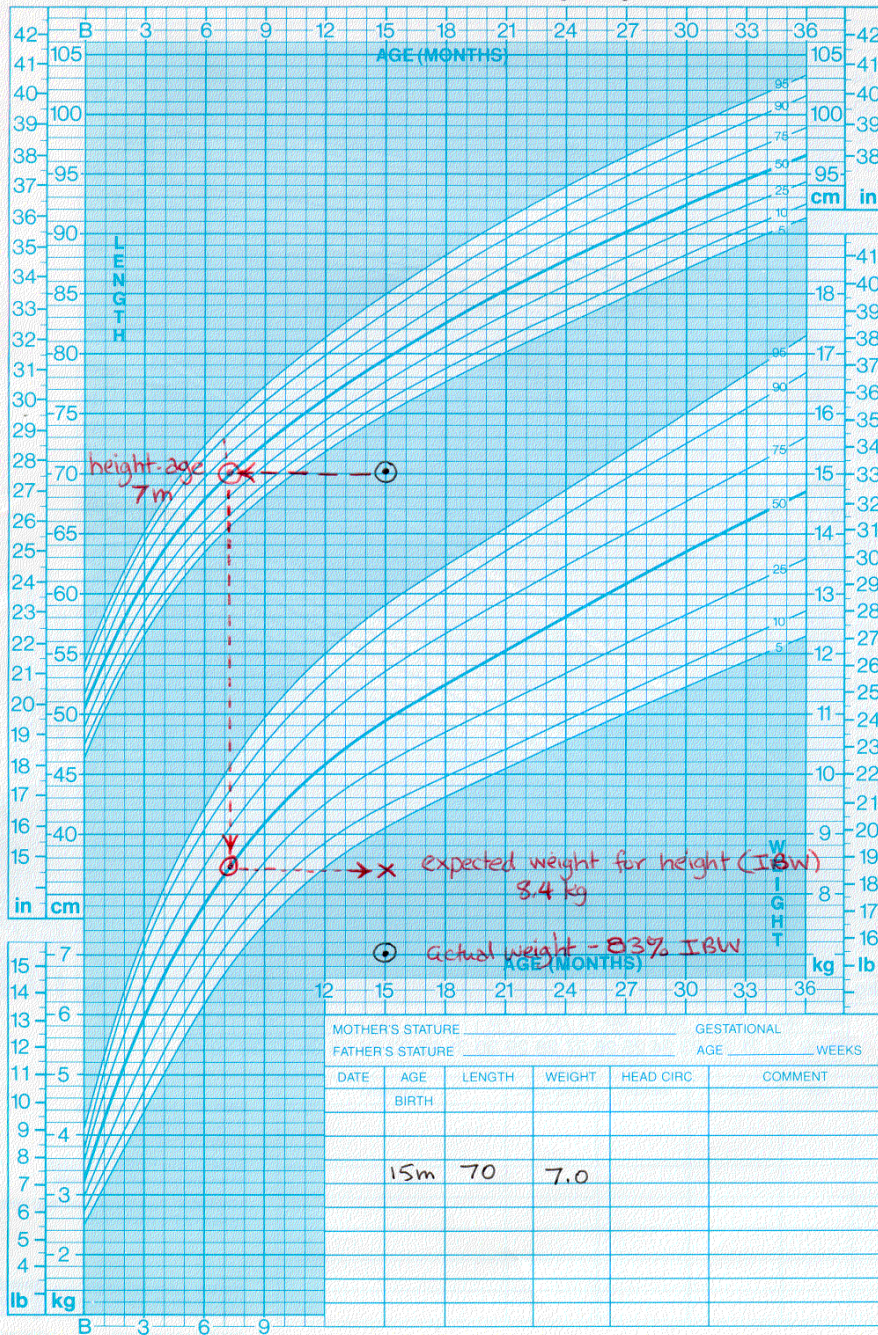
**Overweight:** BMI 85<sup>th</sup> to <95<sup>th</sup> %ile



**BOYS: BIRTH TO 36 MONTHS  
PHYSICAL GROWTH  
NCHS PERCENTILES\***

NAME "IDEAL" Body Weight

RECORD #



Ross Growth & Development Program

\*Adapted from: Hamill P.V.V., Drizd T.A., Johnson C.L., Reed R.B., Roche A.F., Moore W.M.: Physical growth: National Center for Health Statistics percentiles. AM J CLIN NUTR 32:607-629, 1979. Data from the Fels Longitudinal Study, Wright State University School of Medicine, Yellow Springs, Ohio.  
© 1982 Ross Laboratories

Determination of  
% weight for height age:

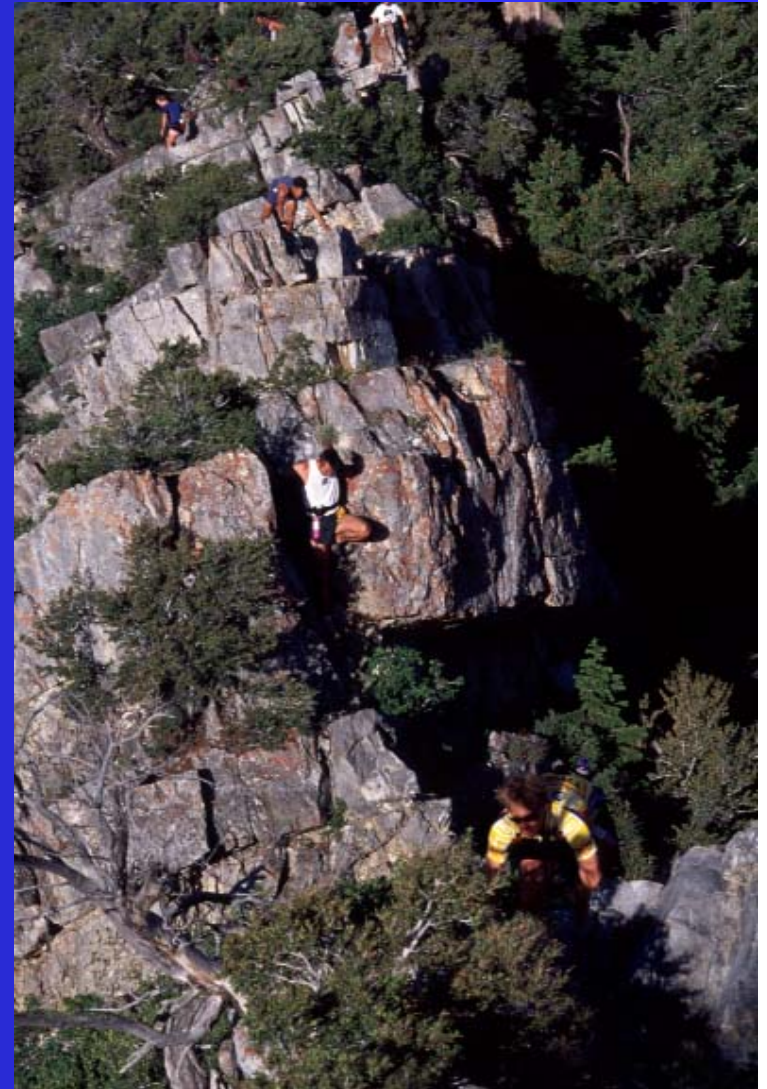
Actual Wt: 7 kg

Expected Wt: 8.4 kg

$7/8.4 = 0.83$  or 83%

# Hazards Around the Curve

- Inadequate nutrient intake
- Maldigestion
- Malabsorption
- Gut/Renal losses
- Metabolic demands
- Cardiopulmonary disease
- Endocrinopathy
- Neuropathology
- Psychosociopathology



# Genetic/Congenital

- Dysmorphic/chromosomal syndromes
  - ◆ Down's, Turner's, Noonan's, Prader-Willi
- Mutations
- Parental/sibling growth pattern
- Constitutional delay
- Familial short stature
- Intrauterine growth retardation



# Patterns of Failure to Thrive

- Nutritional

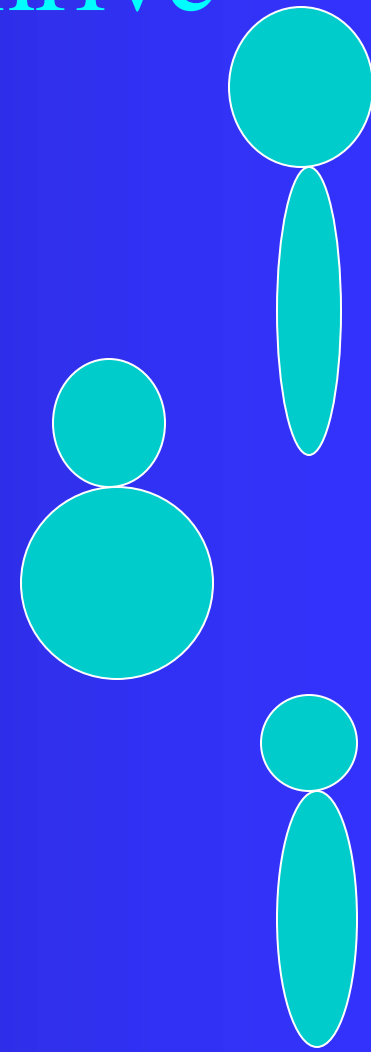
- ◆  $\text{Weight} < \text{Length} < \text{Head}$

- Endocrine

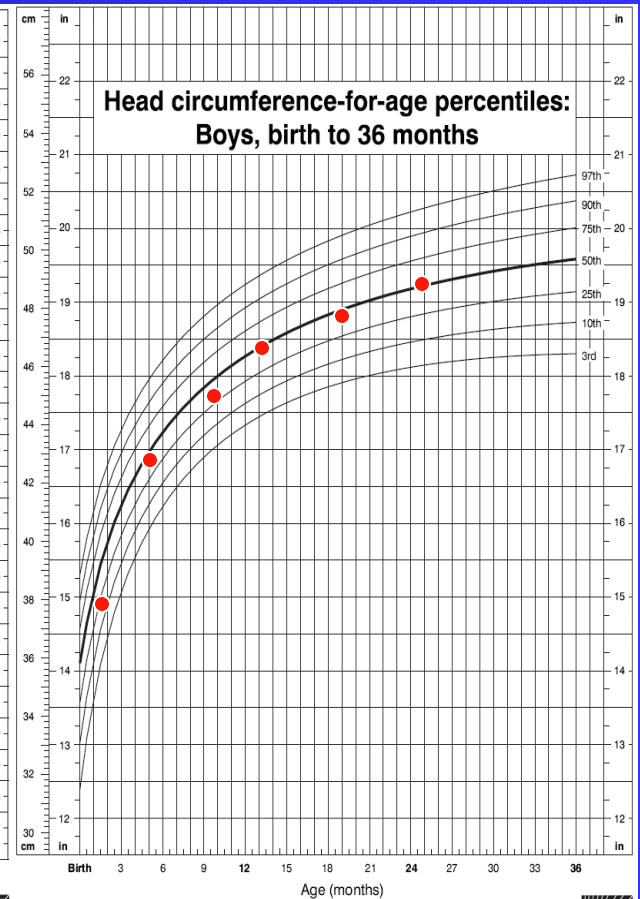
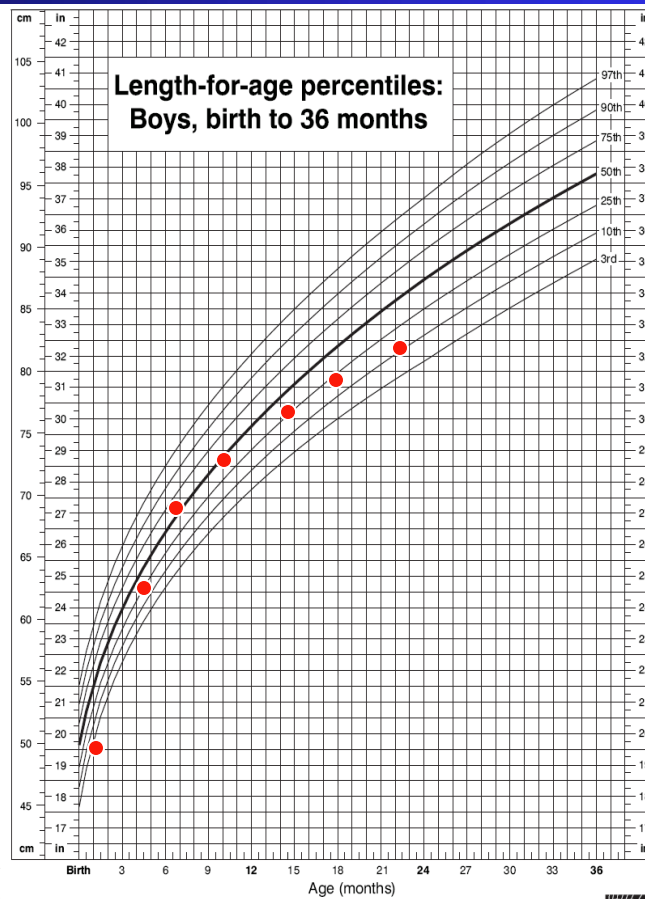
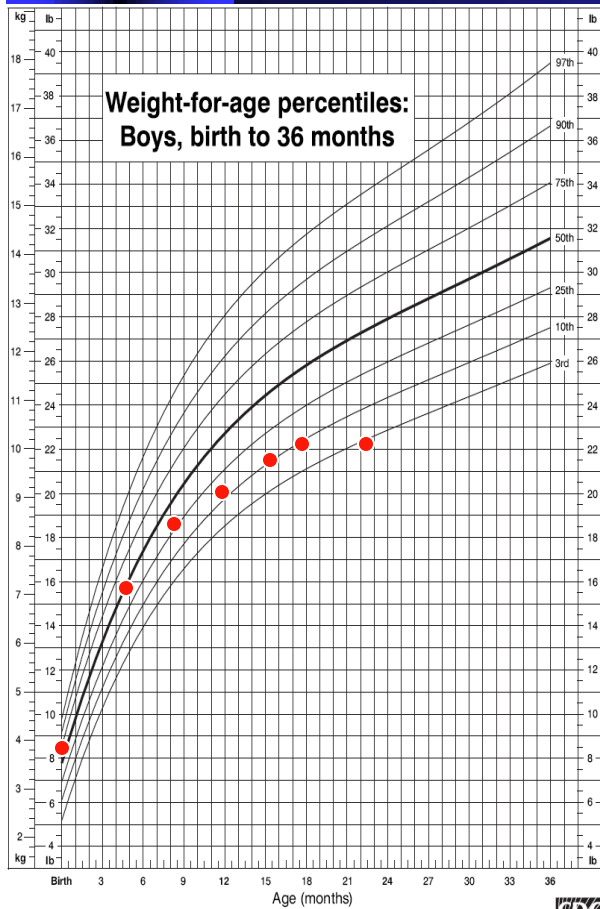
- ◆  $\text{Length} < \text{Weight} < \text{Head}$

- Neurologic

- ◆  $\text{Head} < \text{Weight} < \text{Length}$



# Nutritional Pattern



# Nutritional Pattern: DDx

## ■ Inadequate Net Intake

- ◆ Deprivation
- ◆ Aversion, Dysphagia
- ◆ Vomiting/Reflux

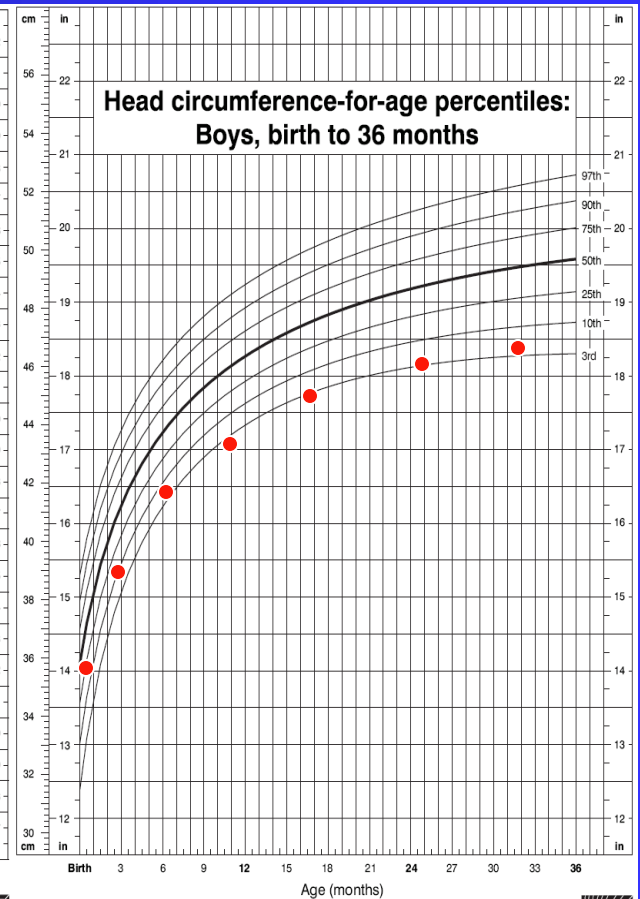
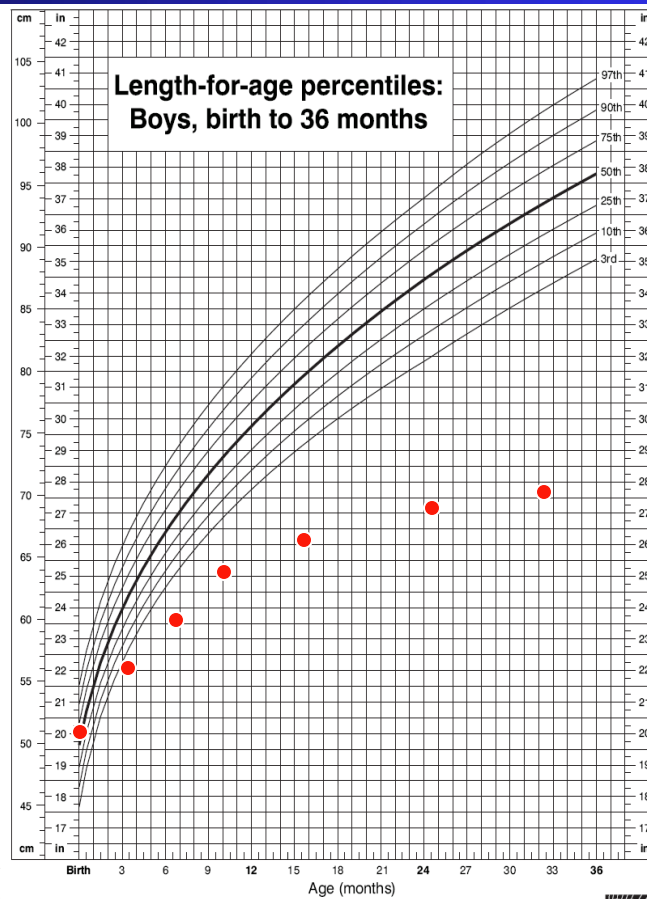
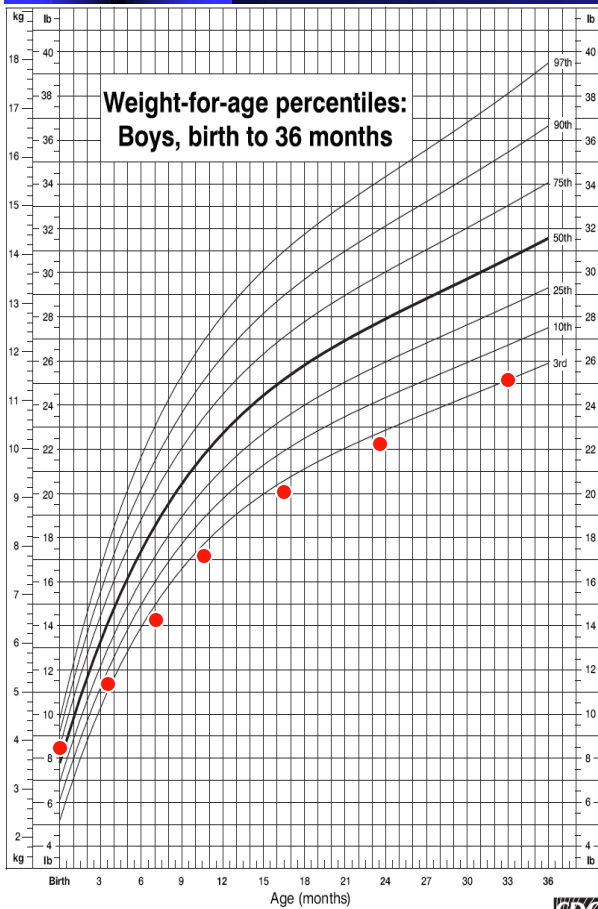
## ■ Maldigestion/Malabsorption

- ◆ Pancreatic Insufficiency: Cystic Fibrosis, Shwachman
- ◆ Mucosal disease: Giardia/Cryptosporidia; viral enteritis; Celiac disease

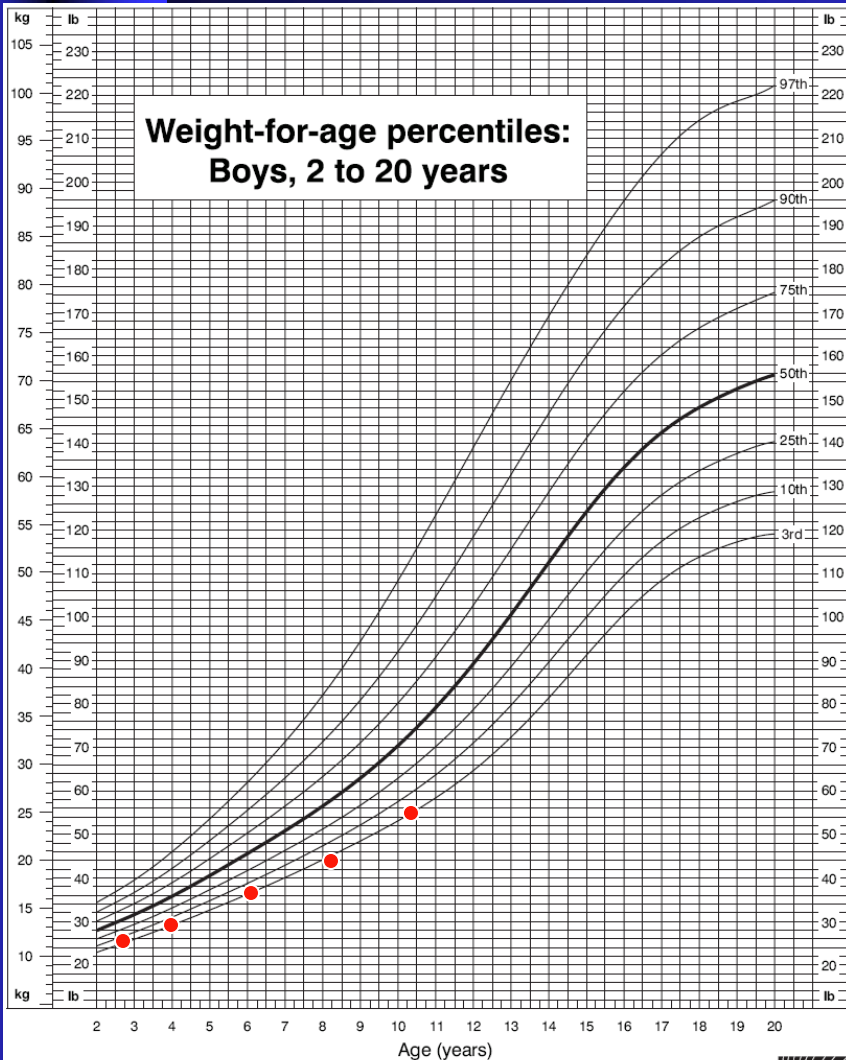
## ■ Increased Metabolic Requirements

- ◆ Inflammation
- ◆ Cardiopulmonary disease

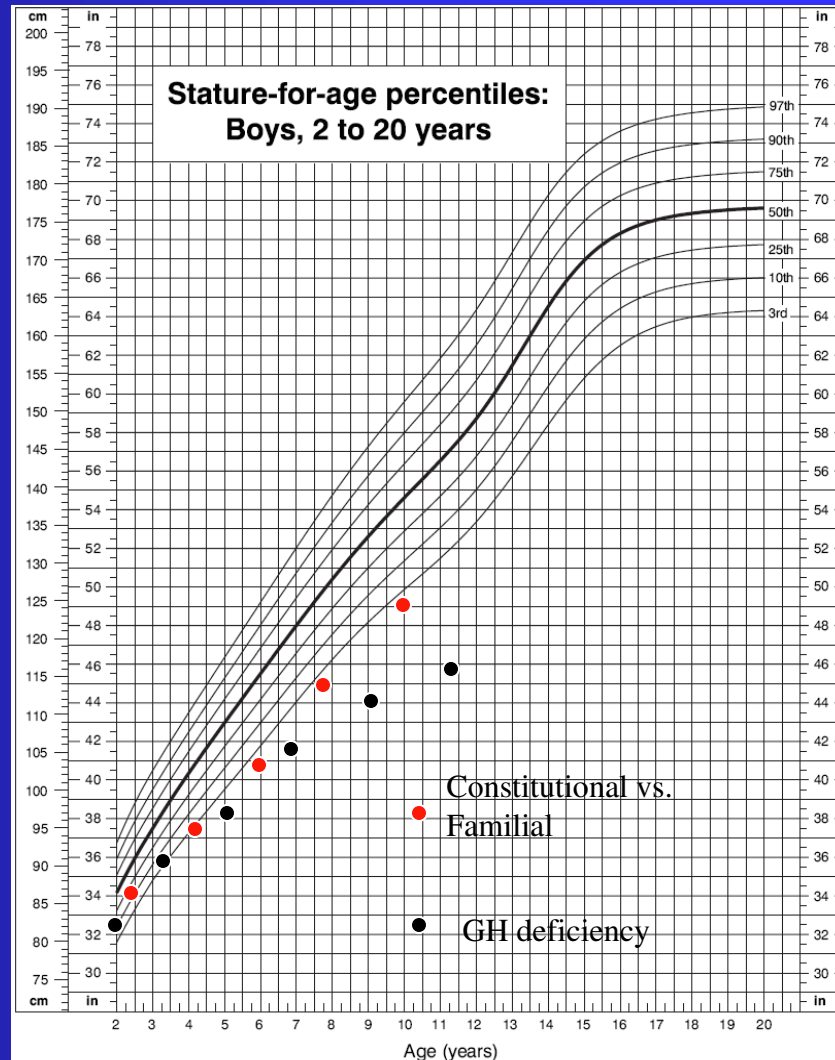
# Endocrine Pattern



# Short Stature: Patterns



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# Endocrine Pattern: DDx

## ■ Hypothyroidism

- ◆ Low Thyroxine (Free T4), High TSH

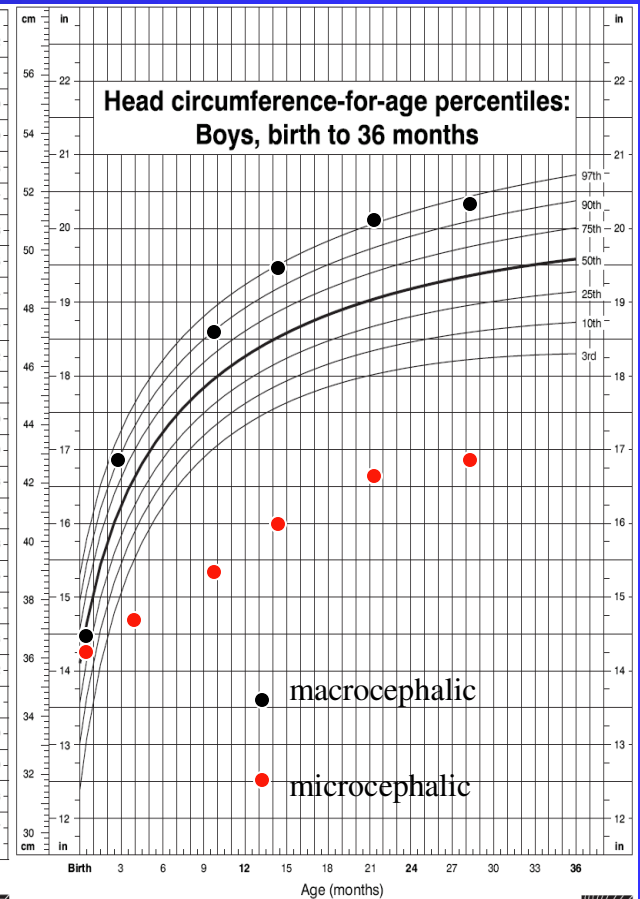
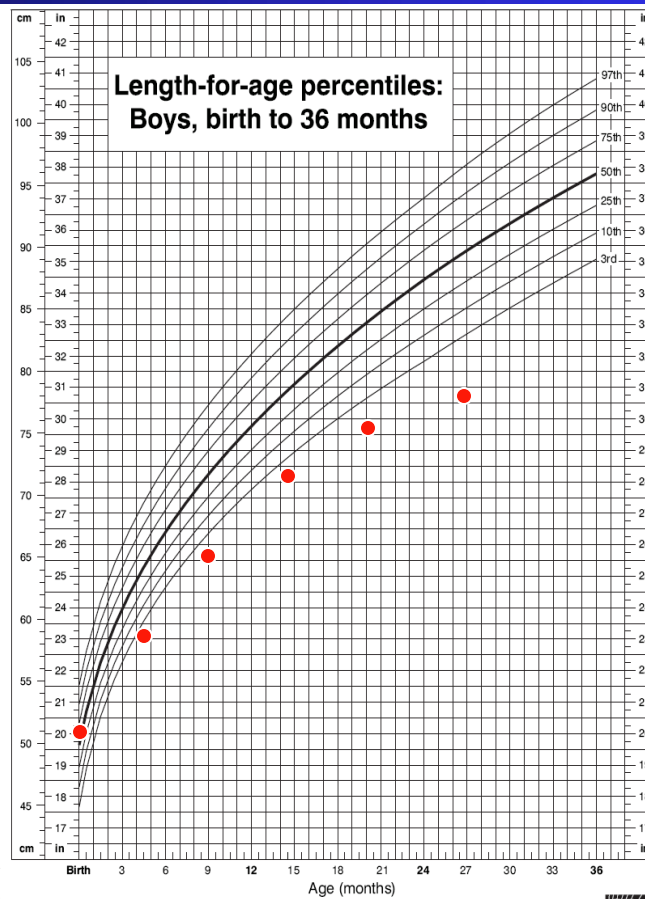
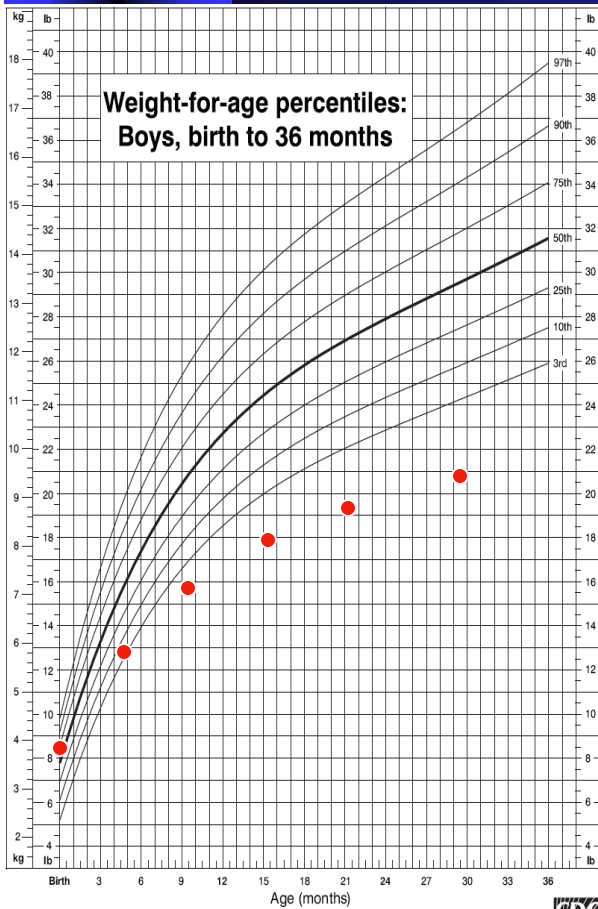
## ■ Growth Hormone deficiency

- ◆ Low Insulin like growth factor (IGF-1)
  - ◆ Unreliable in undernutrition states
- ◆ Low IGF Binding Protein 3 (IGFBP3)

## ■ Hypopituitarism

- ◆ Low cortisol, TSH, glucose, gonadotropins

# Neurogenic Pattern



# Neurogenic Pattern: DDx

## ■ Microcephalic

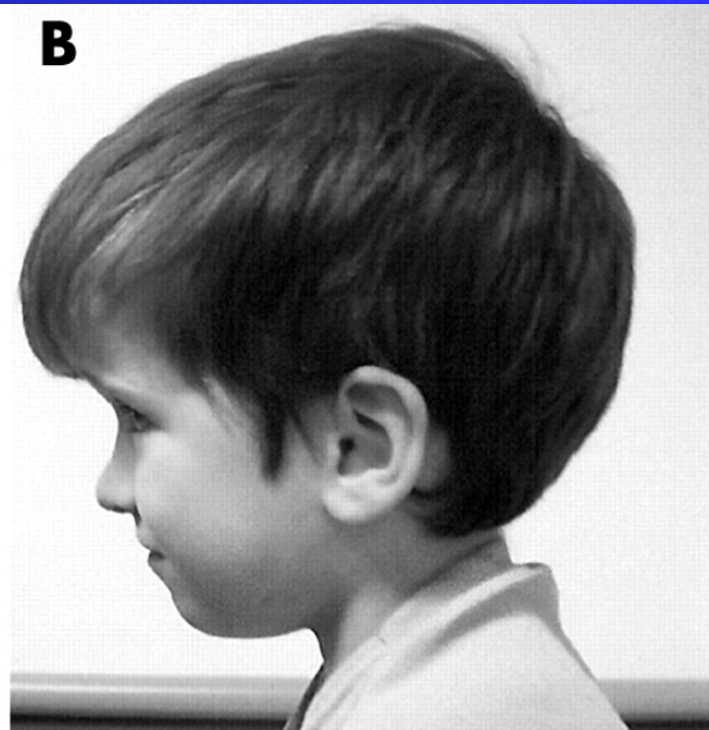
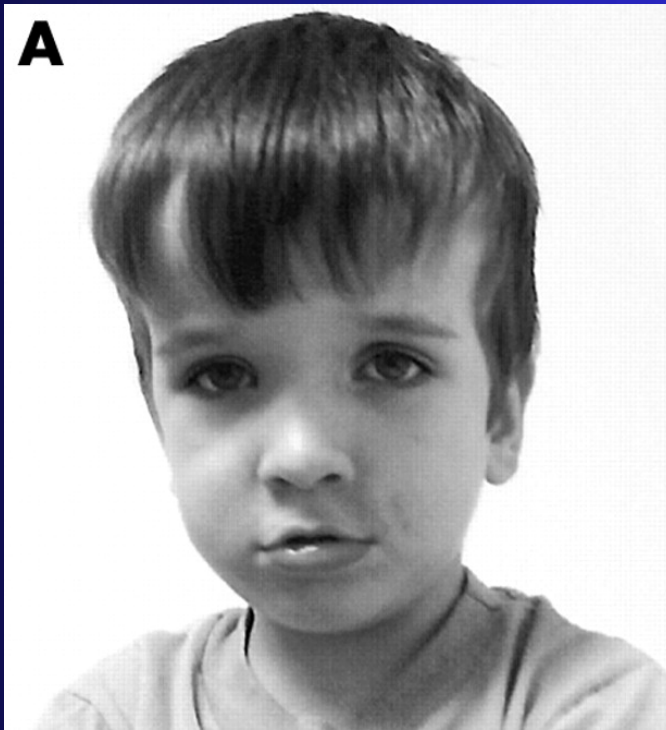
- ◆ Infarction
- ◆ CMV viral infection
- ◆ Embryogenic defect:
  - ◆ neuronal migration
- ◆ Rett syndrome

## ■ Macrocephalic

- ◆ Hydrocephalus
- ◆ Tumor
  - ◆ Brainstem: Diencephalic syndrome
- ◆ Metabolic storage disease
- ◆ Autism



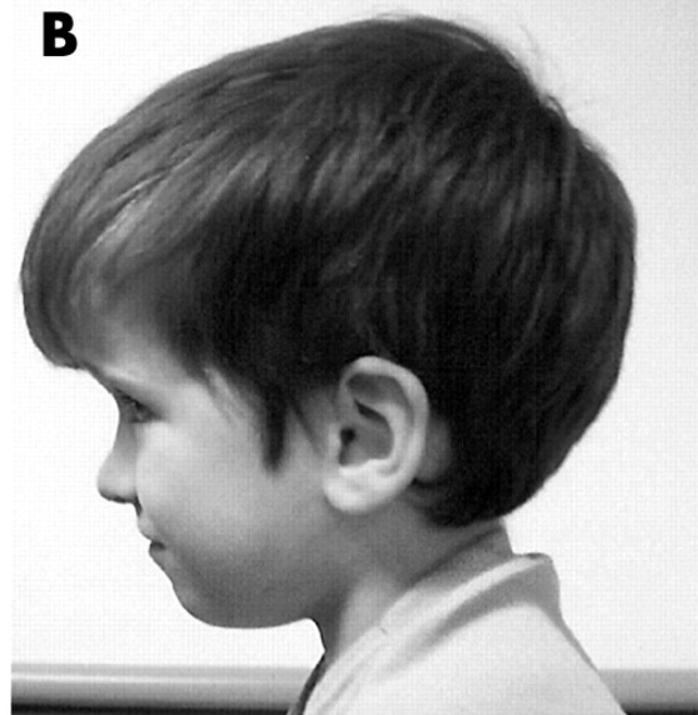


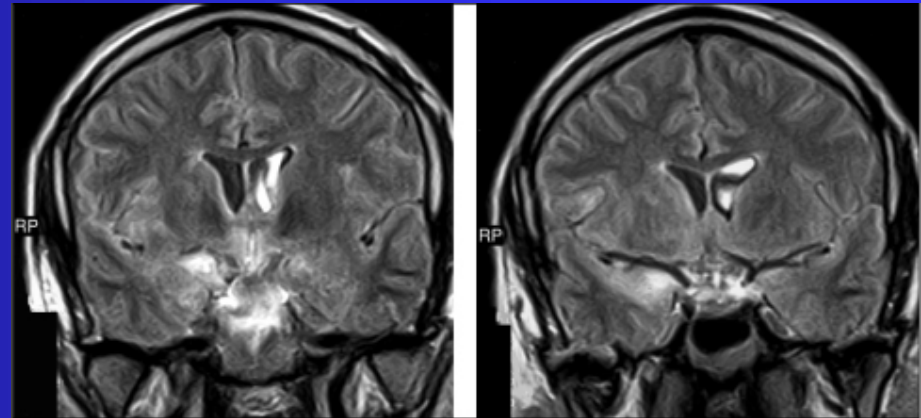




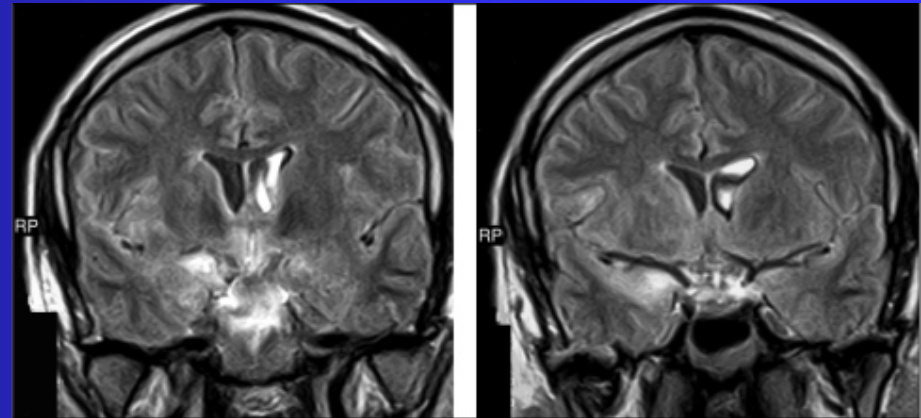
Rett Syndrome

Autism





*Fig 1. MRI images after gadolinium contrast injection: patchy contrast enhanced lesions in the insula and hippocampus in the right and in the hypothalamic-diencephalic region.*



*Fig 1. MRI images after gadolinium contrast injection: patchy contrast enhanced lesions in the insula and hippocampus in the right and in the hypothalamic-diencephalic region.*

## Diencephalic Syndrome

# FTT: Definition

## ■ Static Criteria:

- ◆ Weight for Height  $< 5^{\text{th}}$  %ile
- ◆ Weight  $< 85\%$  median weight for height
- ◆ Triceps skinfold thickness  $< 5$  mm or  $< 5^{\text{th}}$  %ile

## ■ Dynamic Criteria:

- ◆ Subnormal growth velocity:
  - ◆  $< 20$  g/d @ 0-3 months
  - ◆  $< 15$  g/d @ 3-6 months
- ◆ Drop of 2 major centiles

# Diagnostic Approach

- Prenatal/Perinatal medical history
- History of medical/surgical illness
- Diet history
  - ◆ Weaning, Food introduction
  - ◆ Meal Structure: intervals, schedule
- Family History
- Physical Examination
- Strategic laboratories and Radiology

# Diagnostic Evaluation

## ■ History:

- ◆ Maternal Health
- ◆ GA, BW, Perinatal, Infancy, Development, Medical and Surgical illness, interventions
- ◆ Link events to growth history: map on curve
- ◆ Feeding history
  - ◆ Nursing/weaning
  - ◆ Sequence of foods: introduction of solids
  - ◆ Frequency of feeding
  - ◆ Coercive feeding
  - ◆ Parental/infant feeding transactions/communication
- ◆ Psychosocial Problems



# Diagnostic Evaluation

## ■ Physical Examination:

- ◆ Measurements
- ◆ Hygiene
- ◆ Dysmorphisms: craniofacial, skeletal, etc.
- ◆ Epithelial integrity: skin, hair, nails, eyes, mucosa
  - ◆ Edema
  - ◆ Micronutrient deficiency
- ◆ Body composition: fat and muscle stores
- ◆ Cardiorespiratory status
- ◆ Neurodevelopmental status
  - ◆ Dysphagia
- ◆ Functional status: tone, responses, strength
- ◆ Child-Parent and Child-Examiner interactions

# Digital Clubbing



# Digital Clubbing



Cystic Fibrosis  
Celiac Sprue  
Cyanotic Heart Disease  
Cirrhosis  
Crohn Disease  
COPD  
Candidiasis Mucocutaneous  
Congenital



# Acrodermatitis enteropathica

Zinc deficiency



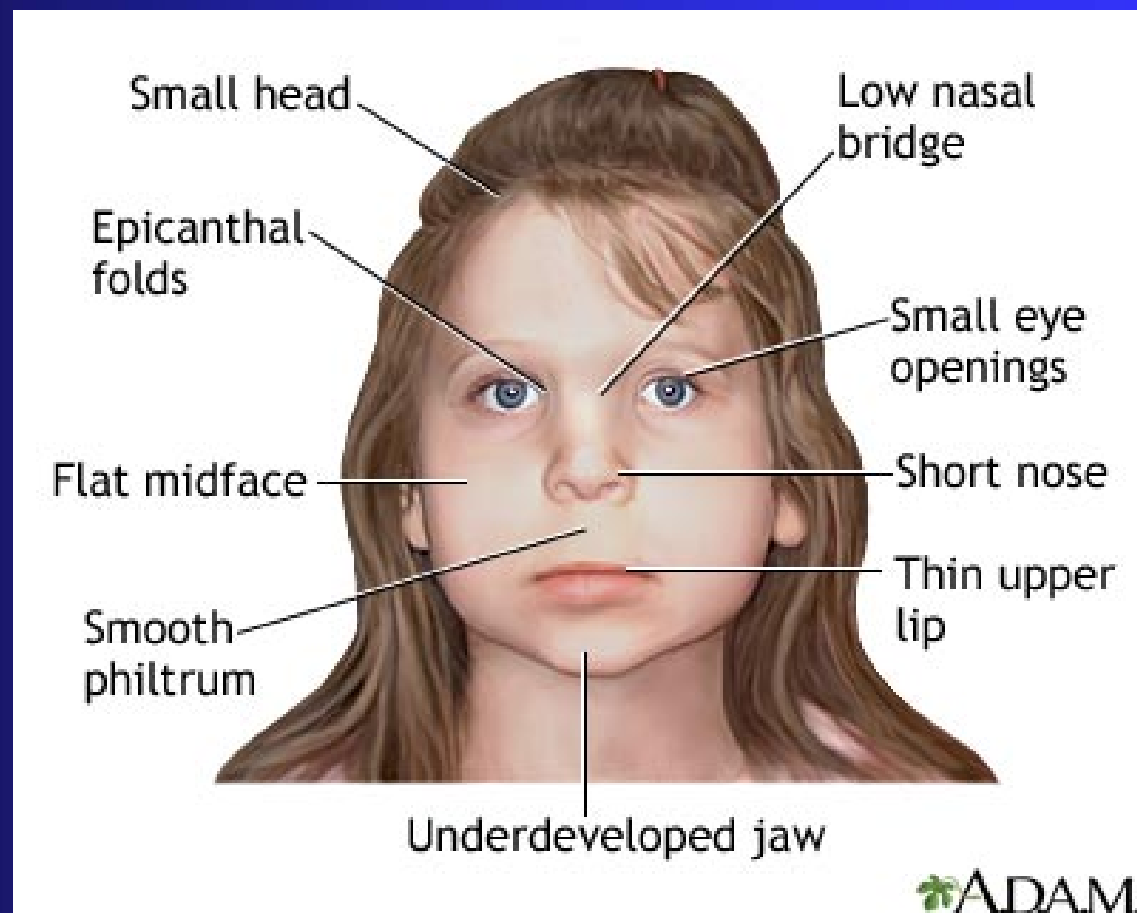


Noonan



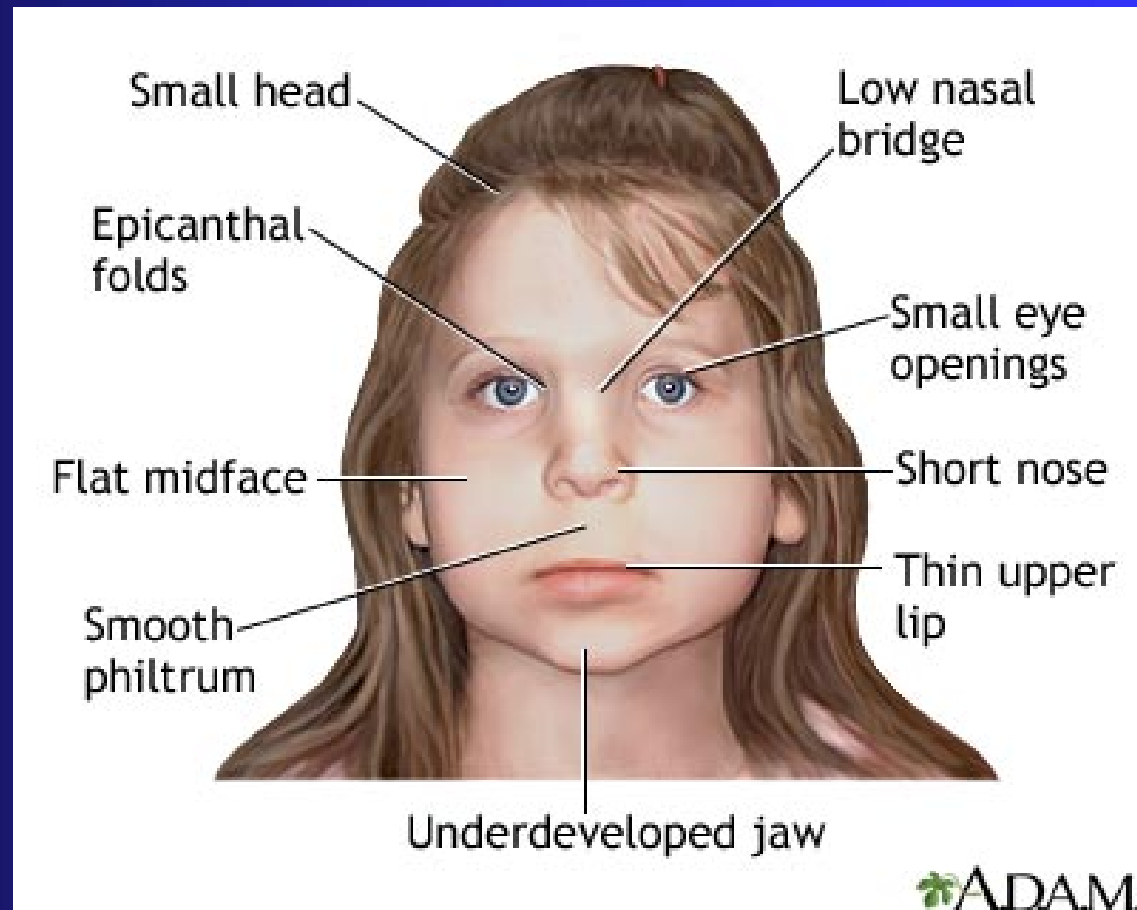
Turner

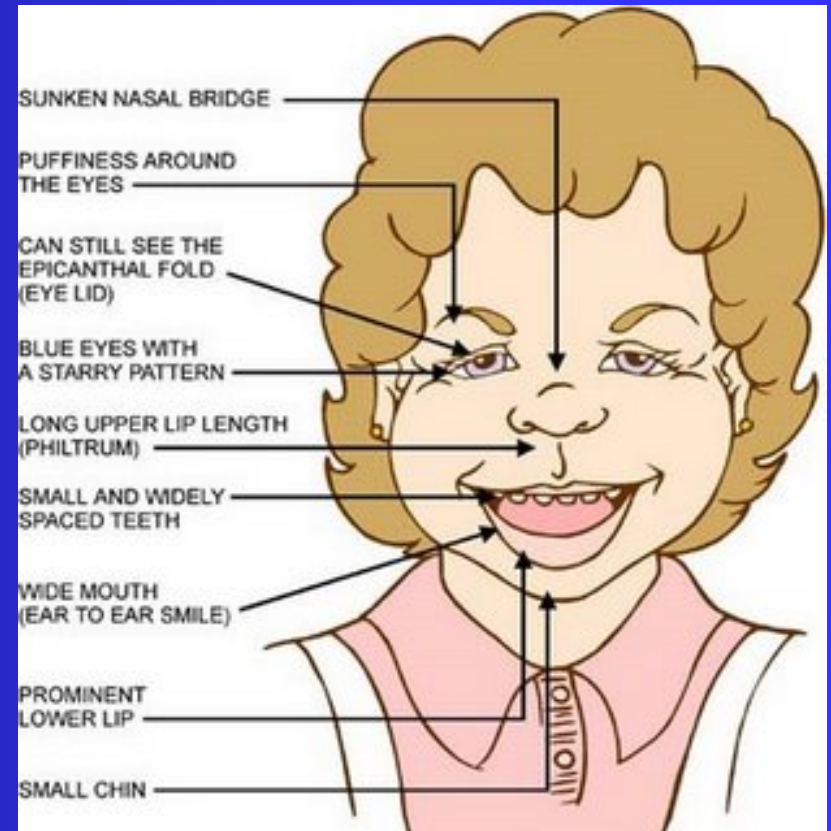




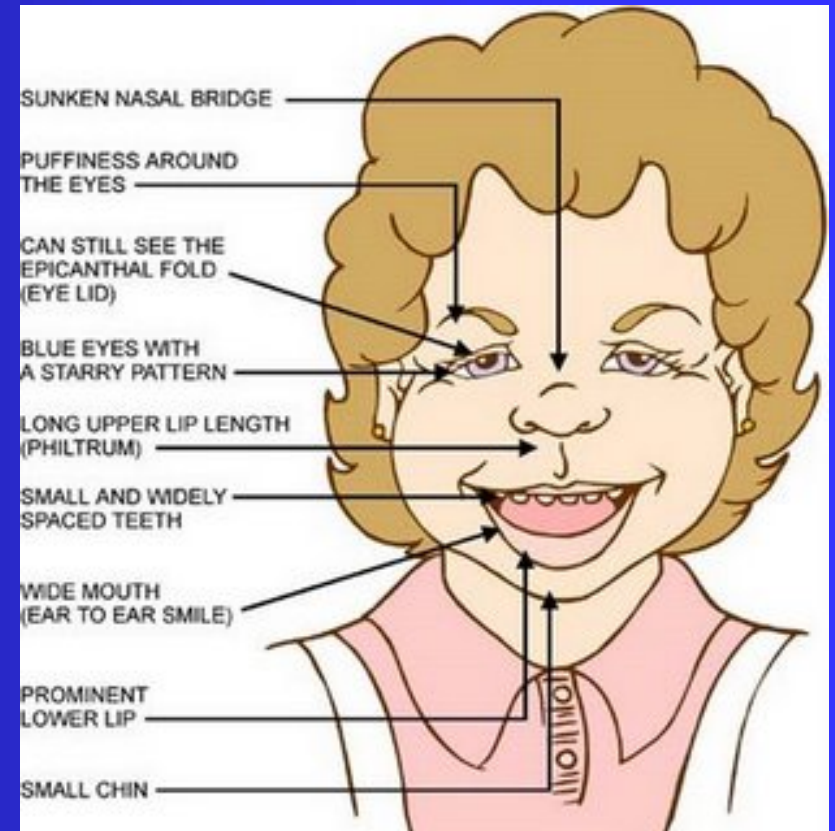


# Fetal Alcohol





# Williams



# Acute vs Chronic

## ■ Acute Undernutrition-- “wasting”:

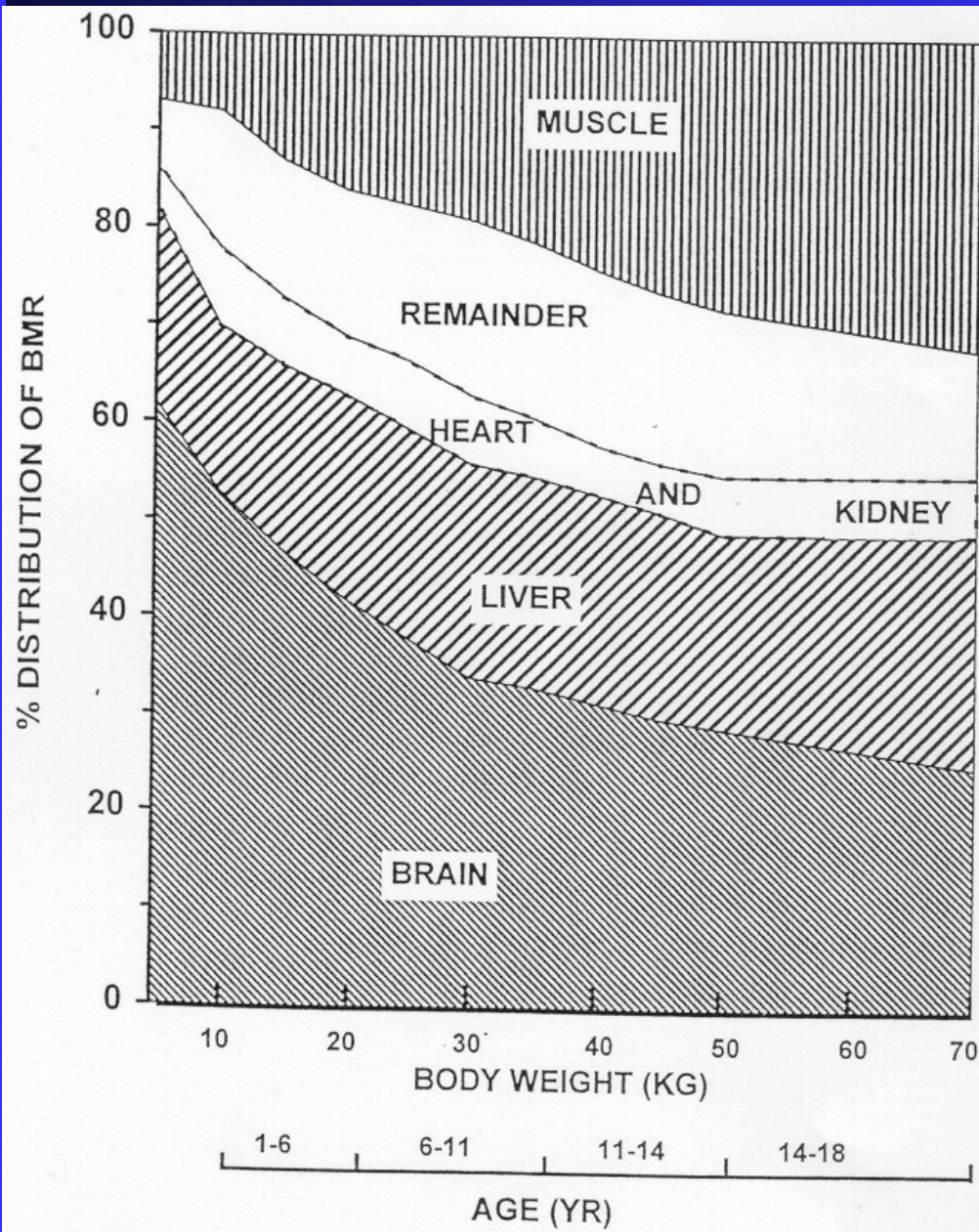
- ◆ Low weight for height or low BMI
- ◆ “wasting” of fat and muscle mass
- ◆ Prelude to stunting
- ◆ Constitutional leanness

## ■ Chronic Undernutrition– “stunting”:

- ◆ Low height for age
- ◆ Normalized weight for height and BMI
  - ◆ Consider constitutional growth delay
  - ◆ Consider Endocrinopathy: hypothyroidism, hypopituitarism

# Cranial growth

- Reflects brain growth/volume
- Brain major metabolic demand in infants
- Relatively preserved in undernutrition
  - ◆ Early infancy: may follow weight deceleration
  - ◆ Low relative to Length:
    - ◆ 1° neurologic etiology
    - ◆ Intrauterine Insult
    - ◆ Metabolic



## Composition of Metabolic Demand

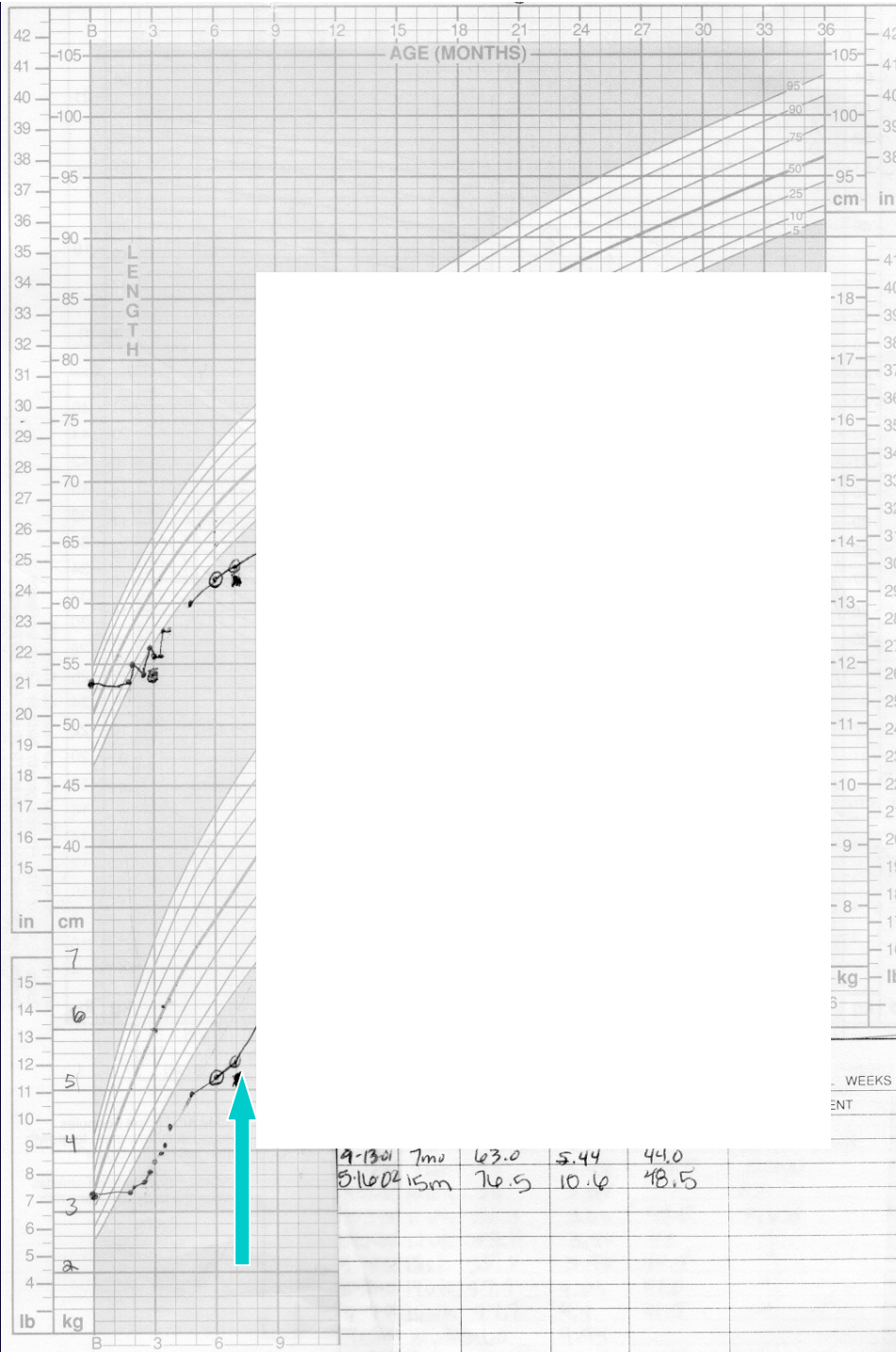
$$\text{TDEE} = [1.4 \text{ to } 1.6] \times \text{BMR}$$

$$\% \text{BMR} / 1.5 = \% \text{TDEE}$$

$$60\% \text{ BMR} = 45\% \text{ TDEE}$$

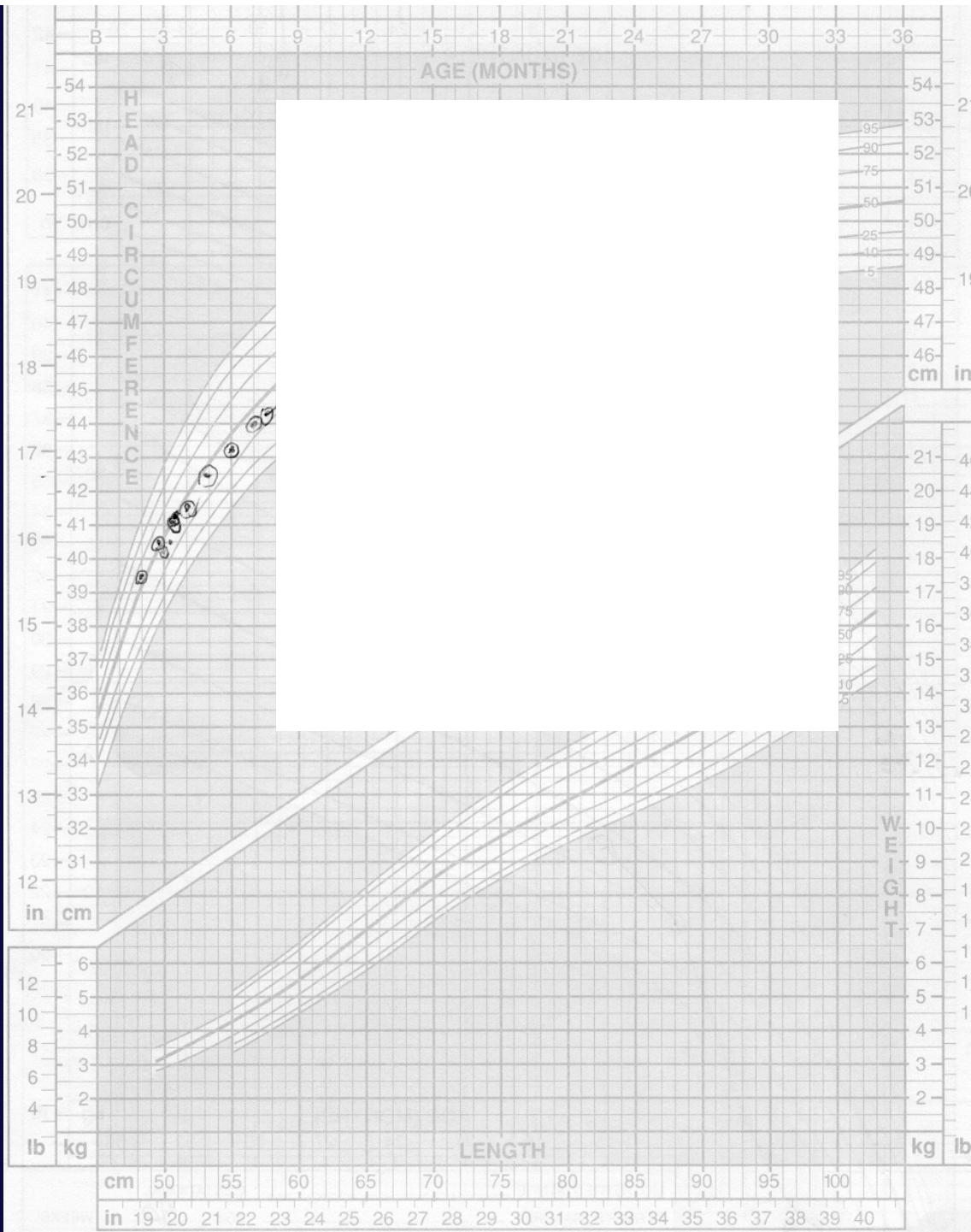
$$40\% \text{ BMR} = 27\% \text{ TDEE}$$

HOLLIDAY, M.A.: Body composition and energy needs during growth. In: Human Growth: A Comprehensive Treatise, 2nd ed., pp. 101-117, F. FALKNER, J.M. TANNER (Eds.), Plenum Press, New York, NY, 1986.



7 month male with early growth arrest attributed to nursing insufficiency, followed by recovery.

His growth worsened after 5 months age when solids were introduced, despite parental efforts to feed him every 1-2 hours.





# Laboratory

- Directed by History, Validated by Exam, Conditioned by Experience
- Otherwise: reserve for failure to respond to nutritional/behavioral/environmental intervention
- CBC/smear, Urinalysis, Sweat Chloride, Celiac serology, Stool parasites, FEP-Pb, quantitative IgA, Electrolytes-BUN-Creatinine, zinc/alkaline phosphatase, TSH

# Problem with Disease Model: -the hospital FTT workup

- Improbable or Bass-ackwards:
  - ◆ Minority with discernable relevant pathology
- Expensive
- Distraction of medicalization
- Morbidity of testing
- Hospital artifact
  - ◆ Social and family disruption
  - ◆ Patient out of problem context
  - ◆ Nosocomial hazards

# Interventional Strategy

- Schedule Meals q 3-4 hours:
  - ◆ Establish and enhance endogenous rhythms of hunger/thirst followed by satiety
  - ◆ Eliminate between meal grazing/sipping
  - ◆ Trust survival physiology
- Provide, do not Coerce:
  - ◆ respect autonomy and survival instinct
  - ◆ avoid defensiveness/aversion
- Harness thirst drive:
  - ◆ Substitute formula/milks for juice, water, etc
  - ◆ Liquids follow solids
- Increase nutrient density of foods offered

# Caloric Requirements

- Use median (“ideal”) weight for height
  - ◆ Fat is metabolically inert
  - ◆ Brain > Visceral Organs > Muscle consume metabolic energy
  - ◆ Consider using weight for cranial(OFC) age if head relatively large compared to length
- Multiply x RDA kcal/kg for wt-age or ht-age

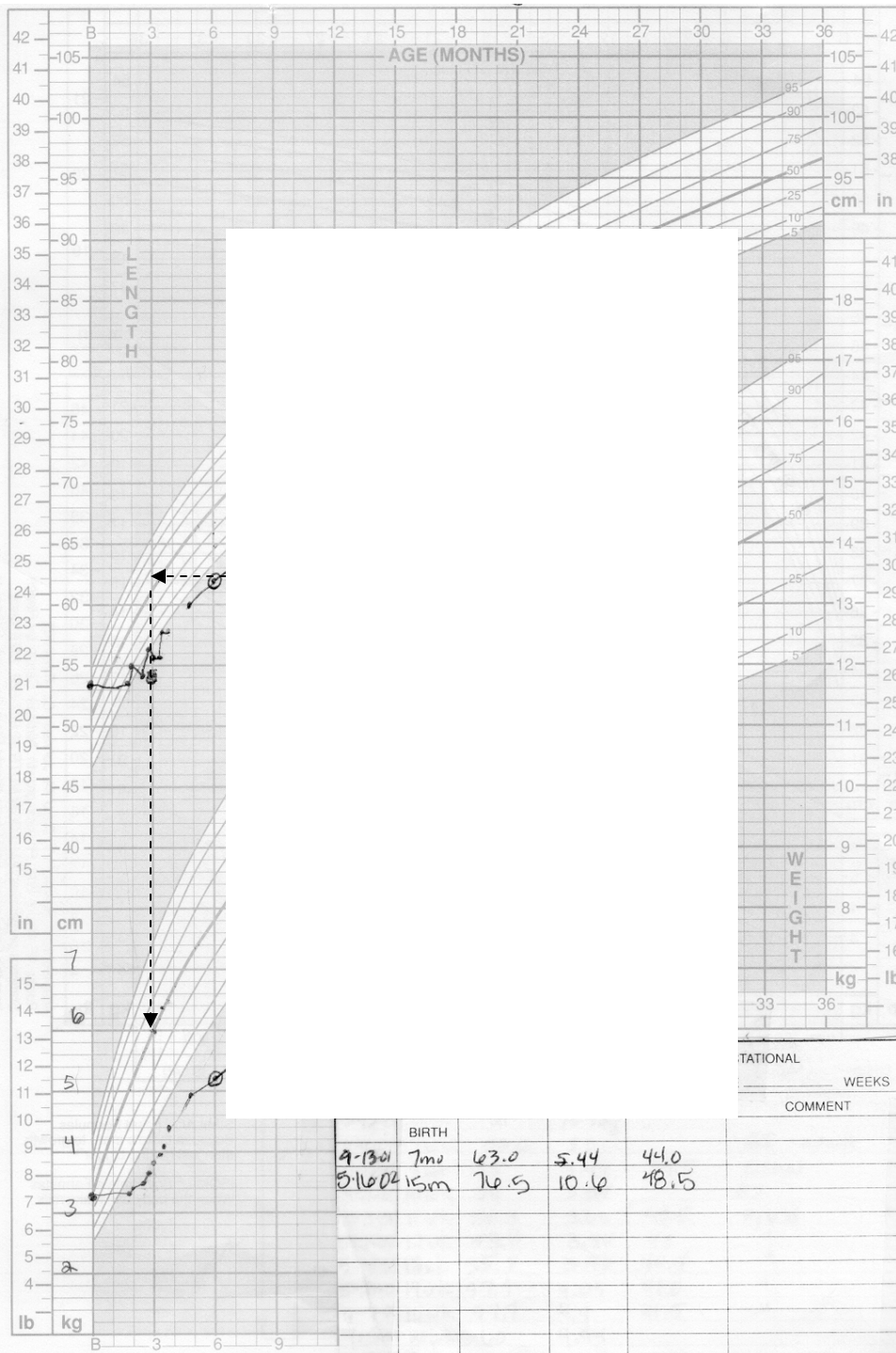
# Estimated Energy Needs (RDA)

Age (years):

- 0-1
- 1-7
- 7-12
- 12-18
- >18

Kcal/kg body weight:

- 90-120
- 75-90
- 60-75
- 30-60
- 25-30



Actual weight: 5.2 kg

6 kg is median weight for height age:

[ $5.2 / 6 = 87\%$  expected wt for length-age]

5.2 kg is 87% of 6 kg weight for length-age

Calorie goal:  $100 \text{ kcal/kg} \times 6 \text{ kg} = 600 \text{ kcal/day}$

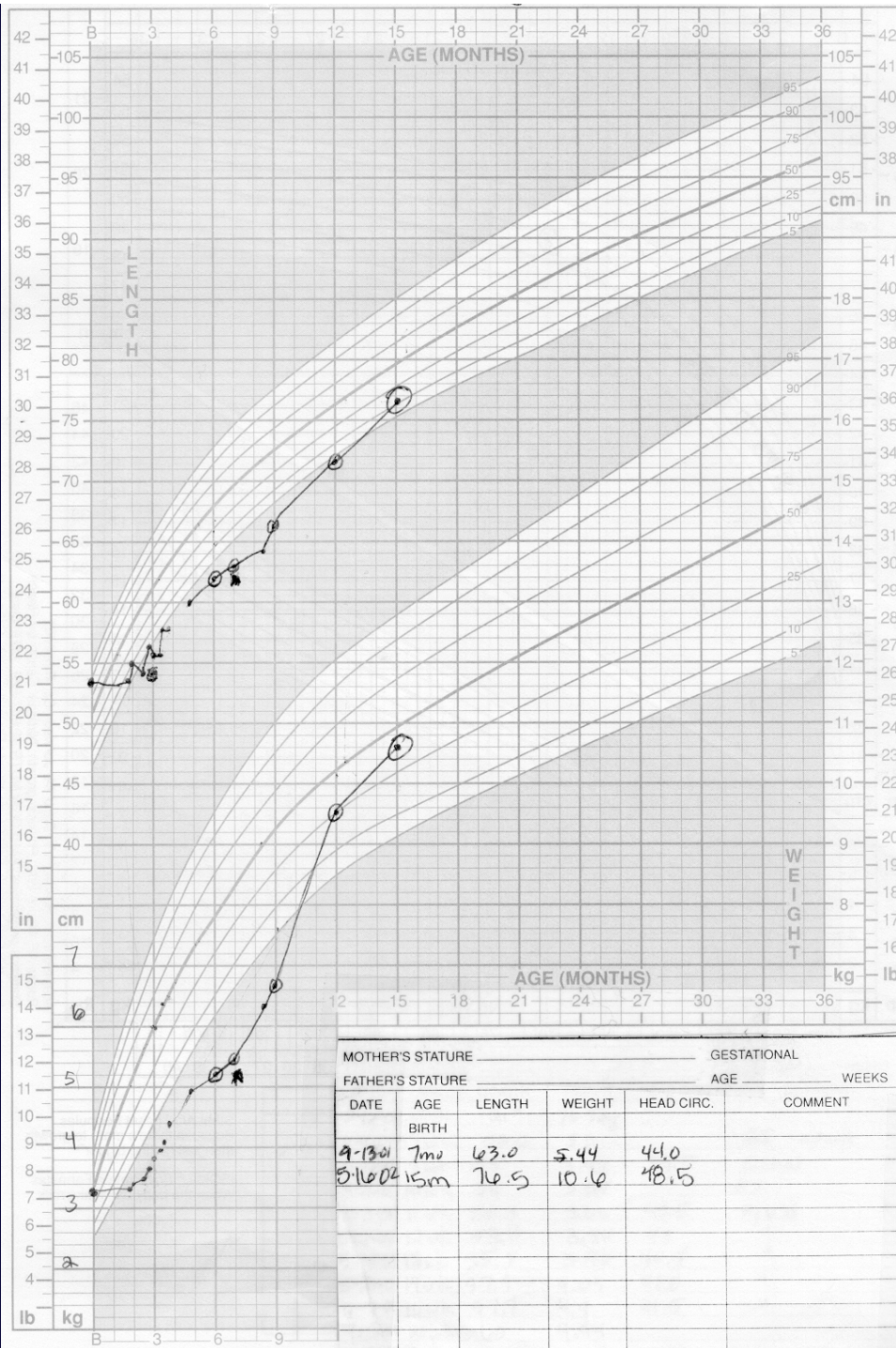
For 24 kcal/oz formula (0.8 kcal/ml):

$600 \text{ kcal} / 0.8 \text{ kcal/ml} = 750 \text{ ml}$

$750 \text{ ml} / 30 \text{ ml/oz} = 25 \text{ oz}$

Kcal/kg actual weight:

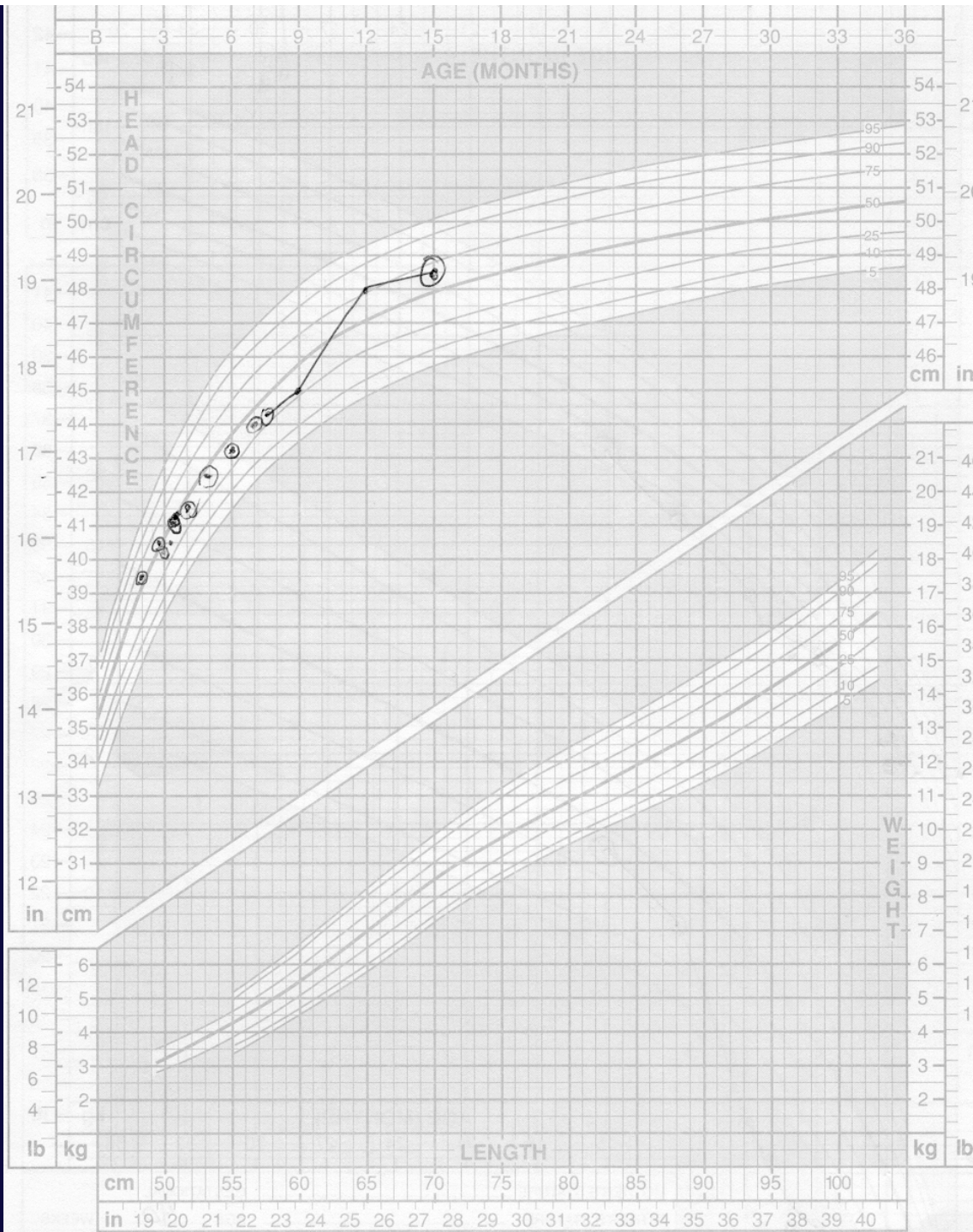
$600 \text{ kcal} / 5.2 \text{ kg} = 120 \text{ kcal/kg/day}$



7 month male with early growth arrest attributed to nursing insufficiency.

His growth worsened after 5 months age when solids were introduced, despite parental efforts to feed him every 1-2 hours.

*He improved in wt, Then length after 7 months age when feeding schedule and strategies began.*



Late cranial  
growth response



# Other Interventions

- Specialized formulas
- Motility/Acid suppression Rx
- Cyproheptadine
- Zinc
- Oxygen
- Naso-gastric feeding
- Naso-jejunal feeding
- Percutaneous endoscopic gastrostomy

# Accommodation /Refeeding Risks

- Chronically malnourished patient is adapted or *accommodated* to the undernourished steady state.
  - ◆ Reduced metabolic rate, cardiac demand
  - ◆ Depleted intracellular ions: K, P, Ca, Mg
  - ◆ Depleted fat and muscle stores, including myocardium
- Providing nutrients increases metabolic demand:
  - ◆ Increased cardiac demand/stress
    - ◆ Congestive heart failure, edema
  - ◆ Intracellular influx of P, K, Mg, Ca;
  - ◆ P bound in ATP, intermediary metabolism.
    - ◆ Risk of hypophosphatemia, hypoK, hypoMg, hypoCa
    - ◆ Risk of prolonged QTc and ventricular arrhythmia on ECG

# Indications for Hospitalization

- Impaired homeostasis:
  - ◆ dehydration, hemodynamic or electrolyte disturbance, altered neurologic status, acute weight loss
- Complications/comorbidity:
  - ◆ infection, respiratory distress, CNS changes
- Negligence/noncompliance/abuse
- Unsuccessful outpatient intervention:
  - ◆ No weight gain x 2-4 weeks
  - ◆ Sub-optimal gain x 2 months

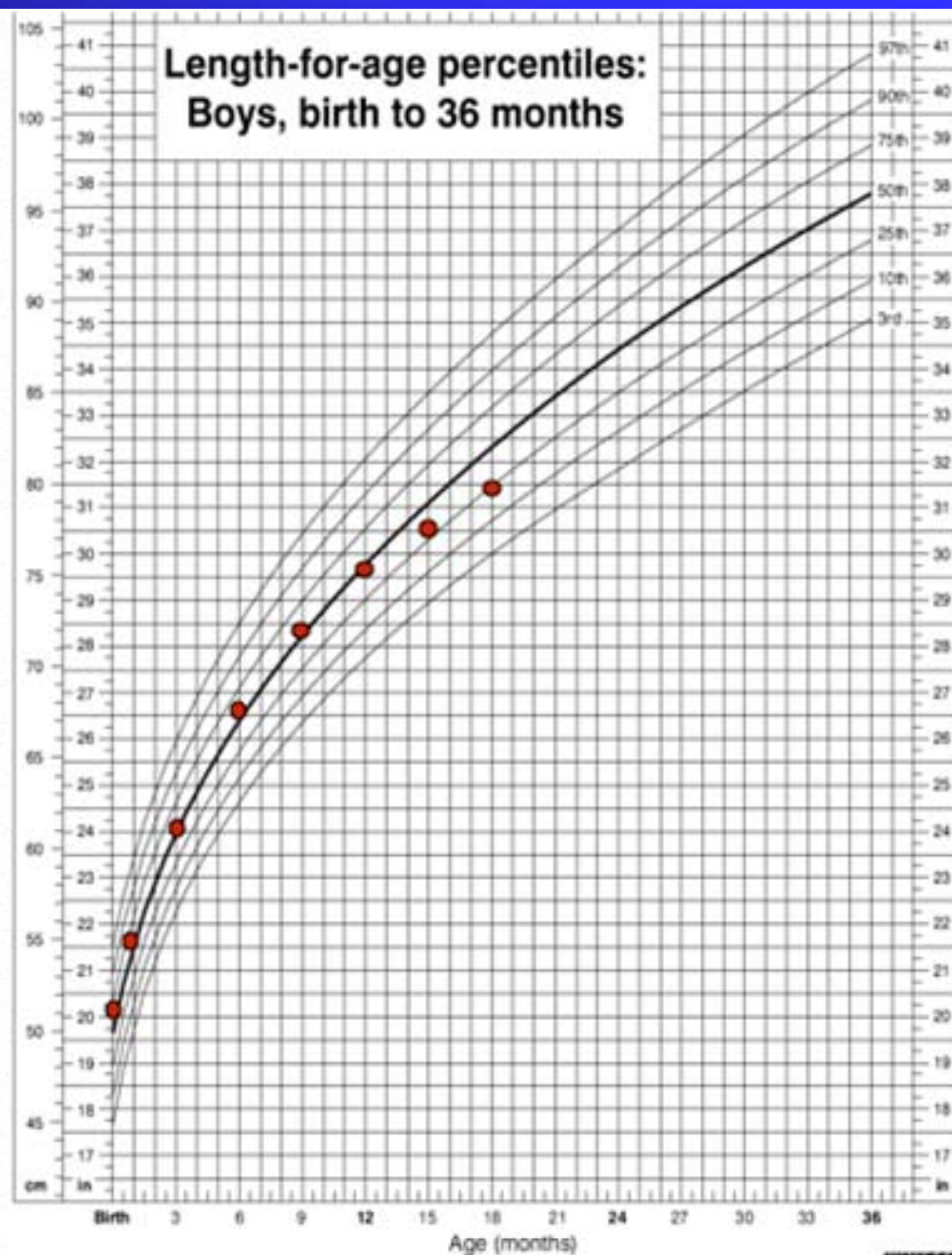
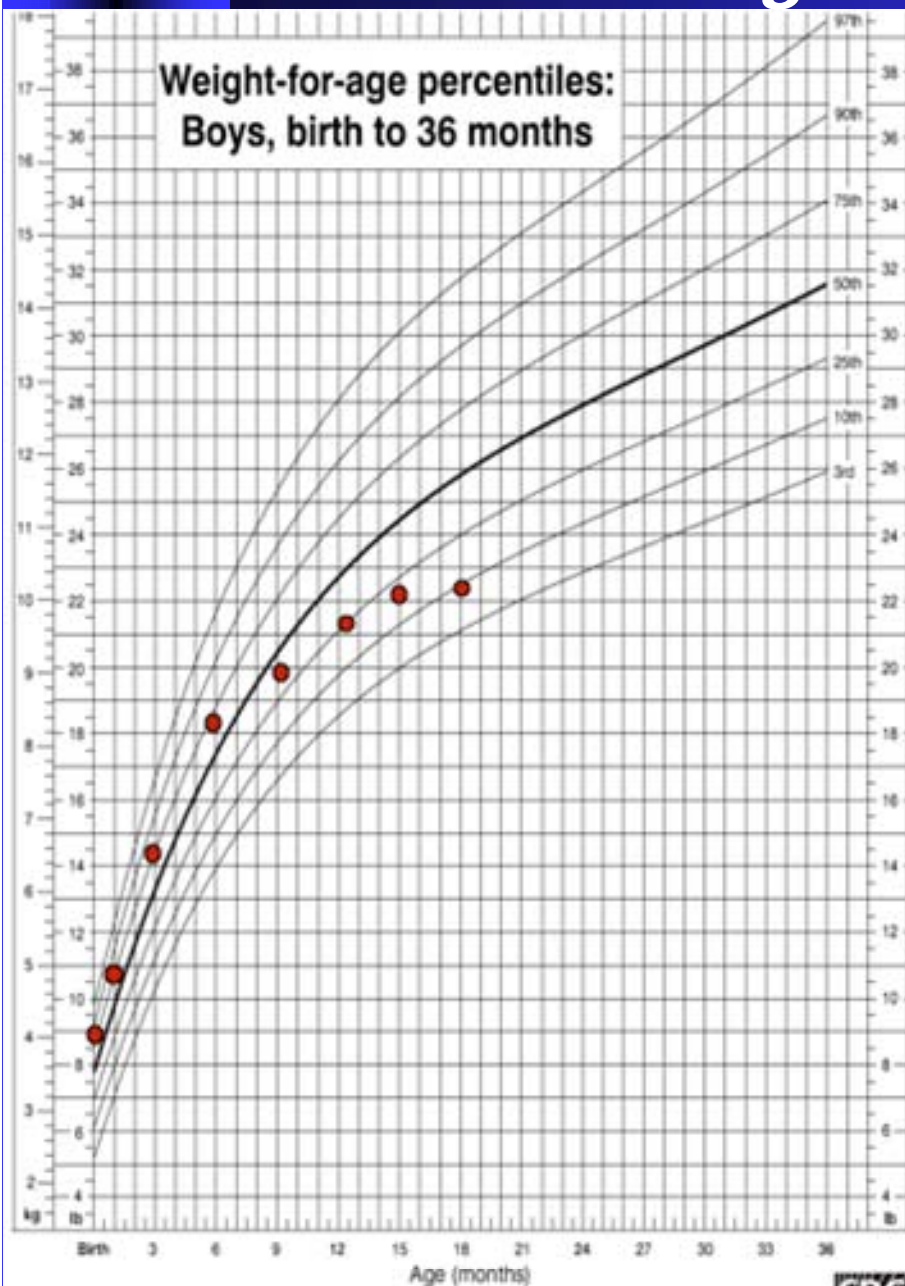
# Indications for Discharge

- Restored Homeostasis
- Resolving Complications
- Established support/monitoring system
- Restored weight gain or anticipated weight gain in outpatient monitored context



That  
happy,  
healthy  
face  
recognized all  
the over world.

# Failing to Thrive



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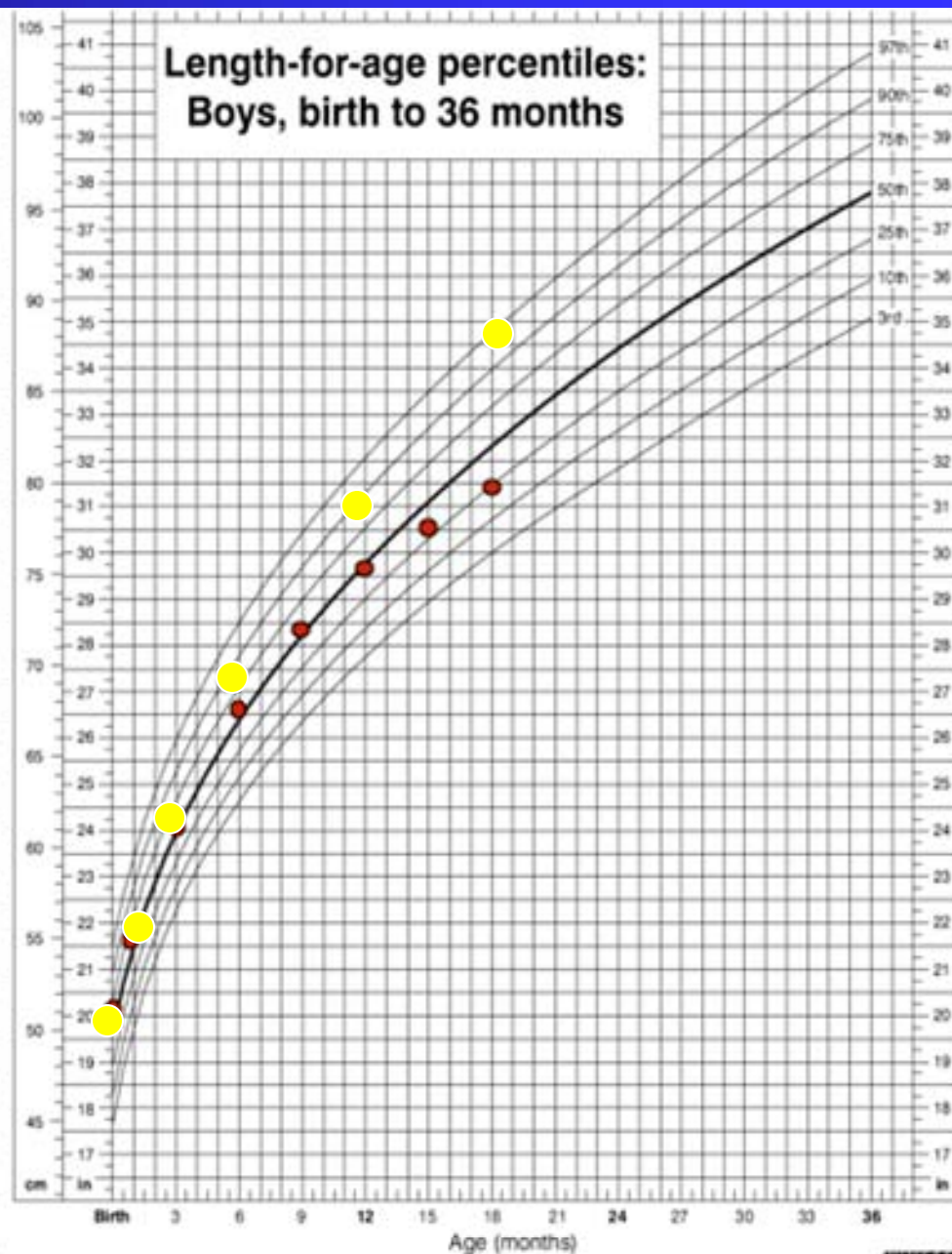
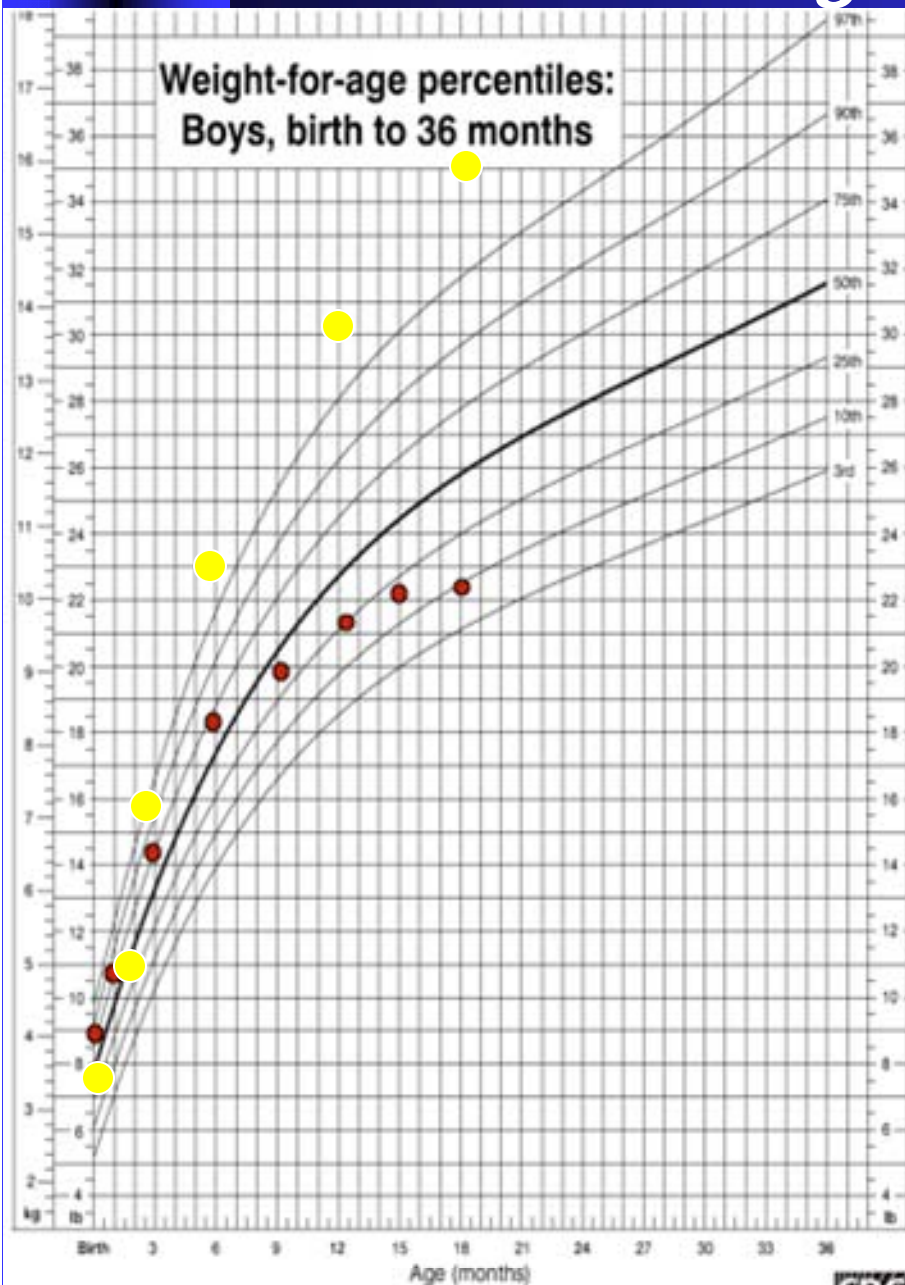
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SOURCE: Developed by the National Center for Health Statistics in collaboration with



# Thriving to Fail ?



Published May 30, 2000.

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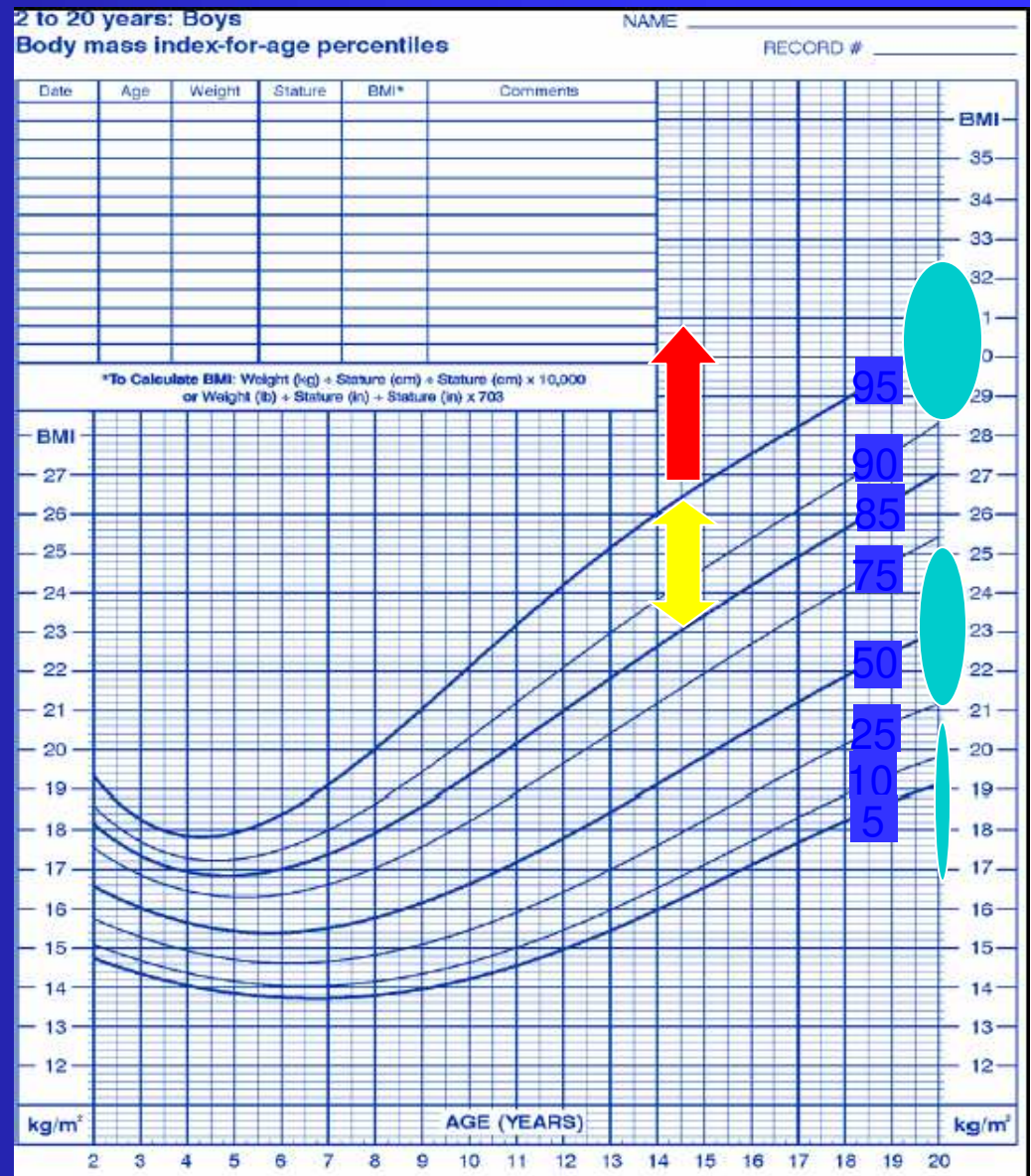
# Body Mass Index [BMI]: 2 years to 20 years

$$\text{BMI} = \text{weight (kg)} / \text{height}^2 \text{ (m}^2\text{)}$$

**Extremely Obese:** BMI  $\geq$ 99<sup>th</sup> %ile

**Obese:** BMI 95<sup>th</sup> to <99<sup>th</sup> %ile

**Overweight:** BMI 85<sup>th</sup> to <95<sup>th</sup> %ile





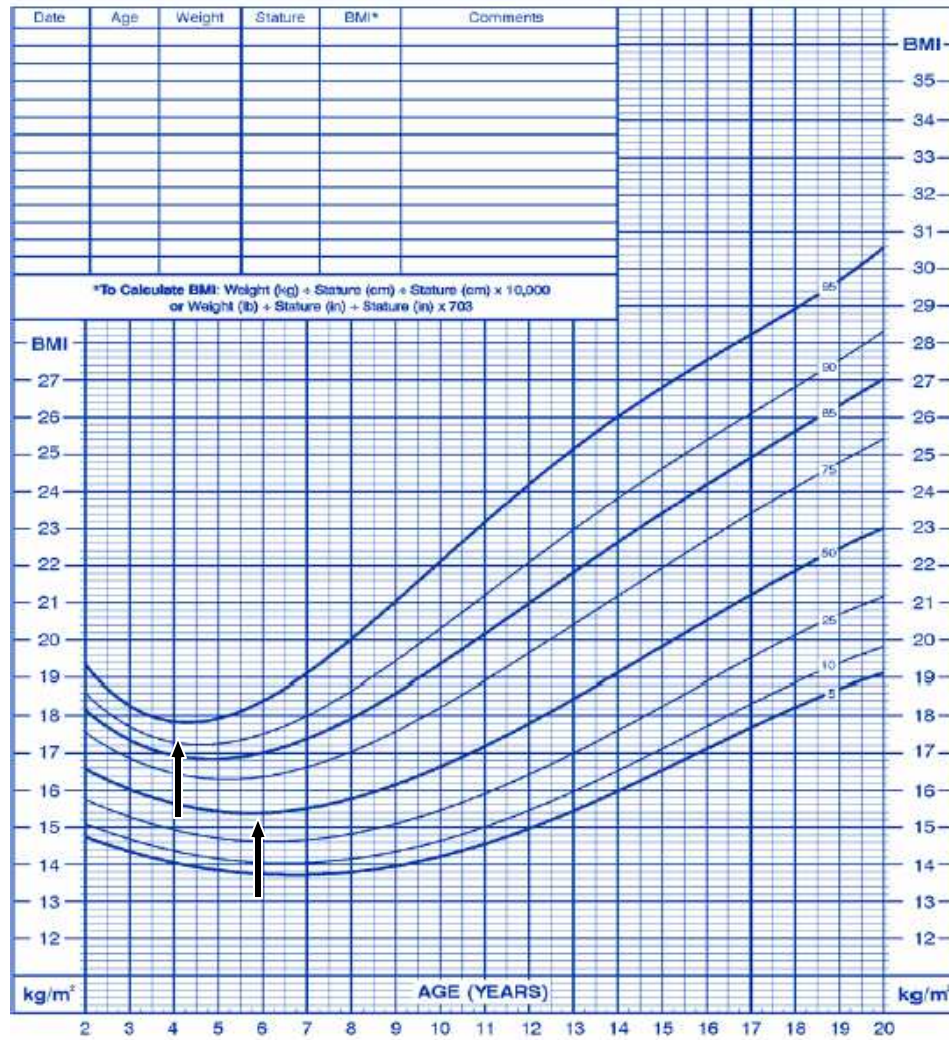
# Adiposity (Fatness) Rebound

2 to 20 years: Boys

Body mass index-for-age percentiles

NAME \_\_\_\_\_

RECORD # \_\_\_\_\_



Published May 30, 2000 (modified 10/16/00).

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.edc.gov/growthcharts>



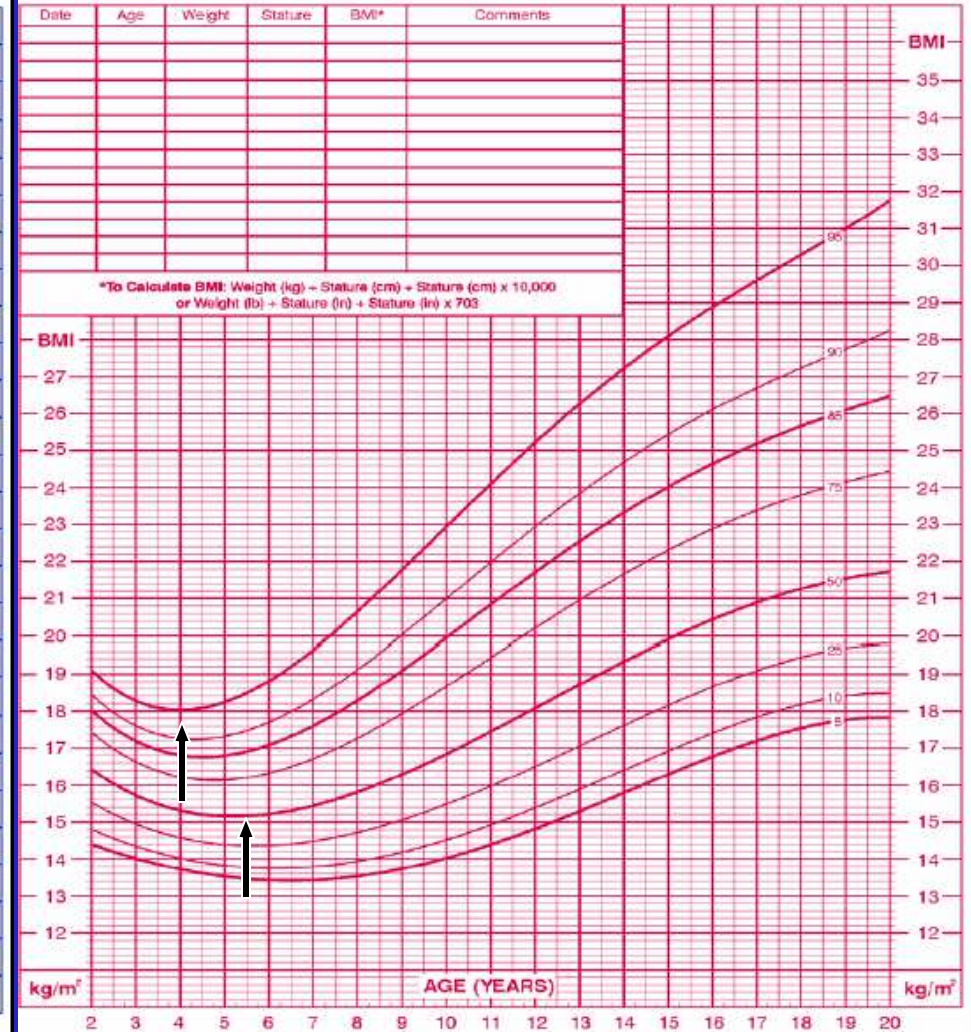
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2 to 20 years: Girls

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# To Over-Thrive

- *Rapid weight gain* before age 4 months is associated with overweight at 7 years.

Stettler et al Pediatrics 2002;109:194-9

- Correlation between rate of weight gain in infant males and fatness at 10.5 years

Melbin and Vuille Br J Prev Soc Med 1976;30:239-43

- AGA infants with rapid weight gain were taller and fatter at 9 years of age.

Cameron et al. Obes Res 2003;11:457-60

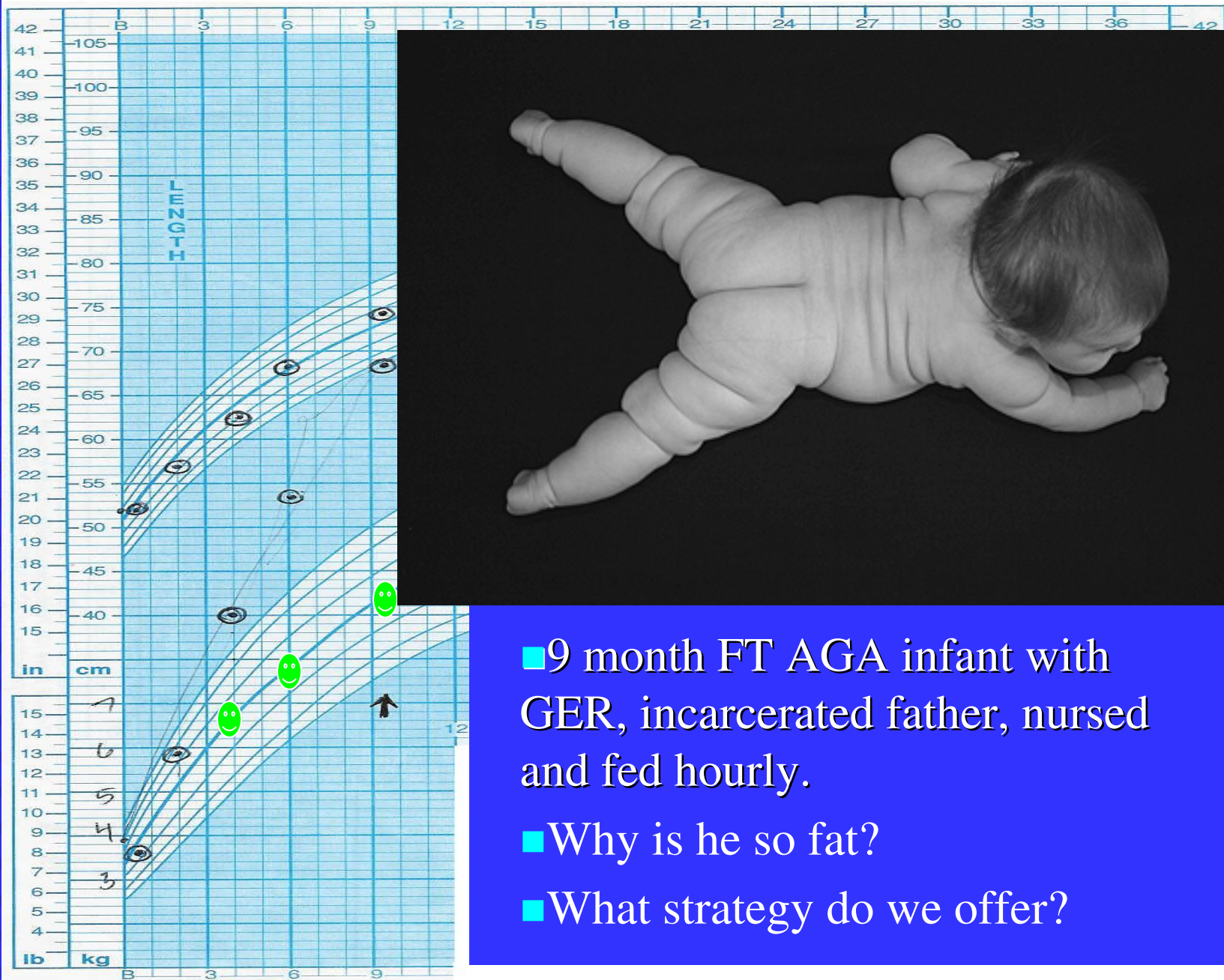
# To Over-Thrive

- *Adiposity Rebound* in BMI < 5 yrs related to increased adulthood BMI of 4-5 kg/m<sup>2</sup>.

Freedman et al. Int J Obes Relat Metab Disord. 2001;25:543-9

# Undernutrition → Overnutrition: Metabolic Programming?

- Smaller(IUGR) FT infants with catch-up growth before age 2 yrs were taller and fatter at 5 years of age. Ong et al. BMJ 2000;320: 967-71
- Low rate of gain in infancy AND/OR rapid weight gain > 12 months associated with increased coronary disease risk. Eriksson et al BMJ 2001; 323:572-3



- 9 month FT AGA infant with GER, incarcerated father, nursed and fed hourly.
- Why is he so fat?
- What strategy do we offer?

# Beyond FTT: Thriving to Fail

- Epidemic Obesity and associated morbidity
- Infantile antecedents of adult Obesity
- Interest in early recognition
- Symmetry with diagnosis of FTT
- Observation: Threshold for referral for overweight greater than that for underweight children.
- Miller LA et al: J Pediatr 2002;140:121-4

# Can Failure to Thrive Lead to Obesity?

- Prader-Willi paradigm
- Control rate of catch-up weight gain.
- Longer term monitoring of recovered FTT
- Intake restriction of over-thriving infants
- The paradox of grazing:
  - ◆ Impaired appetite for meals: faltering
  - ◆ Chronic insulinemia: obesigenic

# Recognize Early Signs:

## *Thriving to Fail*

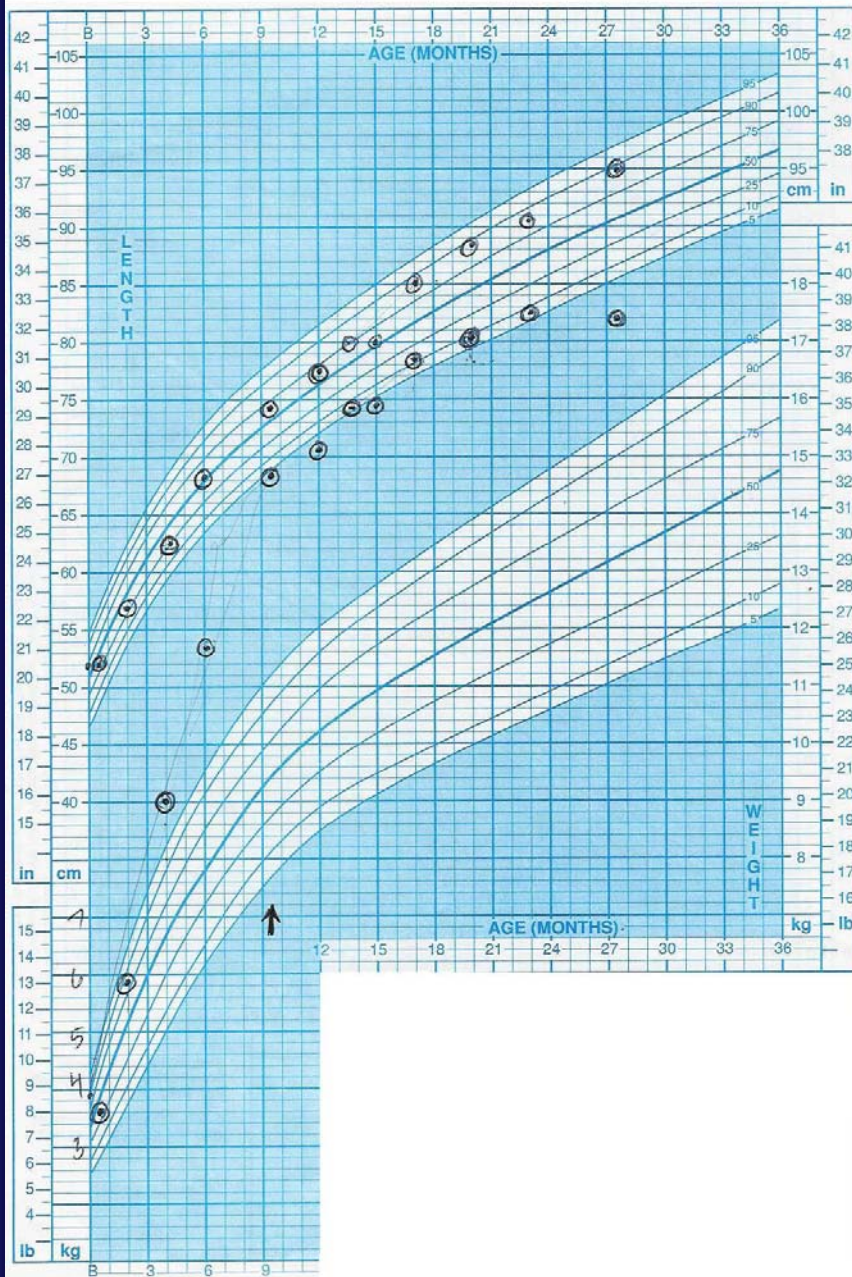
- **Rapid Weight Gain in early childhood = High Risk for Obesity in later life**
- **Designate overweight as Weight-for-Length greater than 95th %ile [WHO BMI curves exist for < 2 years.]**
- **Weight gain crossing 2 major percentiles (1 standard deviation) = up to 5 times increased risk of later overweight.**
- **Early or infantile obesity more likely associated with genetic or endocrine obesity syndromes.**

Baird J, et al. BMJ 2005, 12:331(7525):1145



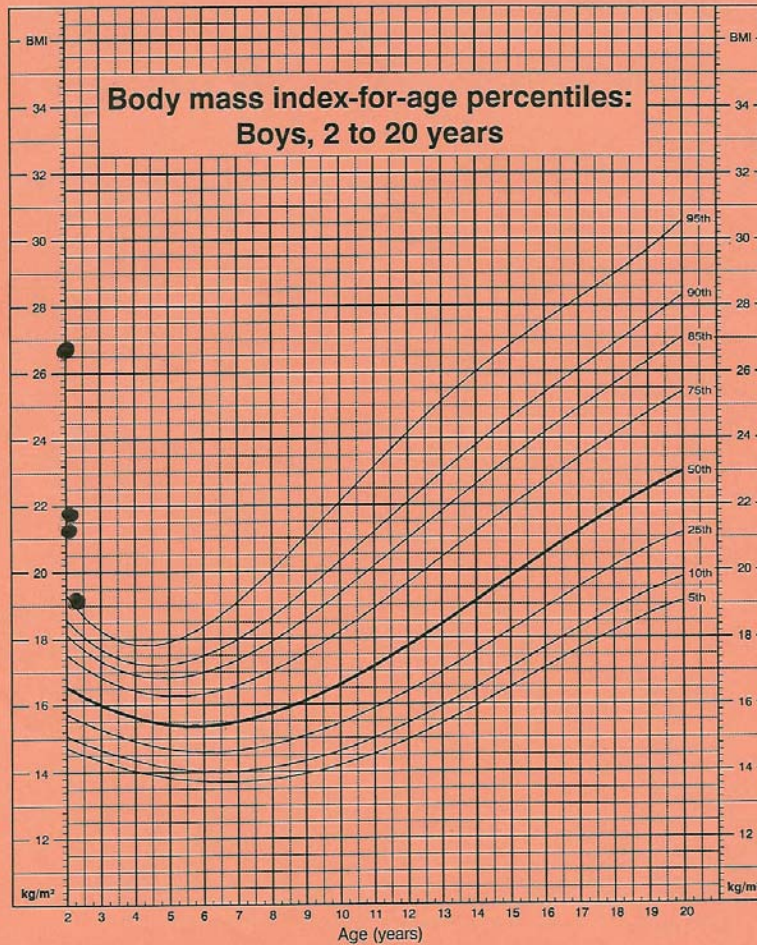
# Proposed Strategy

- Identify over-thriving infants/toddlers
- Schedule meals with 3-4 hour intervals
- No grazing, nibbling, sipping between
- Control Carbohydrates as well as Fats:
  - ◆ portion control, complex vs low glycemic foods and preparation;
  - ◆ eliminate fructose/limit sucrose
- Physical Activity: limit screen time
- Family Involvement/Education



- 9 month FT AGA infant with GER, incarcerated father, nursed and fed hourly.
- Response to feeding strategies; mom also lost weight.

CDC Growth Charts: United States



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).



- Body mass index response to slowed rate of weight gain.

