

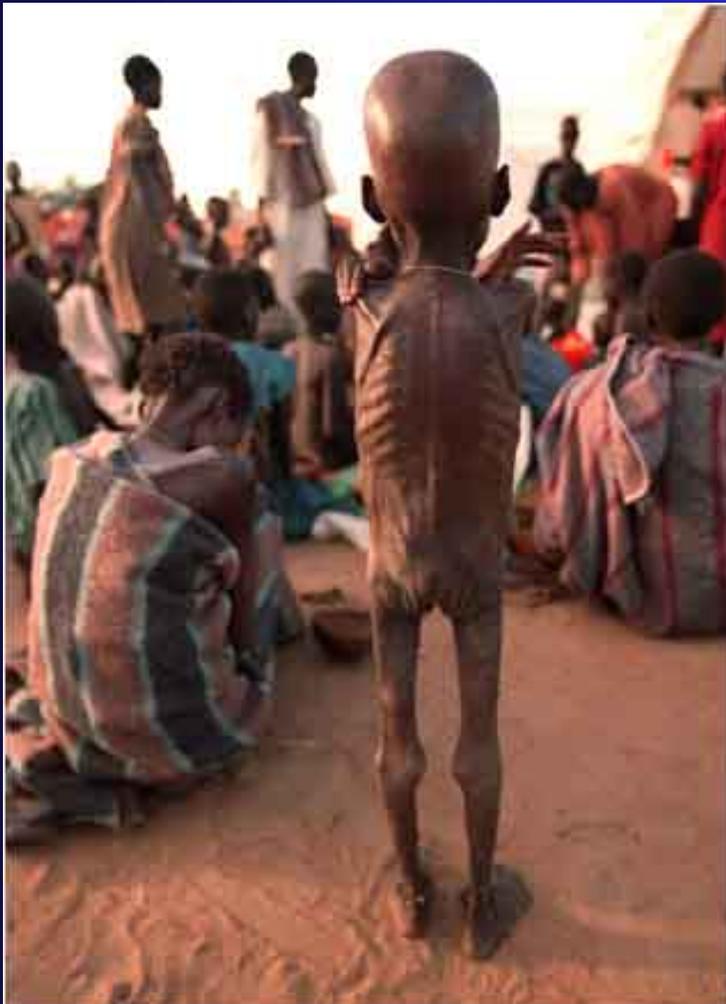
Pediatric Malnutrition: Under- and Over-weight in Children

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University of Utah School of Medicine

2012

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

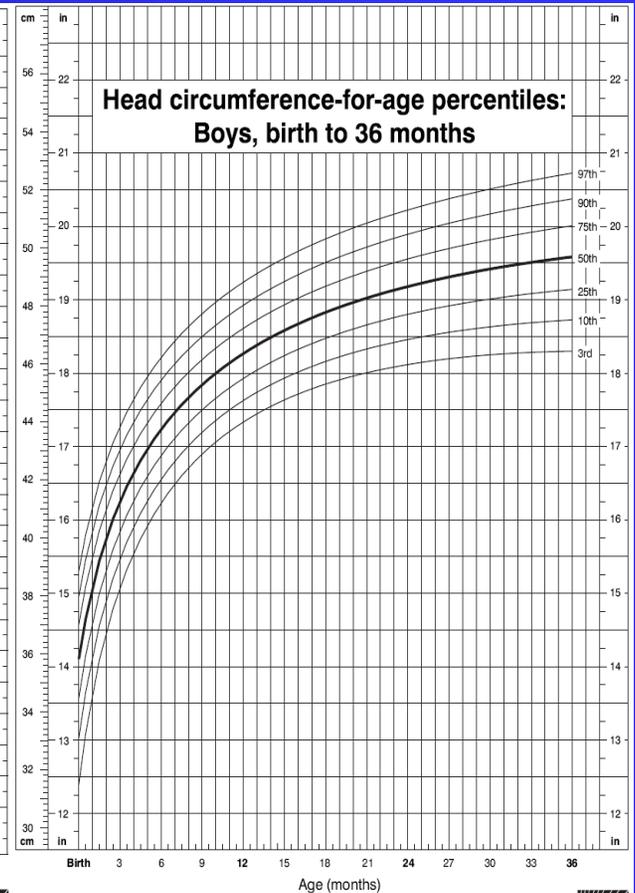
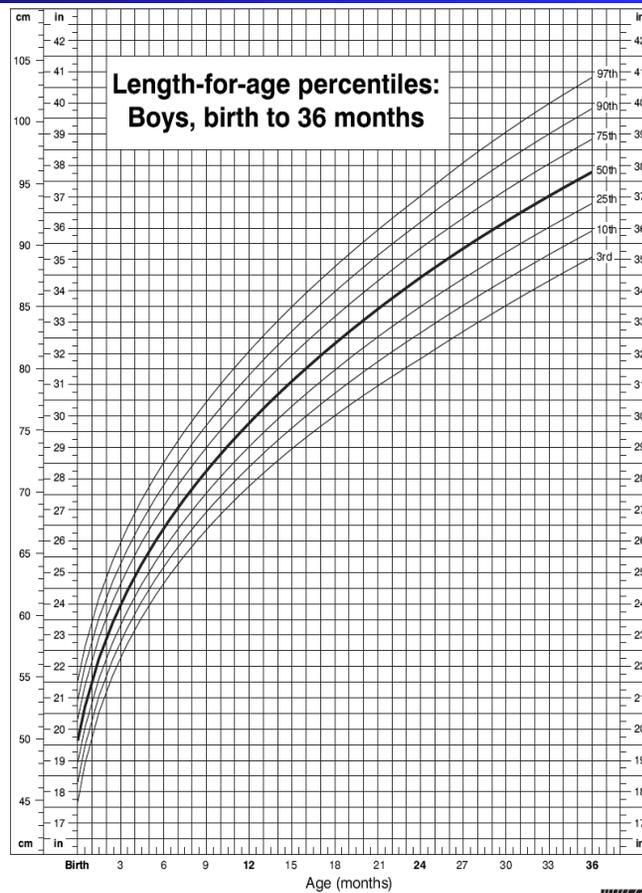
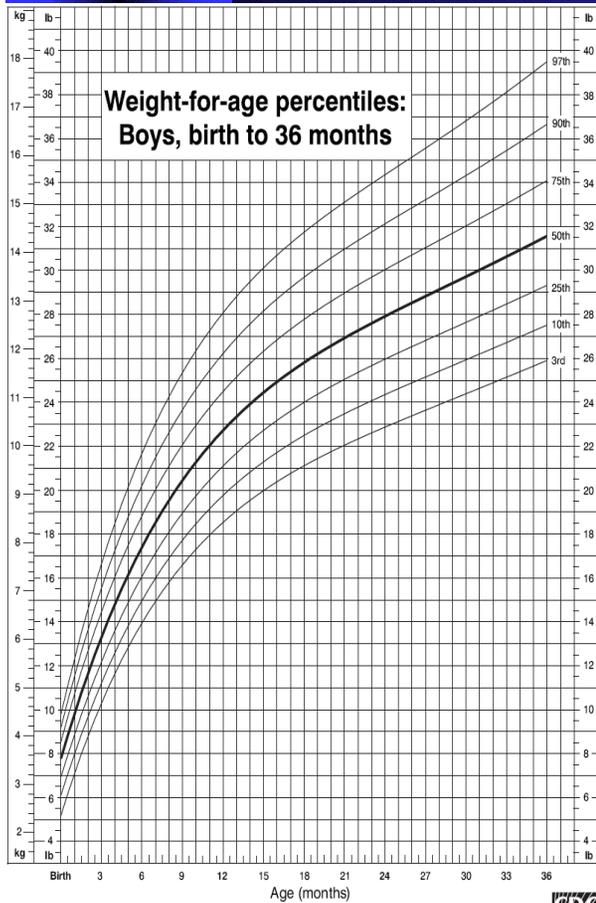
- Homeostasis
- Full physiologic function
- Weight gain
- Linear growth
- Cranial growth
- Neurodevelopment
- Social integration

Navigating The Growth Curve

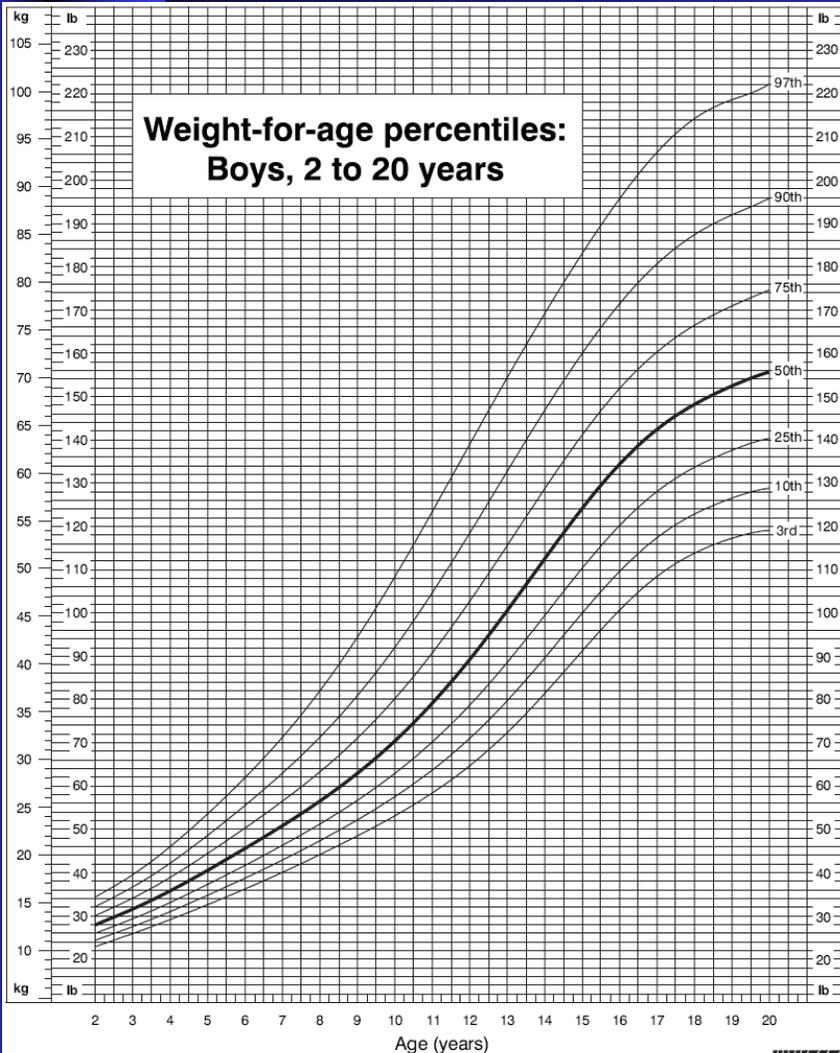
- Expectations
- Deviations
- Recovery
- Faltering
- Acute wasting
- Chronic stunting
- Cranial stasis



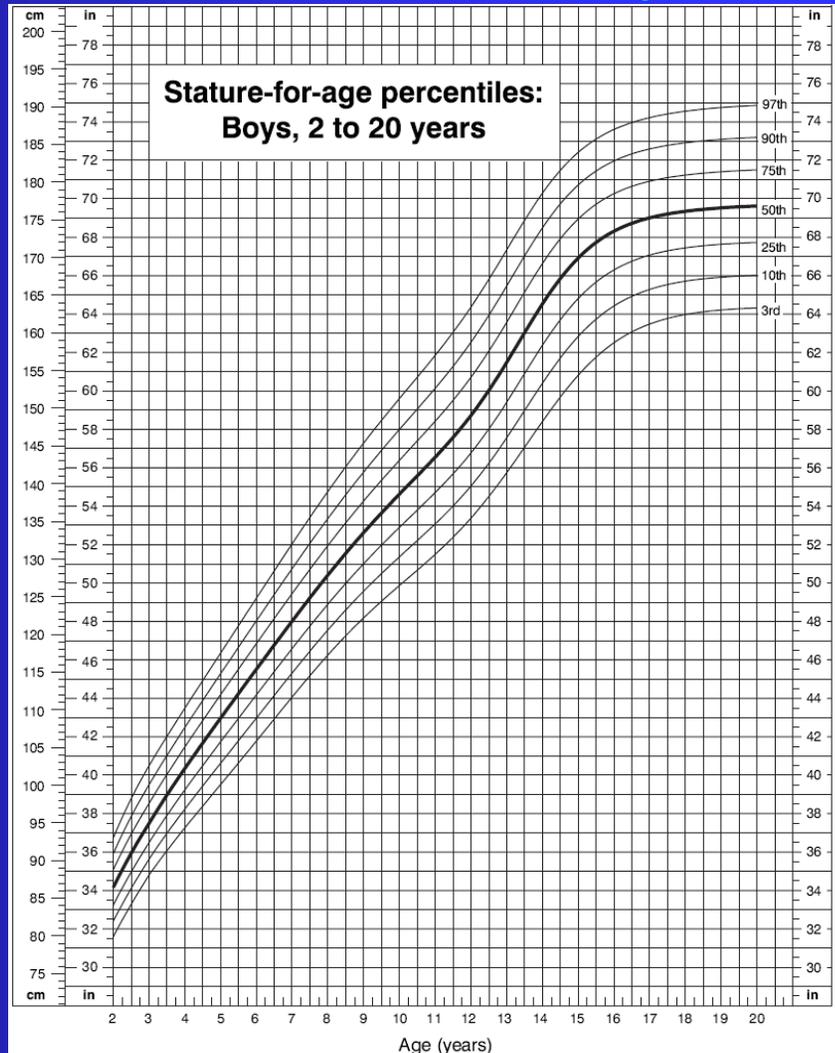
CDC Growth Curves: 0-36 months



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).



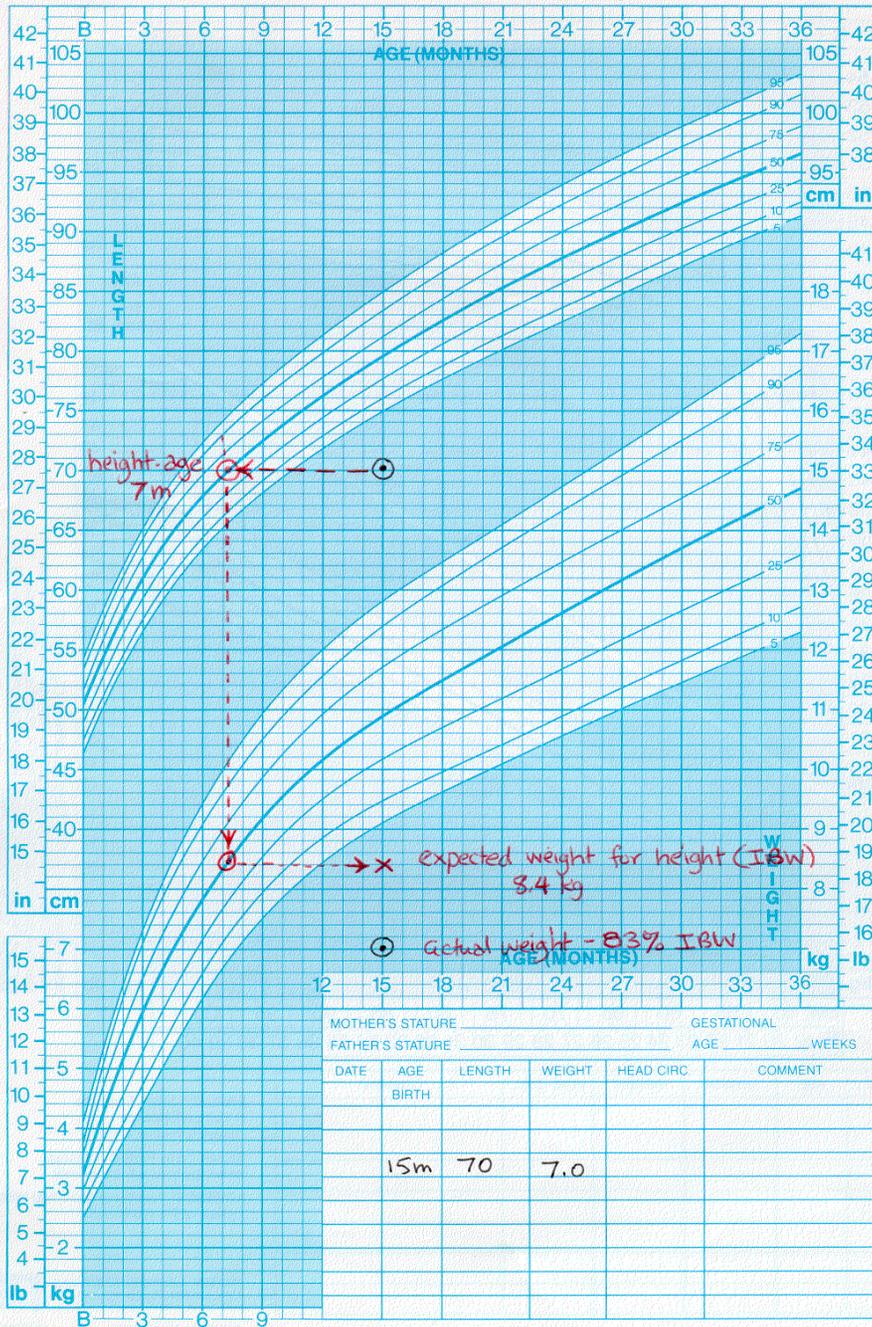
Published May 30, 2000.
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the National Center for Chronic Disease Prevention and Health Promotion (2000).



**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:

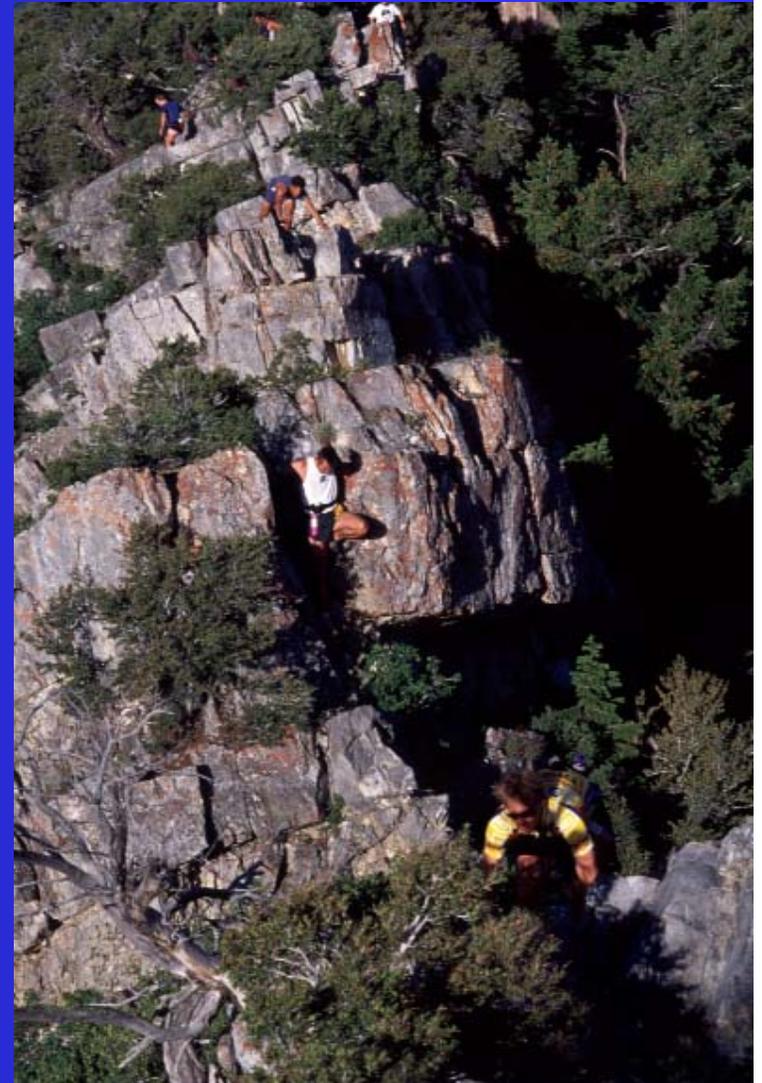
Actual Wt: 7 kg

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

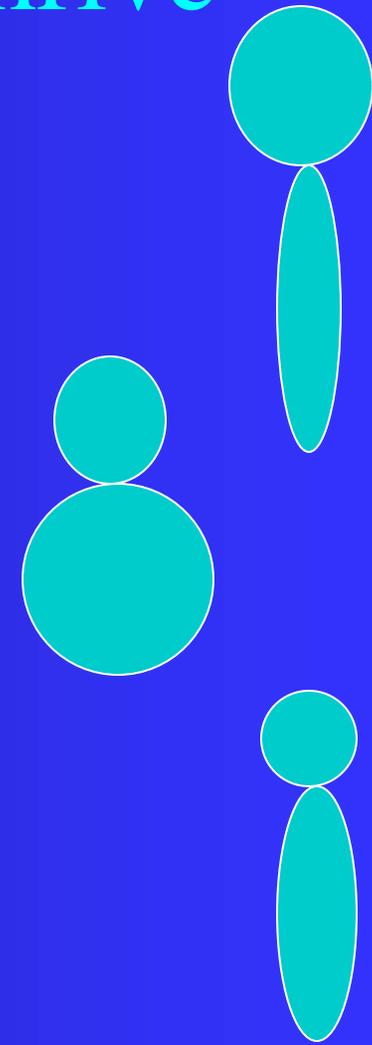
- ◆ $\text{Weight} < \text{Length} < \text{Head}$

- Endocrine

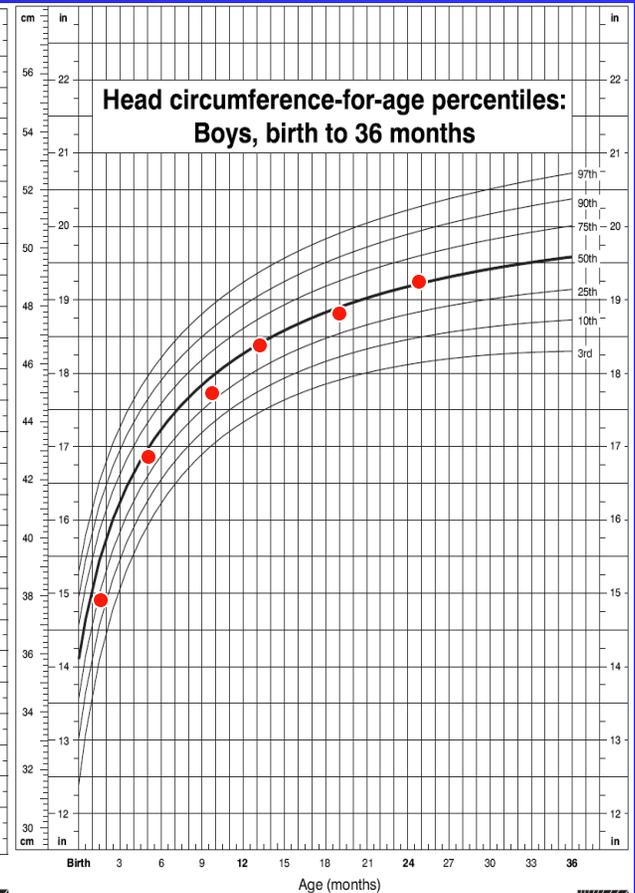
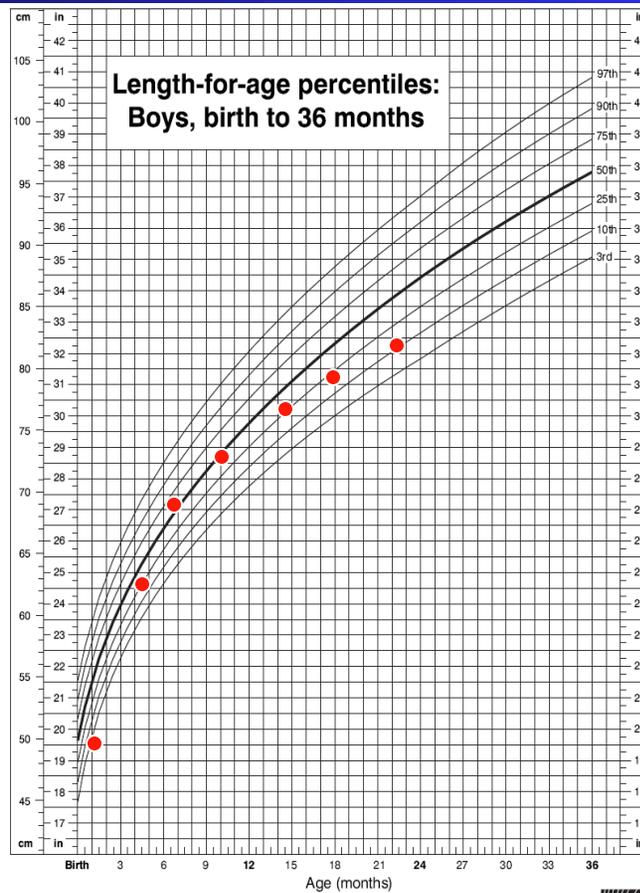
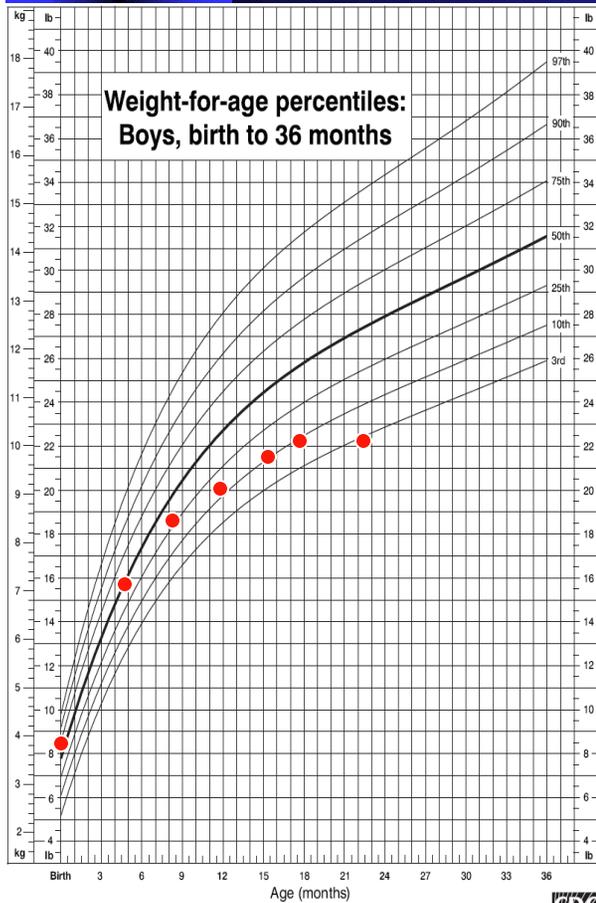
- ◆ $\text{Length} < \text{Weight} < \text{Head}$

- Neurologic

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



Nutritional Pattern



Nutritional Pattern: DDx

■ Inadequate Net Intake

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

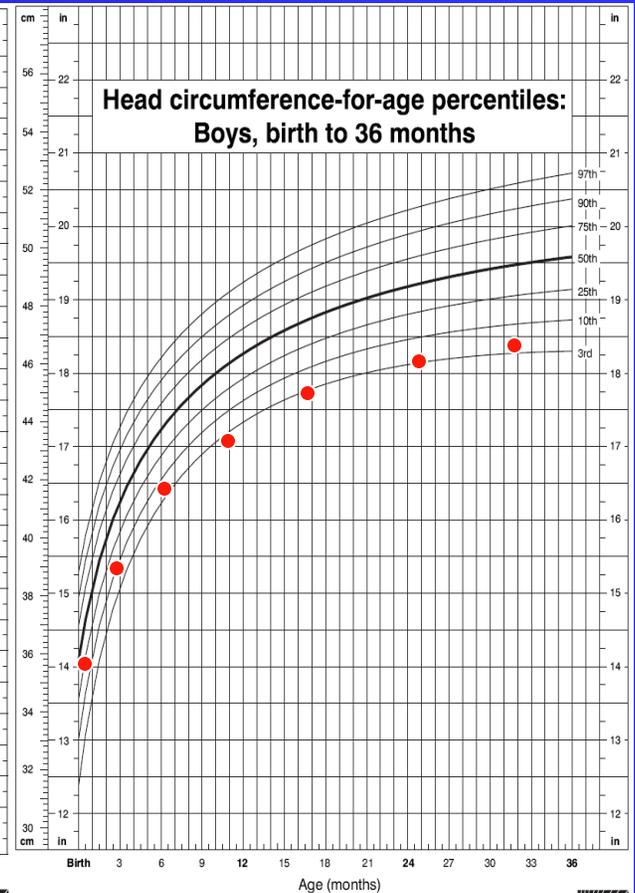
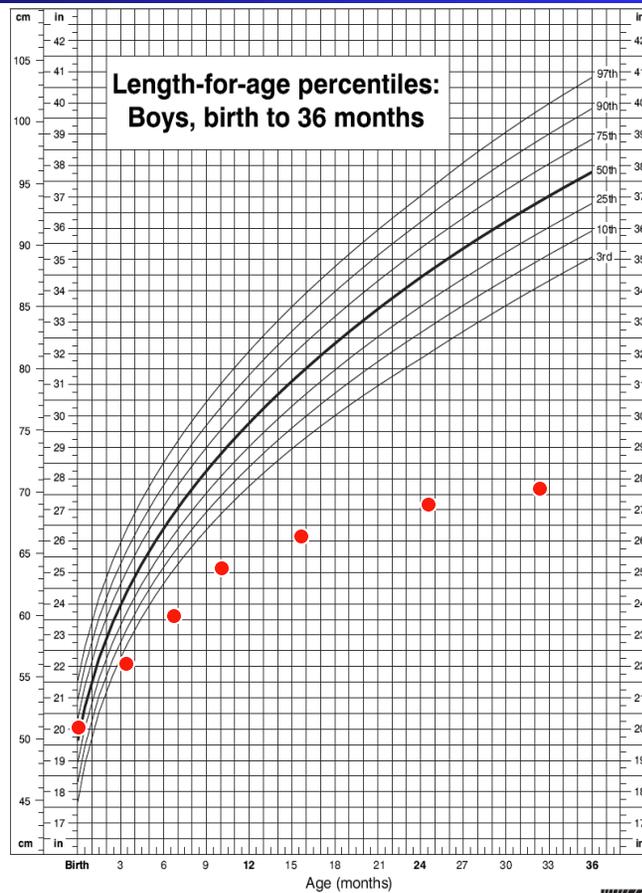
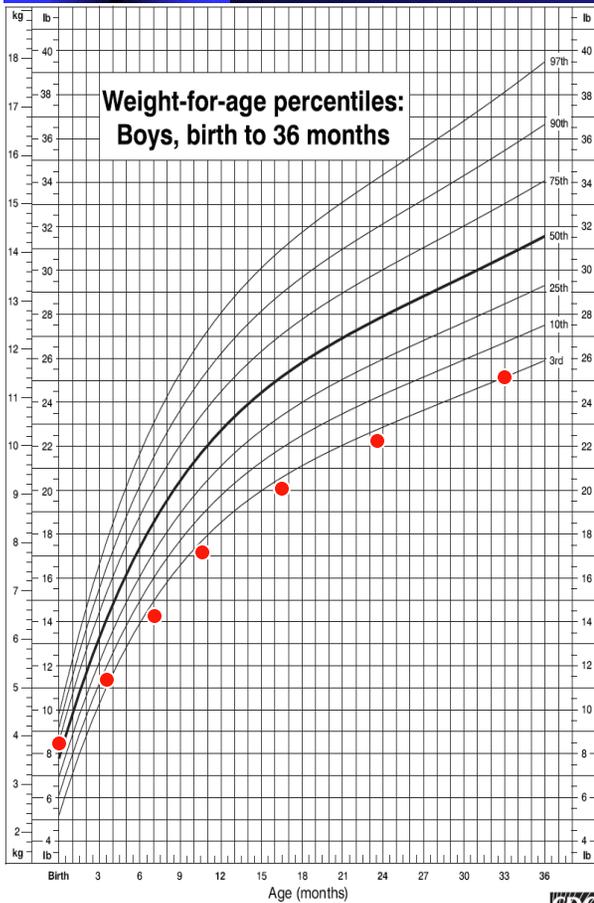
■ Maldigestion/Malabsorption

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

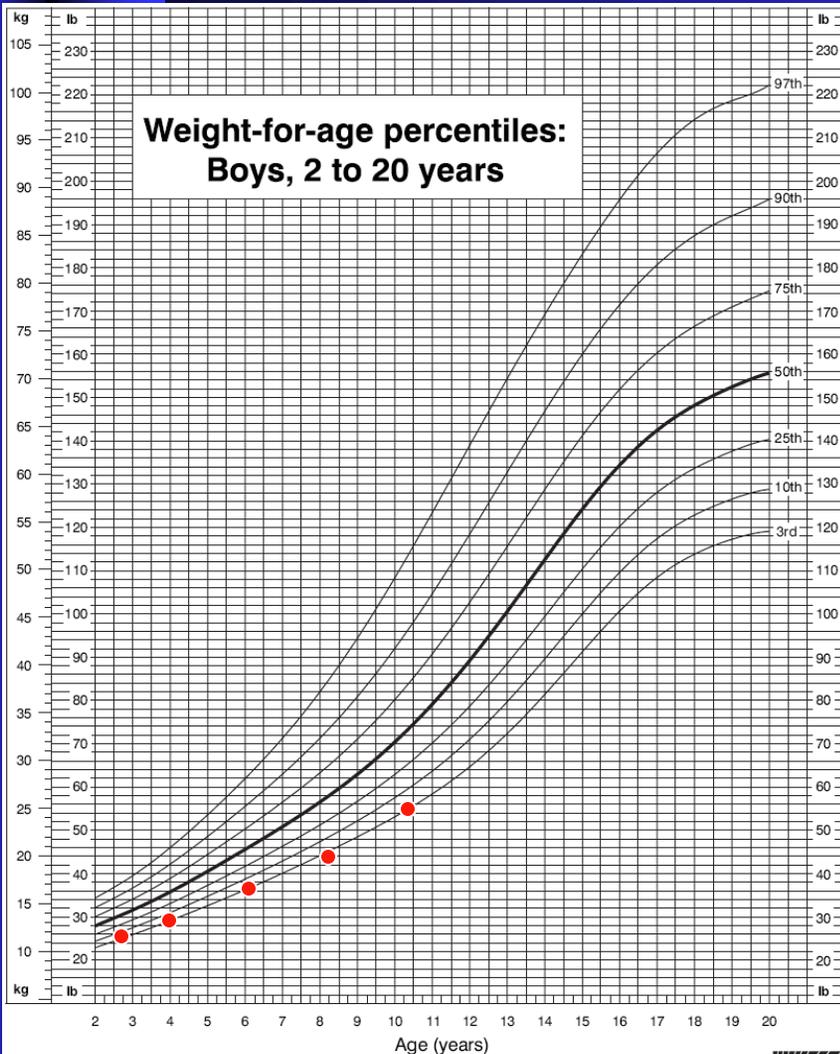
■ Increased Metabolic Requirements

- ◆ Inflammation
- ◆ Cardiopulmonary disease

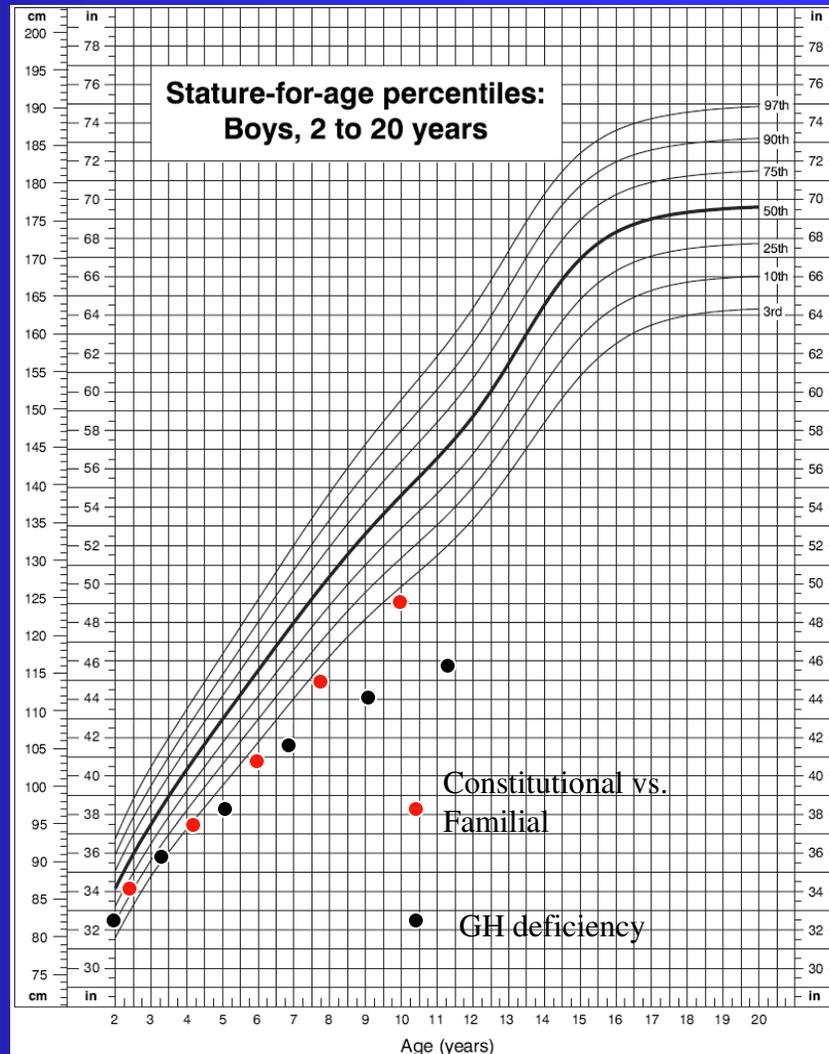
Endocrine Pattern



Short Stature: Patterns



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Endocrine Pattern: DDx

■ Hypothyroidism

- ◆ Low Thyroxine (Free T4), High TSH

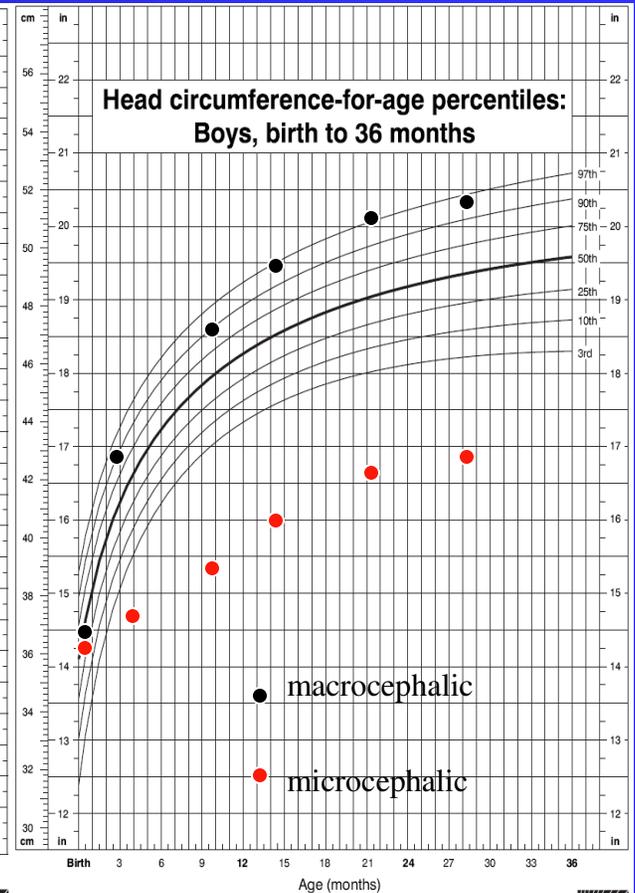
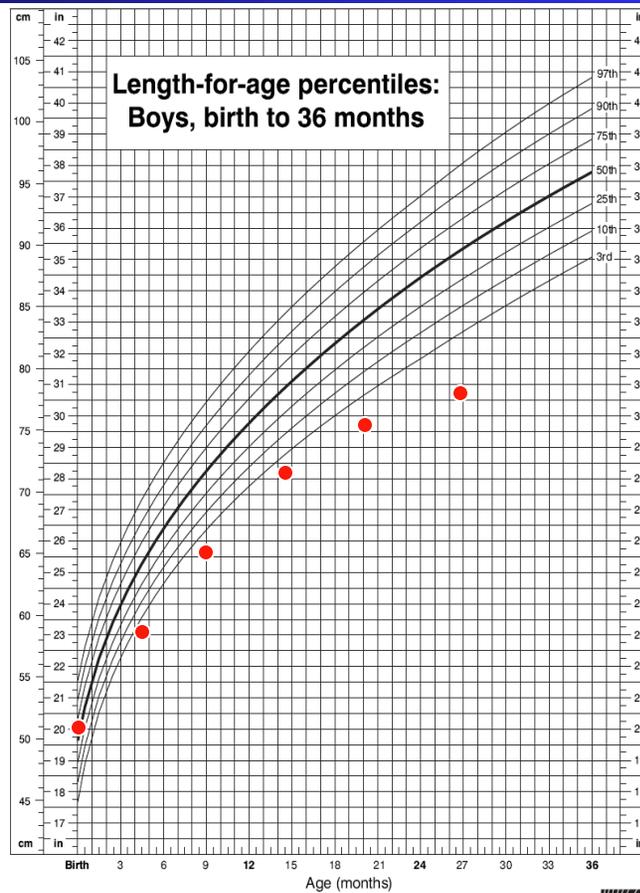
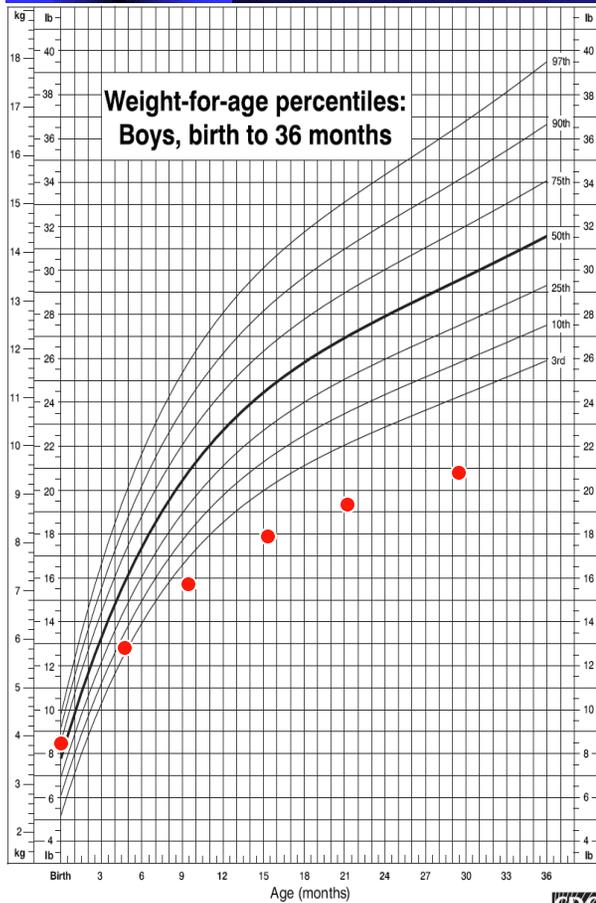
■ Growth Hormone deficiency

- ◆ 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

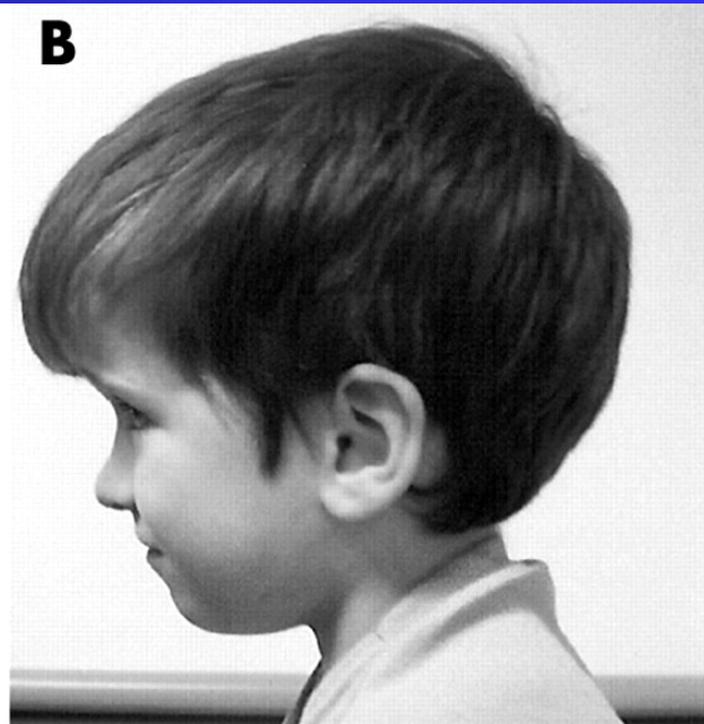
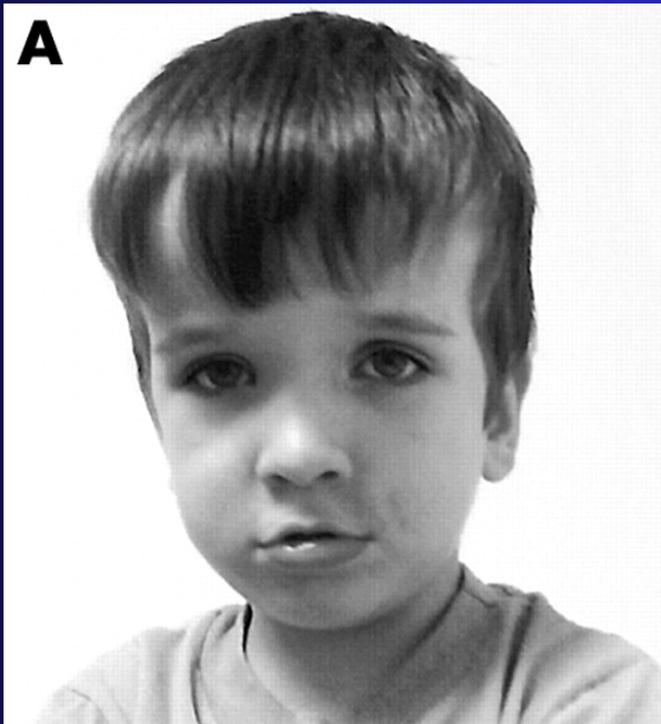
■ Microcephalic

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

■ Macrocephalic

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

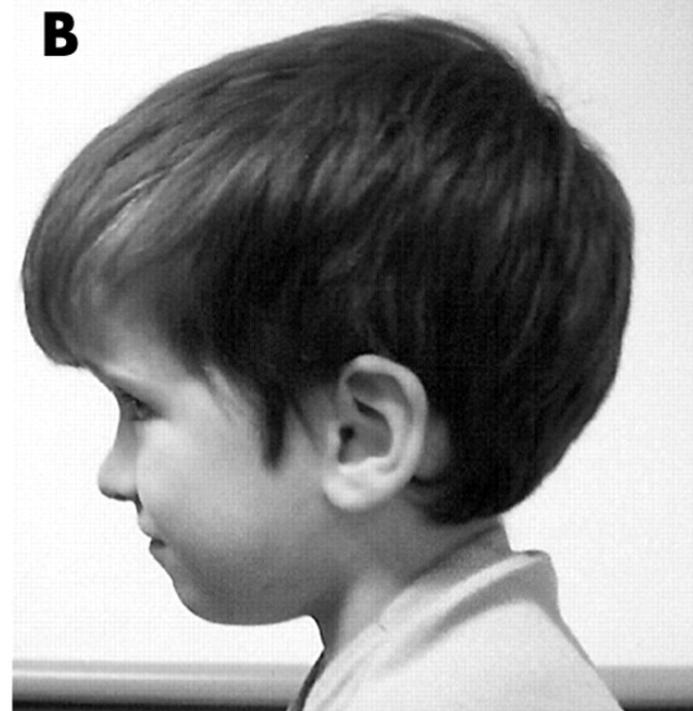
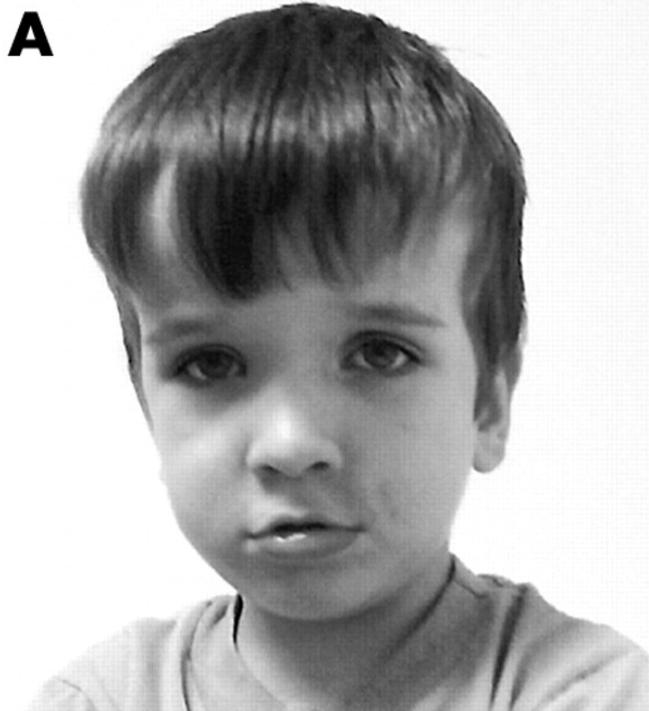






Rett Syndrome

Autism



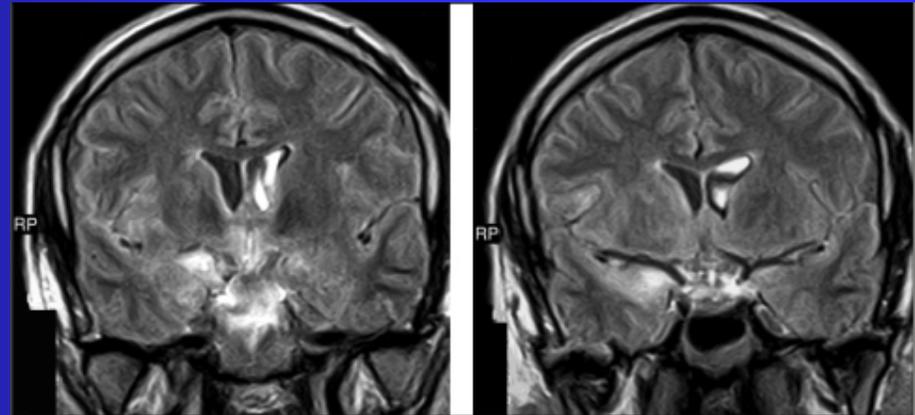


Fig 1. MRI images after gadolinium contrast injection: patchy contrast enhanced lesions in the insula and hippocampus in the right and in the hypothalamic-diencephalic region.

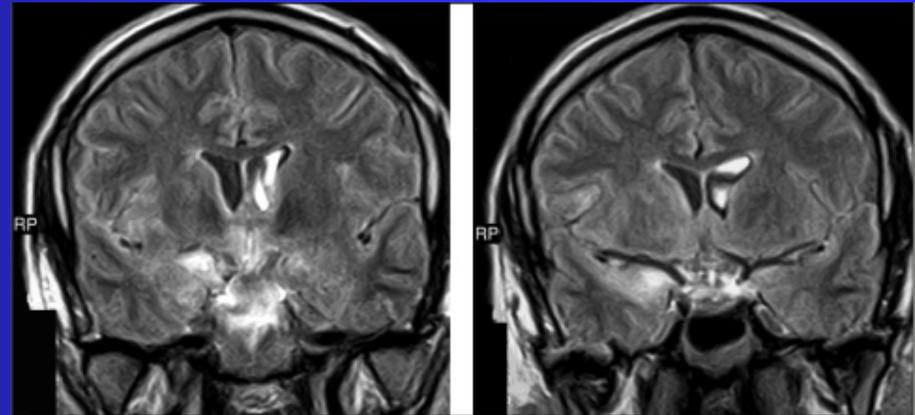


Fig 1. MRI images after gadolinium contrast injection: patchy contrast enhanced lesions in the insula and hippocampus in the right and in the hypothalamic-diencephalic region.

Diencephalic Syndrome

FTT: Definition

■ Static Criteria:

- ◆ Weight for Height < 5th %ile
- ◆ Weight < 85% median weight for height
- ◆ Triceps skinfold thickness < 5 mm or < 5th%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



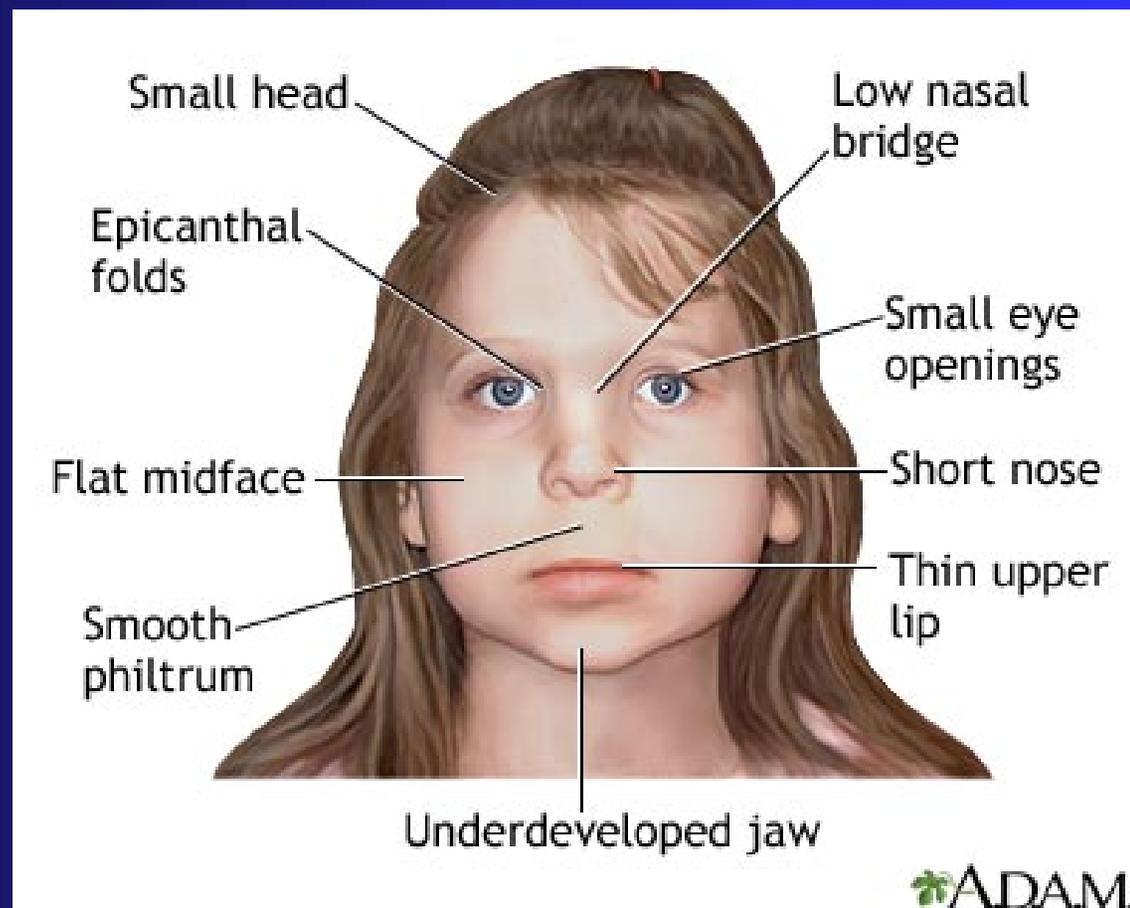


Noonan

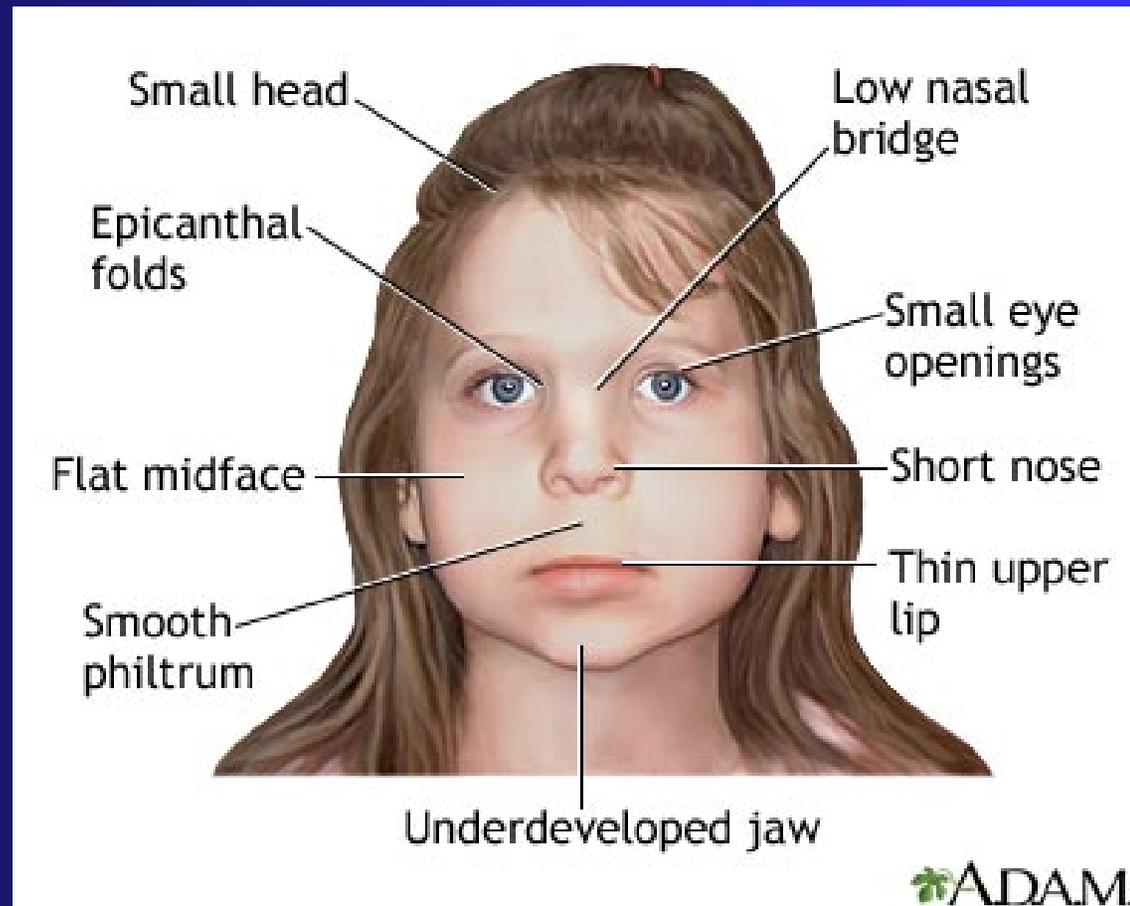


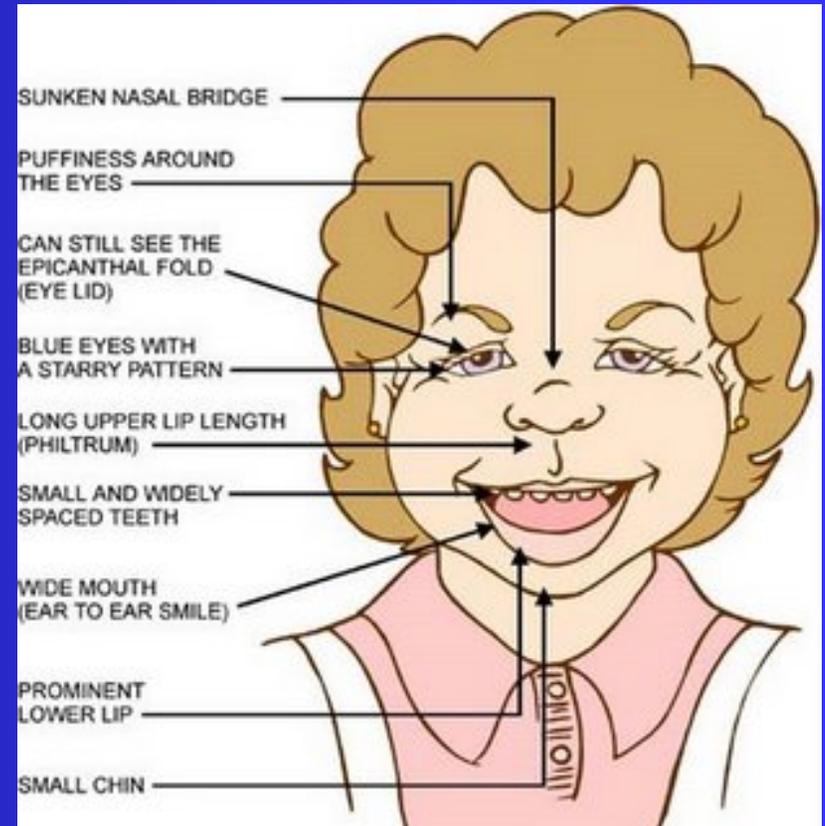
Turner



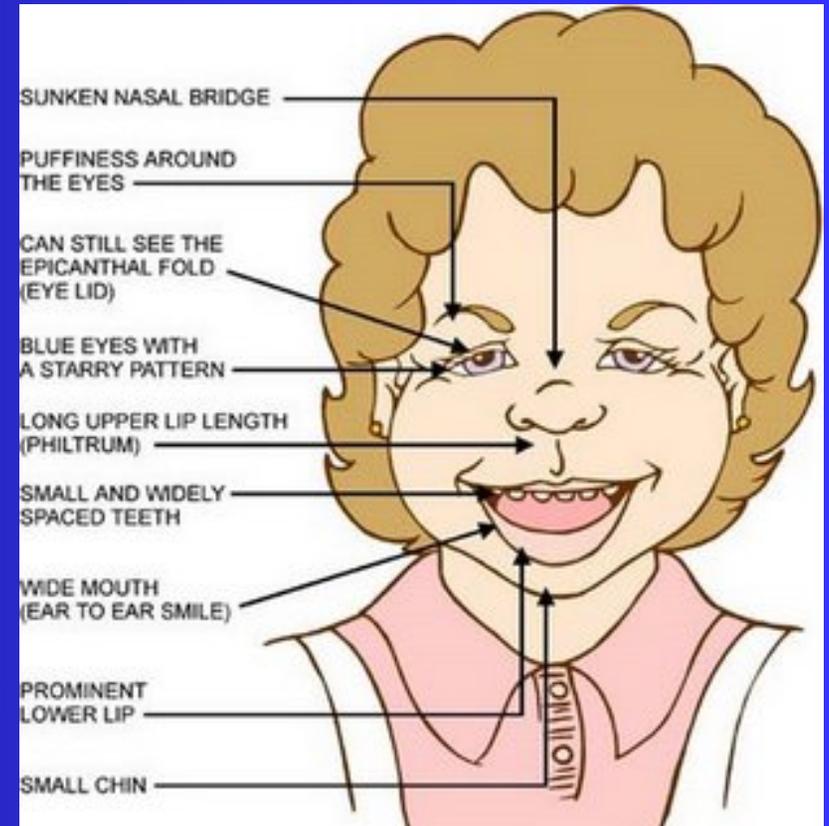


Fetal Alcohol





Williams



Acute vs Chronic

■ Acute Undernutrition-- “wasting”:

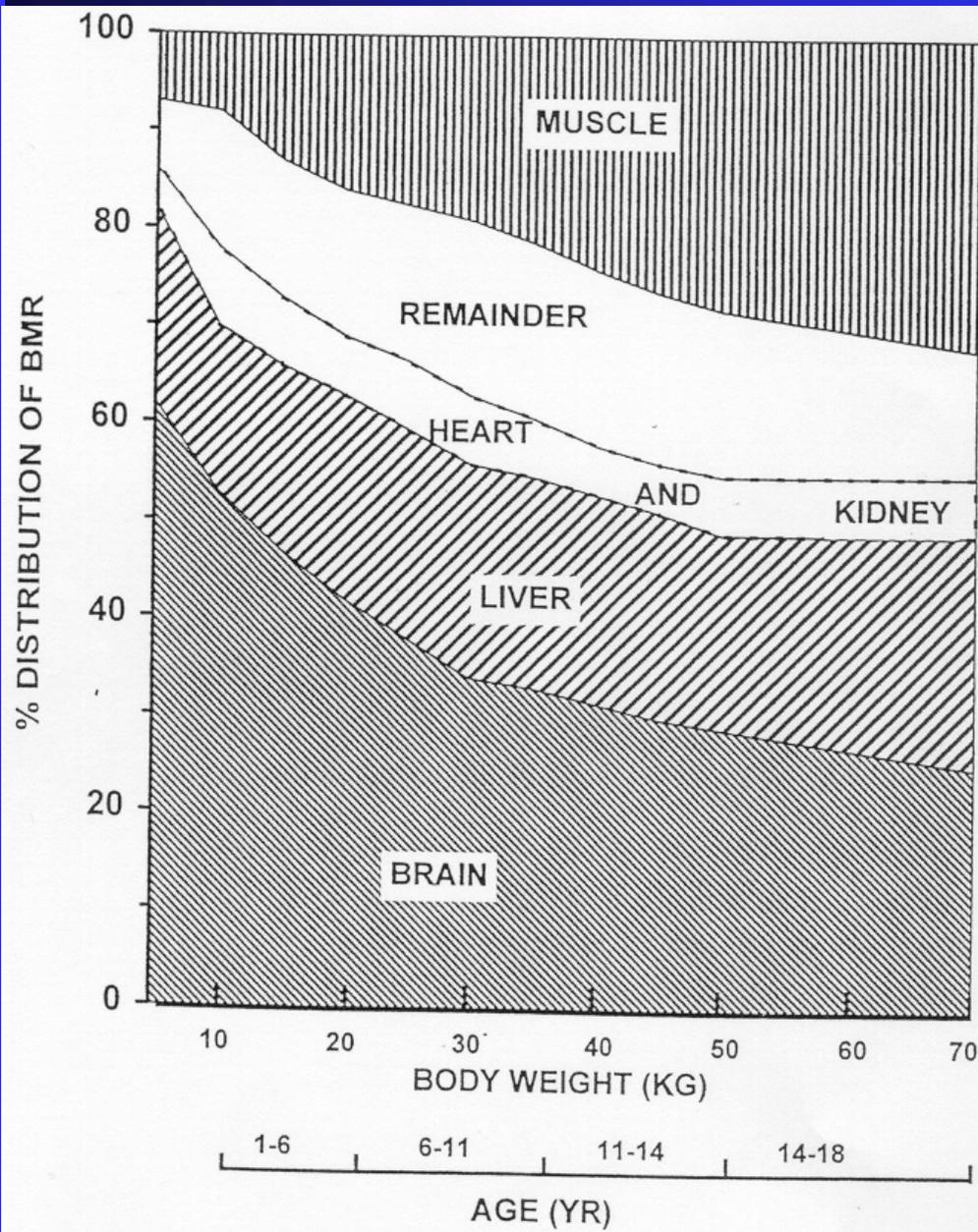
- ◆ Low weight for height or low BMI
- ◆ “wasting” of fat and muscle mass
- ◆ Prelude to stunting
- ◆ Constitutional leanness

■ 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

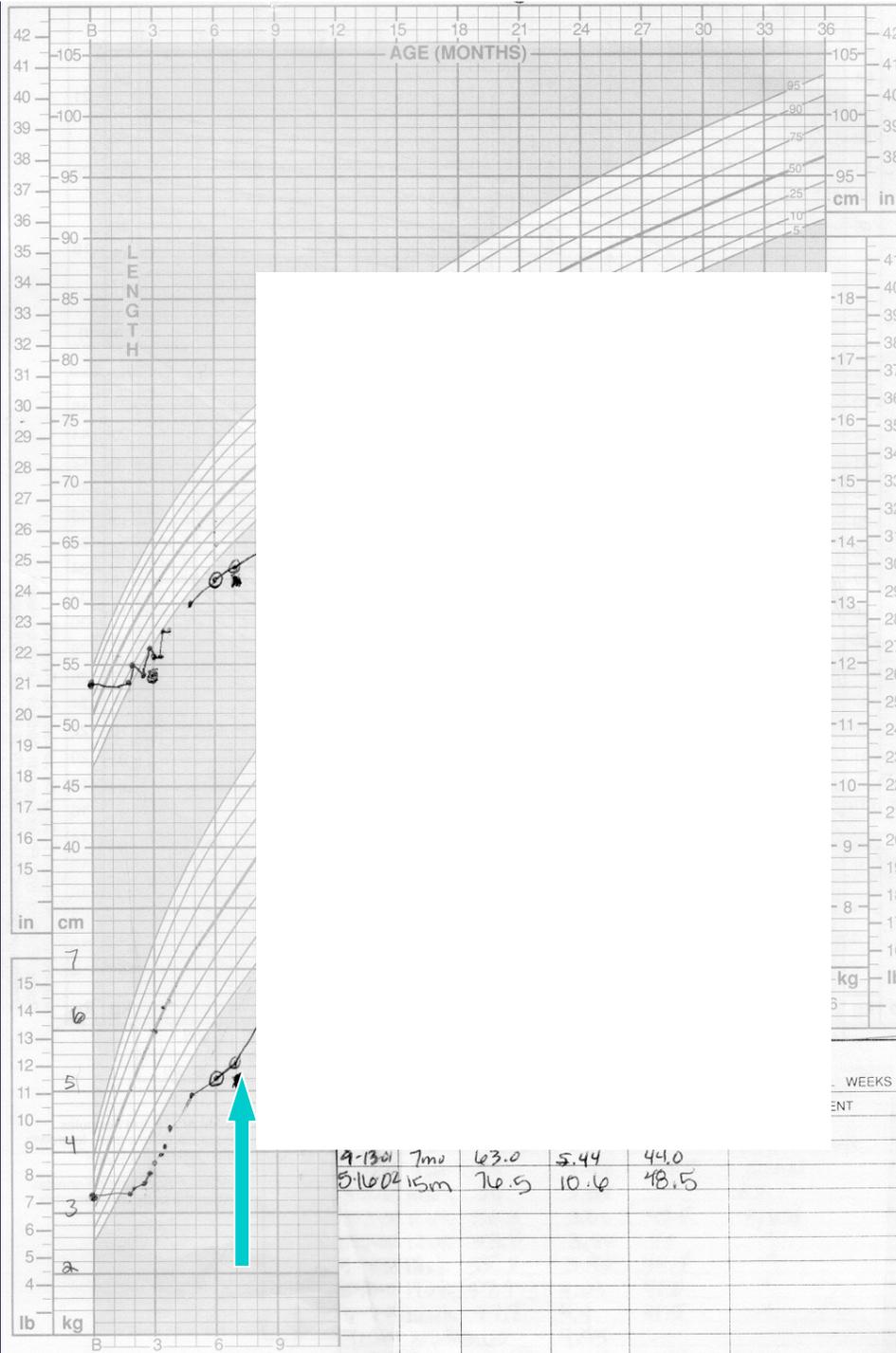
$$\text{TDEE} = [1.4 \text{ to } 1.6] \times \text{BMR}$$

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

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

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

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

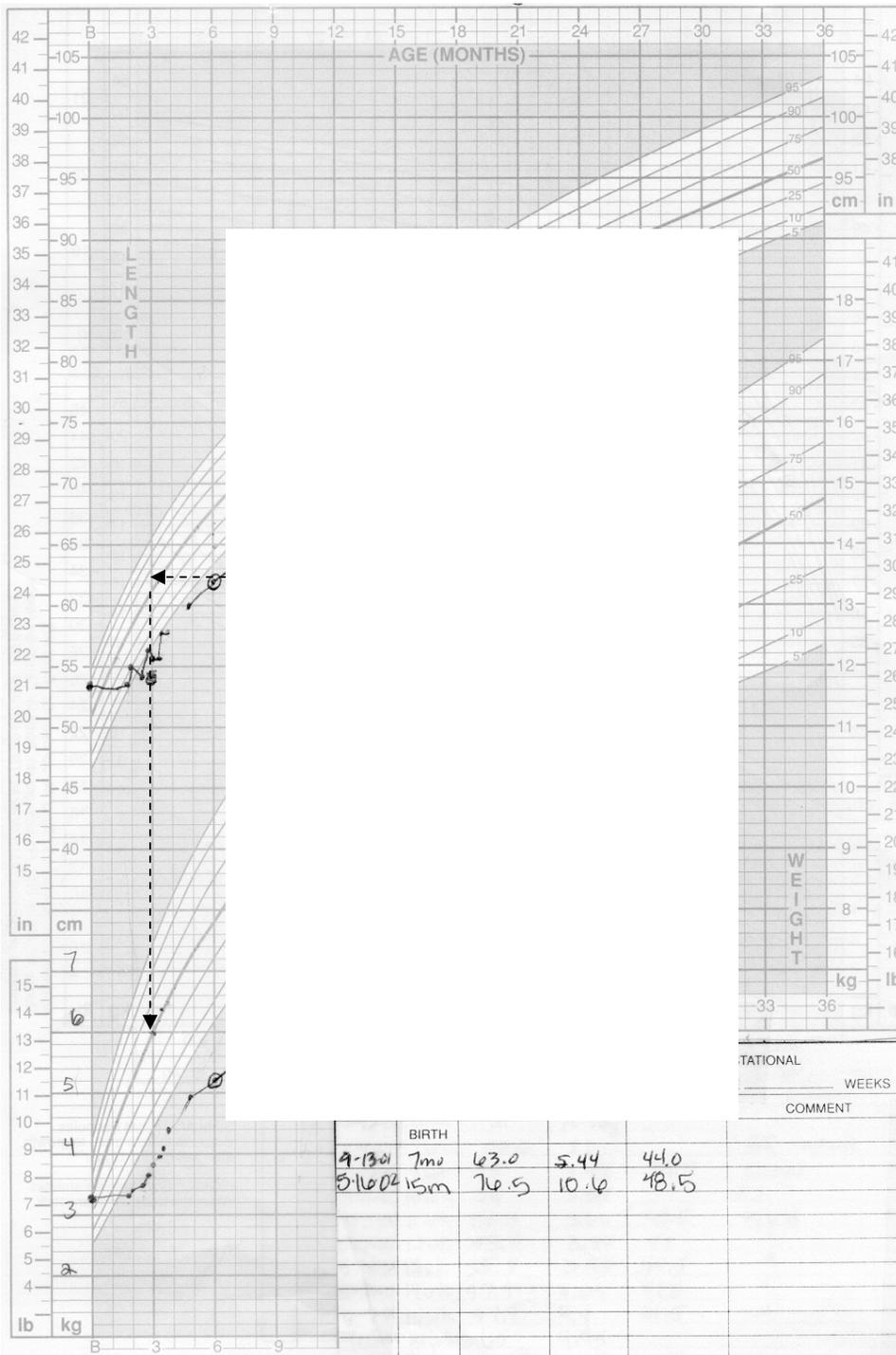
Estimated Energy Needs (RDA)

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

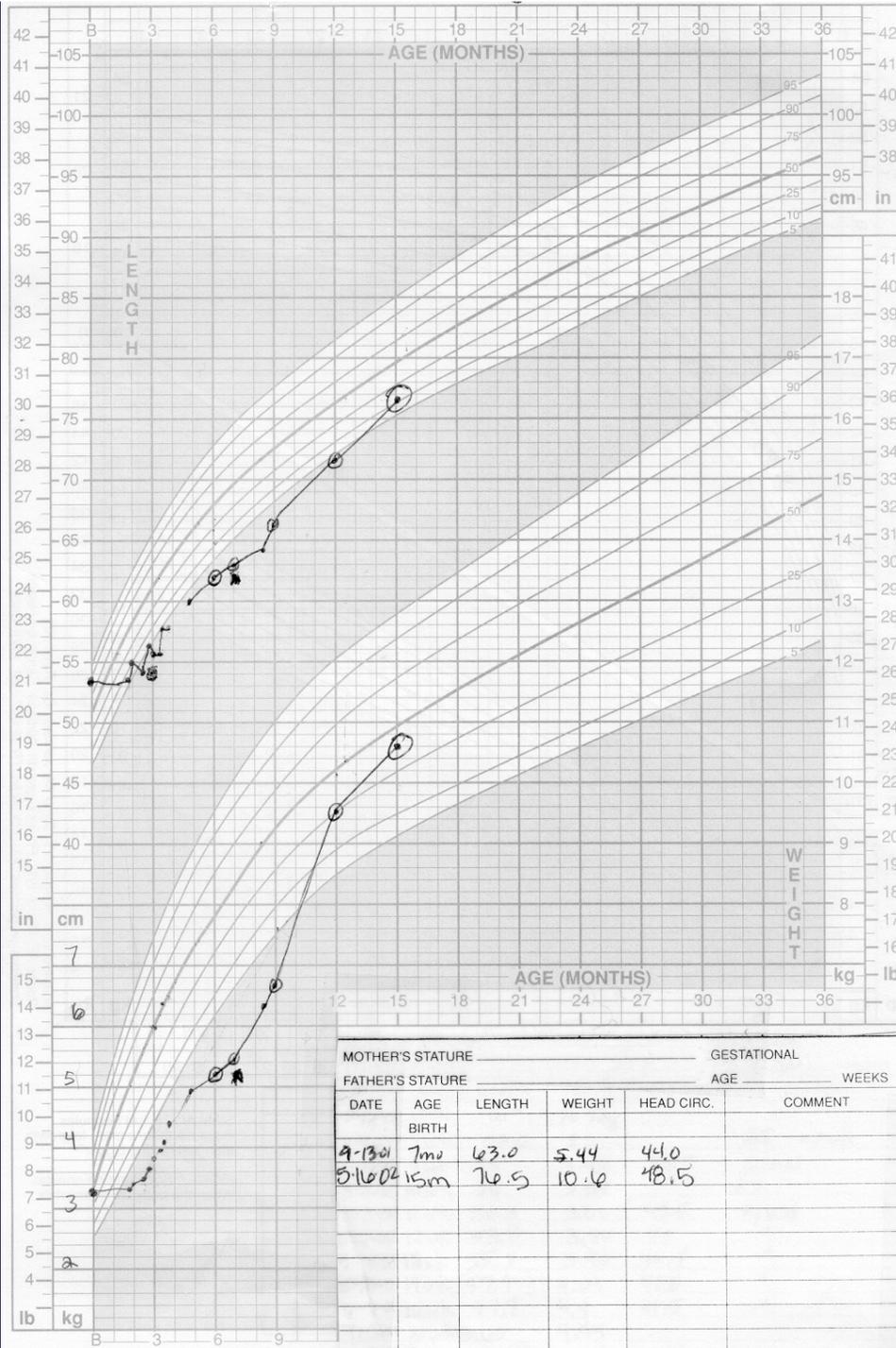
For 24 kcal/oz formula (0.8 kcal/ml):

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

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

Kcal/kg actual weight:

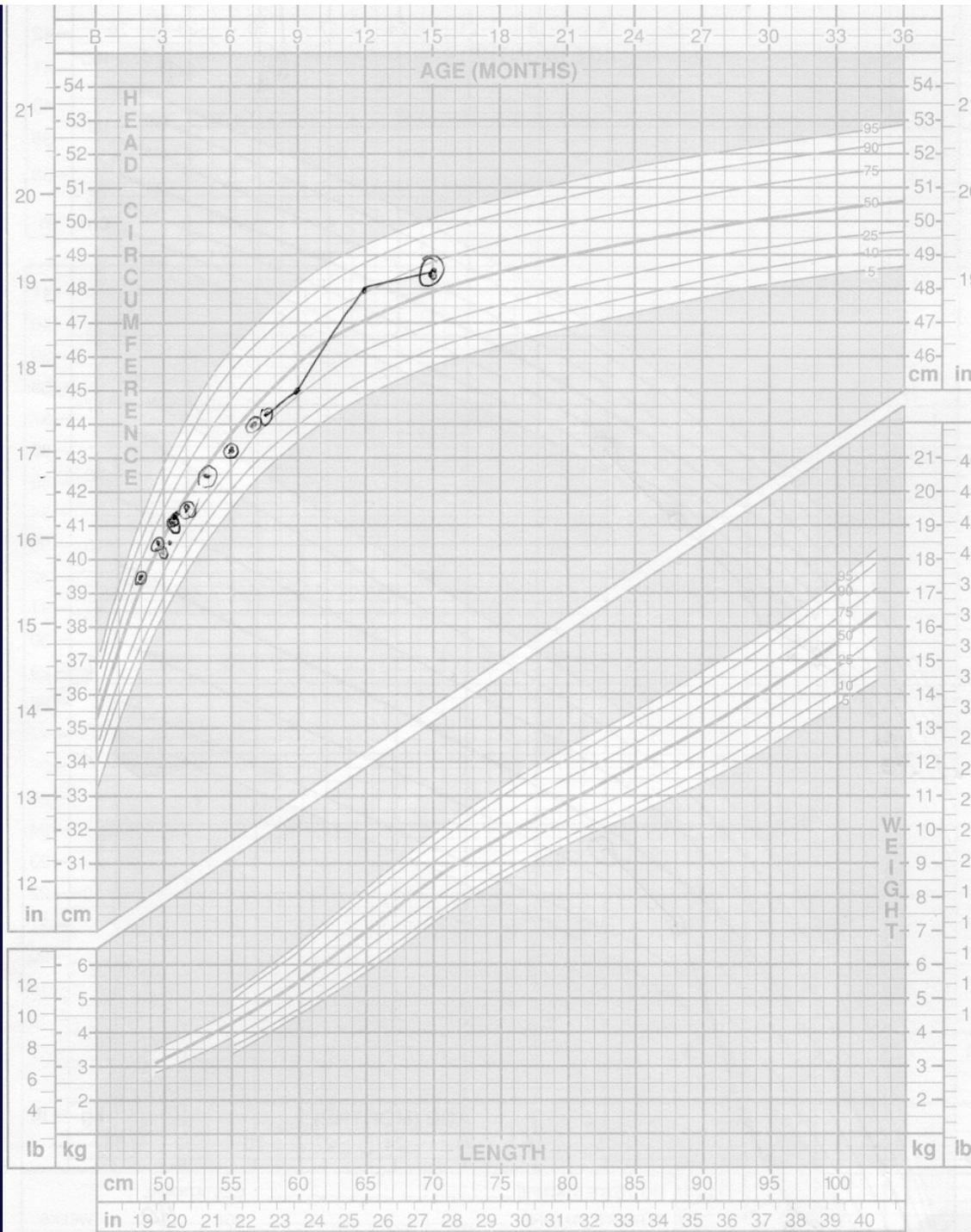
$600 \text{ kcal} / 5.2 \text{ kg} = 120 \text{ kcal/kg/day}$



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

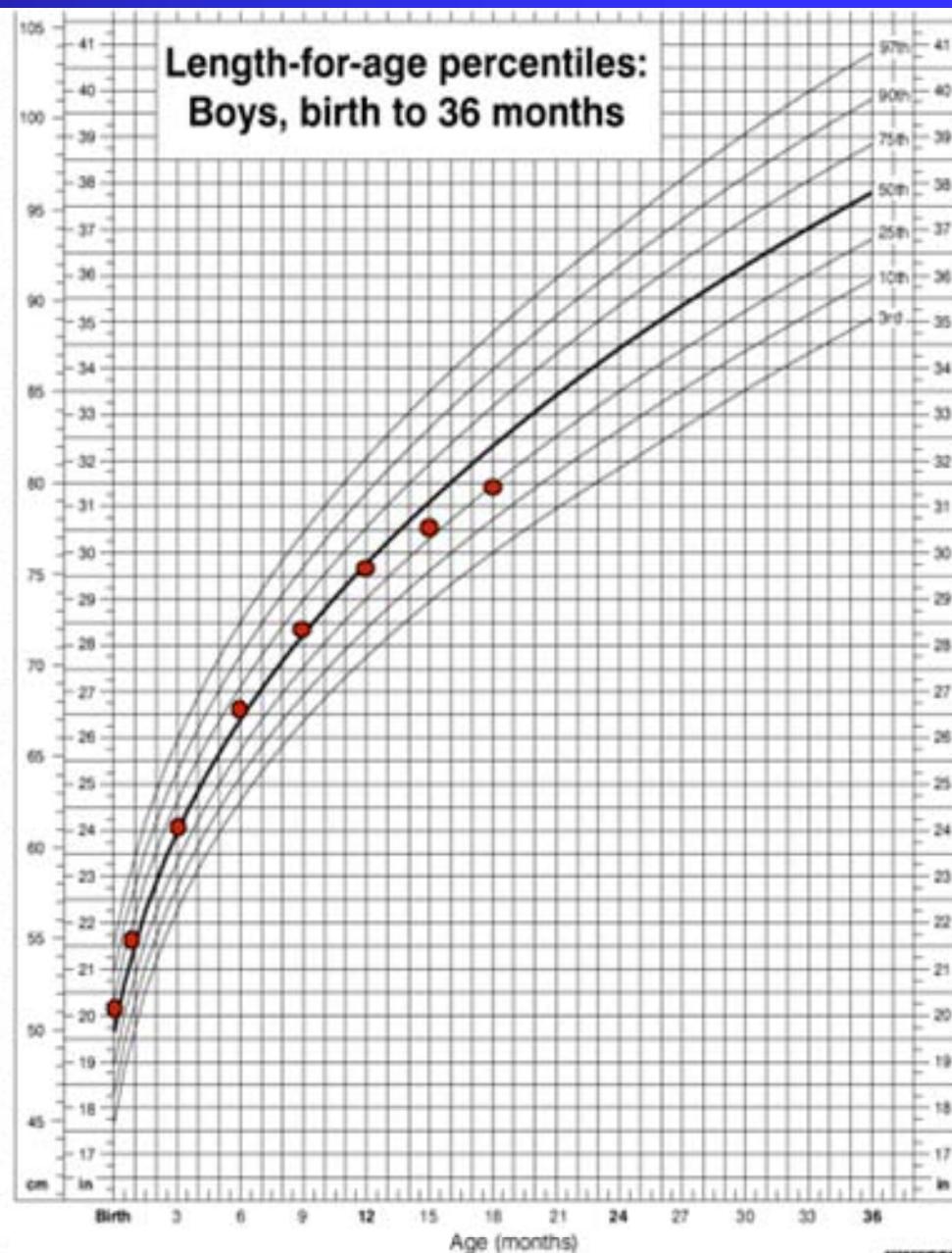
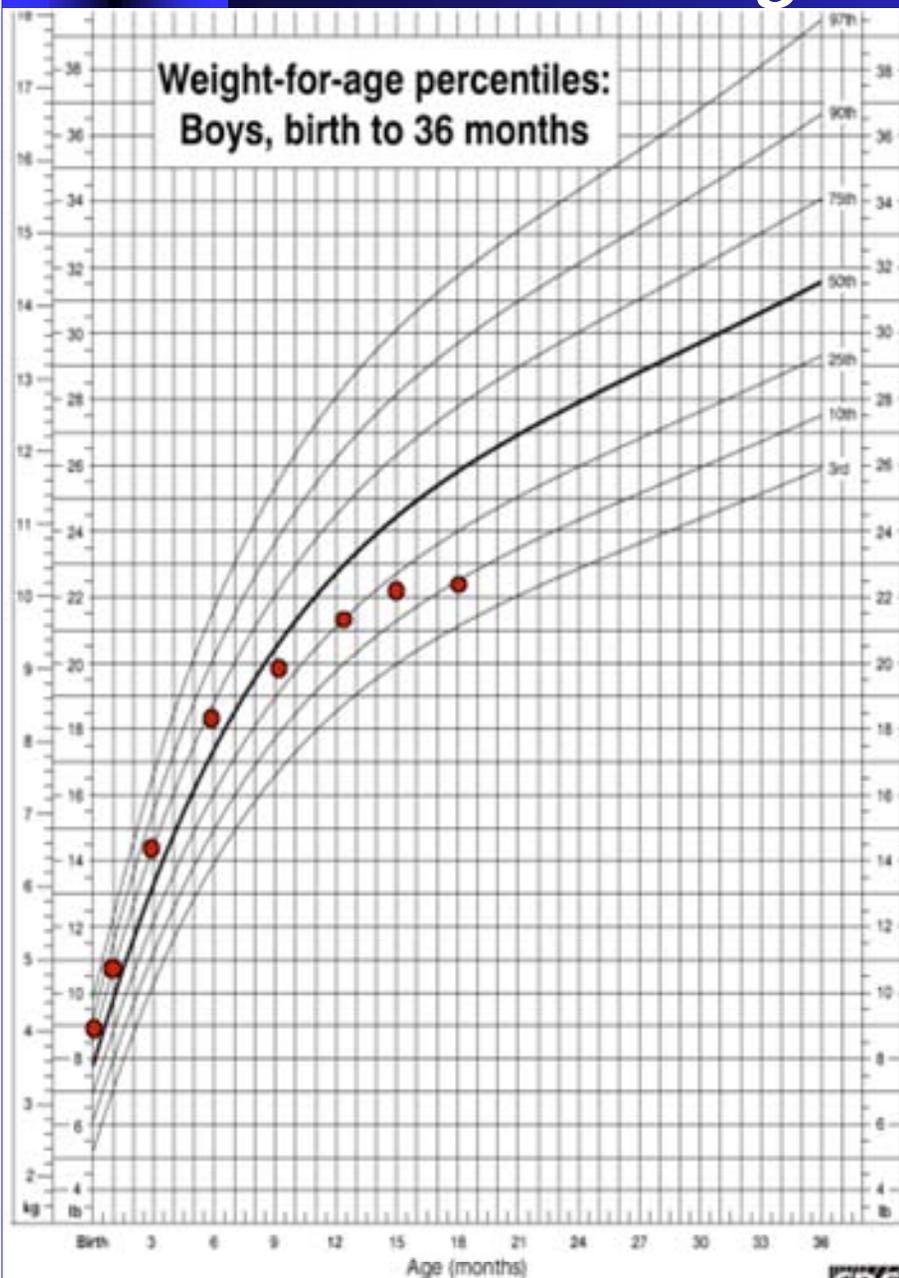
Indications for Discharge

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

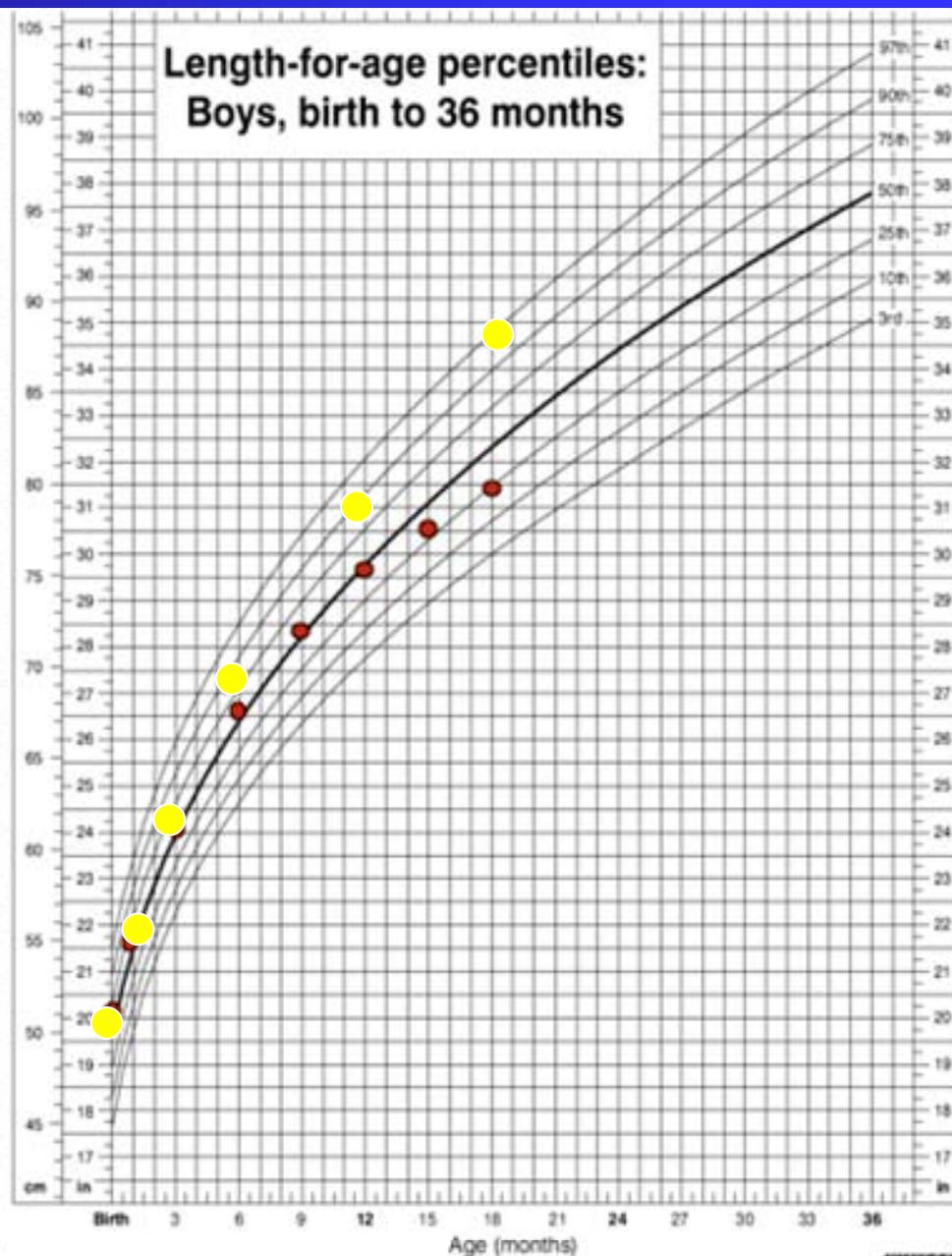
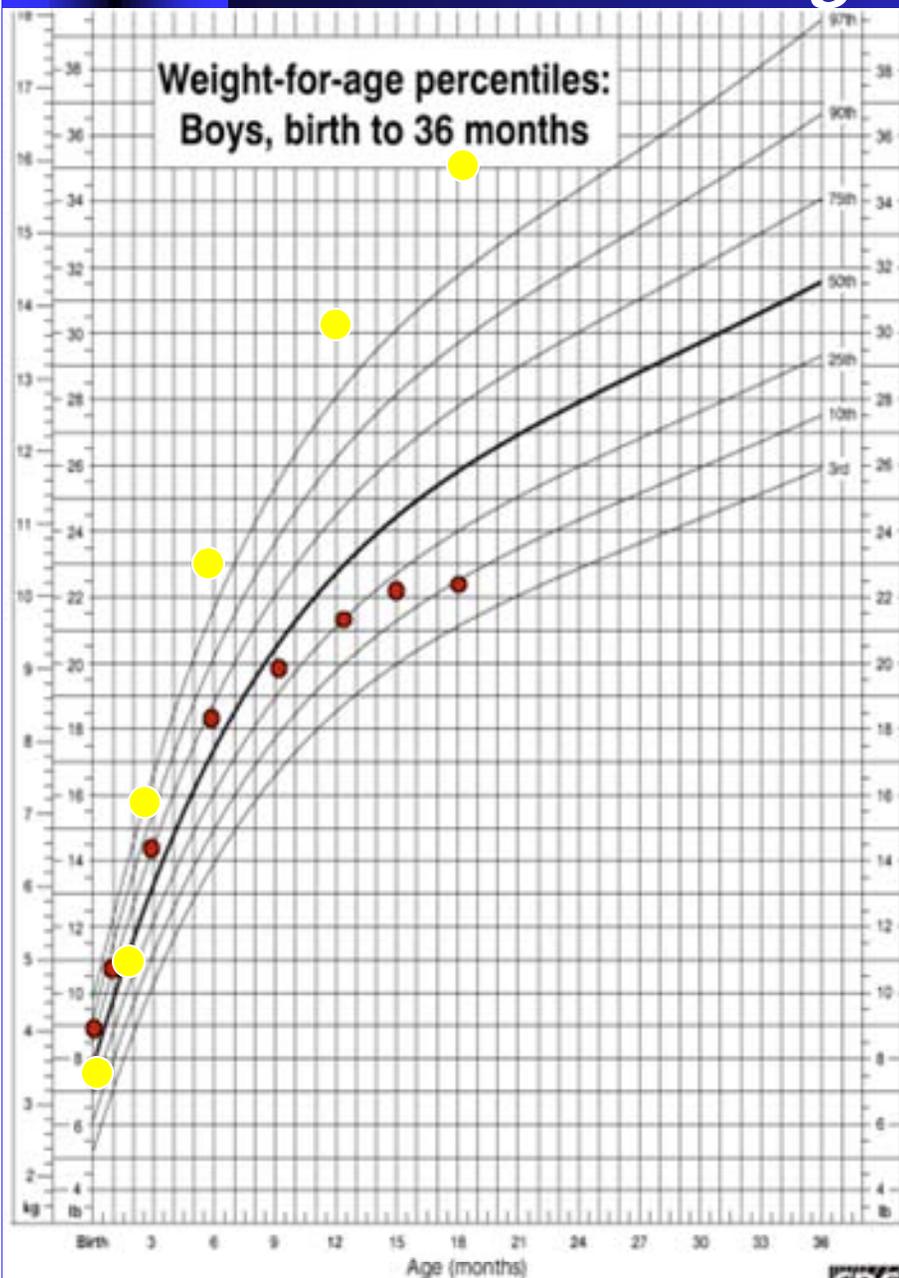


That
happy,
healthy
face
recognized all
the over world.

Failing to Thrive



Thriving to Fail ?



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).



SAFER • HEALTHIER • PEOPLE

Published May 30, 2000.

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



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/m².

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*

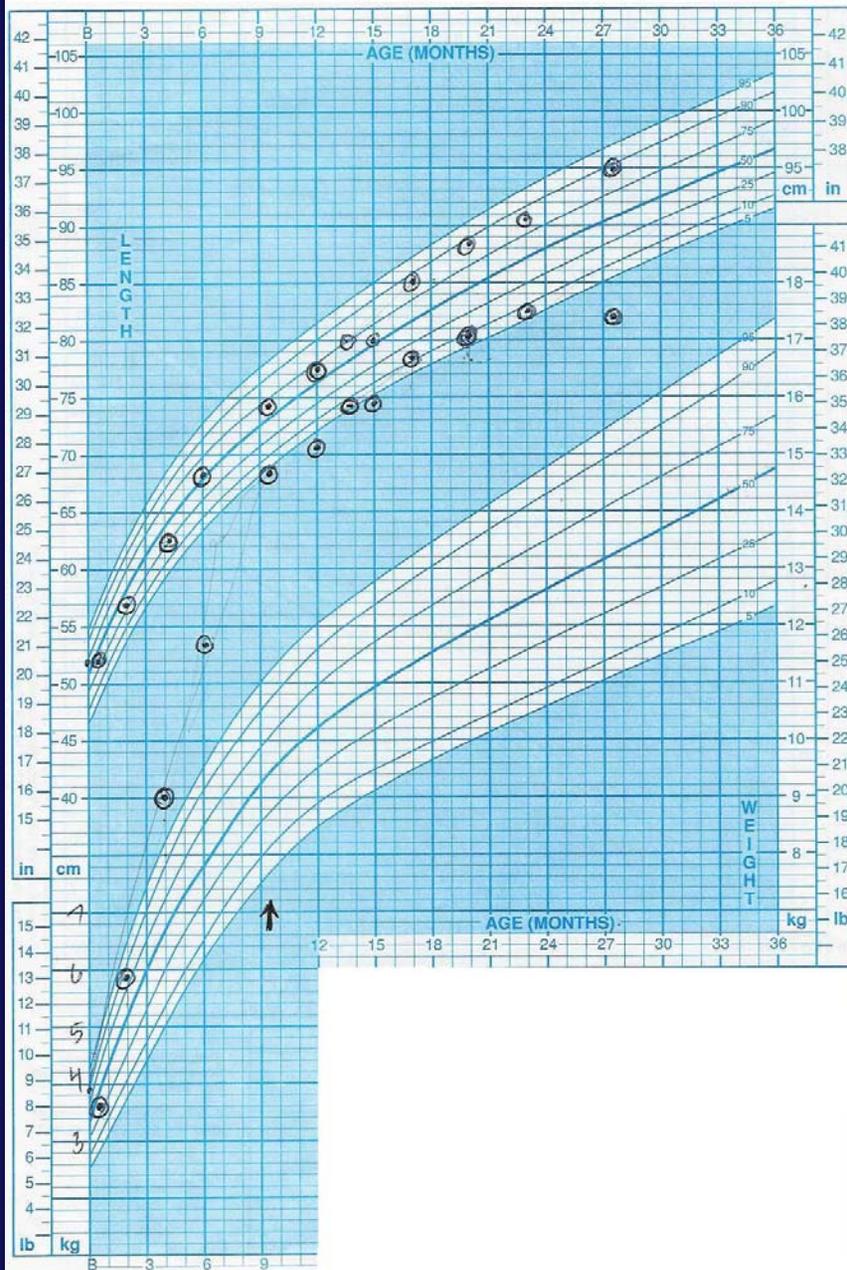
- **Rapid Weight Gain in early childhood = High Risk for Obesity in later life**
- **Designate overweight as Weight-for-Length greater than 95th %ile [WHO BMI curves exist for < 2 years.]**
- **Weight gain crossing 2 major percentiles (1 standard deviation) = up to 5 times increased risk of later overweight.**

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

- **Early or infantile obesity more likely associated with genetic or endocrine obesity syndromes.**

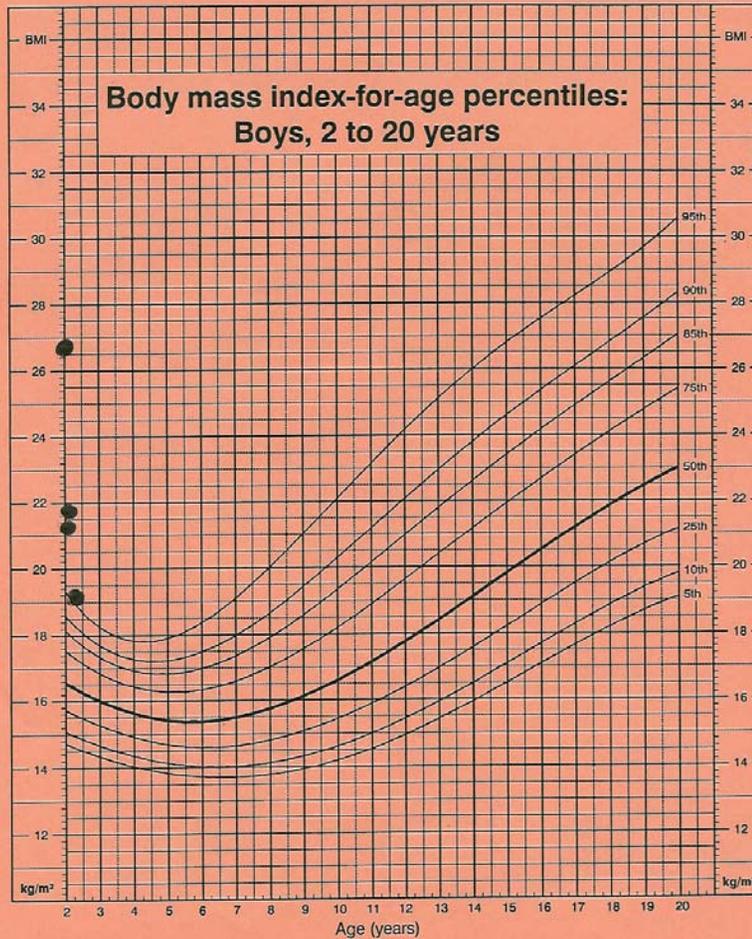
Proposed Strategy

- 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.

