NORMAL GROWTH AND FACTORS AFFECTING GROWTH
DEFINITIONS

• **Growth:** Net increase in the size or mass of tissues which is largely due to multiplication of cells and increase in the intracellular substance.

• **Development:** Maturation of functions associated with maturation and myelination of nervous system.
GROWTH: SIGNIFICANCE

- Essential feature that distinguishes a child from an adult.
- Indicates overall well-being of a child.
- Reflects the nation’s economic status and public health system.
FACTORS AFFECTING GROWTH

• Prenatal period
  – Fetal
  – Placental
  – Maternal

• Postnatal period
  – Genetic
  – Environmental
FACTORS AFFECTING PRENATAL GROWTH

A. Genetic Potential

• Parental trait - Tall parents have tall children
  - Head size related to parents

• Sex - Boys larger than girls

• Race - Growth differs in different races
FACTORS AFFECTING PRENATAL GROWTH

B. Fetal Growth Factors

Growth Promotion

• Insulin like growth factors (IGF-I and IGF-II) (~70%)
• Epidermal growth factor
• Transforming growth factor α (TGF-α)
• Platelet derived growth factor
• Fibroblast growth factor
• Nerve growth factor etc.

Growth Inhibition

• Transforming growth factor β (TGF-β)
• Mullerian inhibiting substance (AMH)
• Inhibin / Activin family of proteins
FACTORS AFFECTING PRENATAL GROWTH

C. Fetal hormones

• Have predominant role in late gestation
• Insulin and Thyroxine: Important for accretion and differentiation of tissues
• Glucocorticoids: Required for maturation of organs like lungs, liver and GI tract
• Note: Influence of Growth hormone on fetal growth is minimal.
FACTORS AFFECTING PRENATAL GROWTH

D. Placental factors

• Placenta is essential for nutrition of fetus
• Fetal nutrition is enhanced by
  – Increased villous surface area
  – Decreased diffusion distance
  – Increased dilatation of fetal capillaries
  – Decreased resistance of vasculature
FACTORS AFFECTING PRENATAL GROWTH

E. Maternal factors

– Poor nutrition
– Anemia
– Recent pregnancy
– High parity
– Tobacco, drug, alcohol intake

– Pregnancy Induced Hypertension
– Multiple pregnancy
– Chronic systemic diseases
– TORCH infections
OVERALL REGULATION OF FETAL GROWTH

Normal glucose and amino acid availability

IGFBP-3  IGF-I  IGFBP-1

GH  IGF-I  Insulin

GROWTH

Normal glucose transport in muscle and brain
FACTORS AFFECTING POSTNATAL GROWTH

A. Sex

- Boys have greater growth potential than girls
- Girls have early pubertal height spurt than boys
- Pubertal height gain is more in boys
FACTORS AFFECTING POSTNATAL GROWTH

B. Genetic

- Chromosome defect
  - Short stature: Down syndrome, Turner syndrome
  - Tall stature: Klinefelter syndrome
- Gene mutation
  - Short stature: Prader-Willi syndrome, Noonan syndrome
  - Tall stature: Marfan syndrome
FACTORS AFFECTING POSTNATAL GROWTH

C. Environmental

• Nutrition
  – PEM, Micronutrient deficiency (Fe, Io, Ca, Zn, VitA, VitD)

• Infections
  – Diarrhea, recurrent RTI, TB, HIV, Malaria, Kala-azar, Chronic giardiasis

• Toxins
  – Food, environment.
Factors affecting postnatal growth

D. Hormonal

• Growth hormone deficiency
• Hypothyroidism
• Growth hormone resistance
FACTORS AFFECTING POSTNATAL GROWTH

E. Social factors

- Low socio economic status: Poor diet, infections
- Hot and humid climate
- Poor emotional support: Broken family, orphans
- Cultural factors: Religious taboos
- Low parental education: Poor health promotion, poor nutrition.
LATE CONSEQUENCES OF POOR FETAL GROWTH (NUTRITION)

Fetal origin hypothesis (Barker’s hypothesis)

• Alterations in fetal nutrition and endocrine status lead to programming
• Permanent changes in structure, physiology and metabolism
• IUGR infants have increased risk of diabetes mellitus, hypertension, hyperlipidemia and coronary artery disease
LAWS OF GROWTH (I)

- Growth is a continuous and an orderly process.
- The rate of growth is not uniform – There are periods of acceleration, deceleration and steadiness.
PHASES OF GROWTH ACCELERATION, DECELERATION AND STEADINESS

• Acceleration (fast) - 1st Half of gestation, 1st year of life, Puberty
• Deceleration - 2nd year
• Steady rate - 6-9 years of age
ICP MODEL FOR POSTNATAL GROWTH (KARLBERG)
HEIGHT ATTAINMENT DURING EACH PHASE

- **Infancy**: Starts before birth and falls off by age 3 to 4 years. Average total height gain is 45%.
- **Childhood**: Begins at the end of the first year of life and continues to mature height. Average total height gain is 47%.
- **Puberty**: This phase starts with initiation of puberty. Average height gain is 8%
PREDOMINANT CONTROL IN EACH PHASE OF GROWTH

- **Infancy:** Nutrition, GH, thyroxine
- **Childhood:** GH and thyroxine
- **Puberty:** Sex steroid and GH.
LAWS OF GROWTH (II)

Growth pattern of every individual is unique.

- Cephalocaudal
- Distal to proximal
LAWS OF GROWTH (III)

• Different tissues of the body grow at different rates
• General growth: Rapid during fetal life, first 1-2 y and at puberty
• Brain and head: Rapid during late fetal and early postnatal life

At birth 70%, at 2 y 90% of adult.
LAWS OF GROWTH (II)

- Lymphoid – maximum growth during mid-childhood (4-8y) Large tonsils and lymph nodes
- Gonads – grow at pubescence only
PERIODS OF GROWTH

Prenatal period
• Ovum: 0-1w
• Embryo: 2-8w
• Fetus: 9w - birth
• Perinatal period: 22wk of gestation to 7 days after birth.

Postnatal period
Newborn: Birth to 28 days
Infancy: First year
Toddler: 2-3y
Preschool: 4-6y
School age: 7-12y
Adolescence: 10-18y
**PRENATAL GROWTH**

### Embryonic period
- **2wk:** Bi-laminar embryo
- **3wk:** Tri-laminar embryo, Heart pumping begins
- **4wk:** 4cms, human shape, arm-leg buds
- **5-8wk:** Major organ system development
- **9wk:** 9g, 5cm. Fetal period begins.

### Fetal period
- **10wk:** External genitalia distinguishable
- **20wk:** 460gm, 19cms, lower limit of viability
- **24w:** Primitive alveoli, surfactant production
- **25wk:** 900gm, 25cm, 3rd trimester begins
- **38wk:** Term, weight triples, length doubles from that of 25 w of gestation
PARAMETERS OF GROWTH

• Weight.
• Length <2 y or Height >2 y.
• Head circumference (HC), Chest circumference (CC).
• Upper segment to lower segment (U:L) ratio.
• Arm span (AS).
AVERAGE GROWTH PARAMETERS AT BIRTH

• Weight: 3 Kg
• Length: 50 cm
• U/L ratio: 1.7
• HC: 35 cm
• CC: 33 cm
# POSTNATAL GROWTH: WEIGHT

<table>
<thead>
<tr>
<th>Age group</th>
<th>Weight gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 m</td>
<td>25-30g/day</td>
</tr>
<tr>
<td>4m-1 yr.</td>
<td>400g/month</td>
</tr>
<tr>
<td>2yr – Pubertal growth spurt*</td>
<td>2-3 Kg/y</td>
</tr>
<tr>
<td></td>
<td>or</td>
</tr>
<tr>
<td></td>
<td>[Wt. in Kg = (Age in years +4) X 2]</td>
</tr>
<tr>
<td>• Weight doubles at 5m, triples at 1 y, quadruples at 2y</td>
<td></td>
</tr>
<tr>
<td>* Boys 12 y, girls 10 y.</td>
<td></td>
</tr>
</tbody>
</table>
# POSTNATAL GROWTH: LENGTH/HEIGHT

<table>
<thead>
<tr>
<th>Age group</th>
<th>Height velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 m</td>
<td>3.5cm/m</td>
</tr>
<tr>
<td>4-6m</td>
<td>2cm/m</td>
</tr>
<tr>
<td>7-9m</td>
<td>1.5cm/m</td>
</tr>
<tr>
<td>10-12m</td>
<td>1.2cm/m</td>
</tr>
<tr>
<td>13-24m</td>
<td>1cm/m</td>
</tr>
<tr>
<td>3-10 yr.*</td>
<td>5-6cm/y</td>
</tr>
</tbody>
</table>

*Weech’s formula: Ht in cms = (Age in years × 6) + 77*
# Postnatal Growth: Adolescence

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>EARLY</th>
<th>MIDDLE</th>
<th>LATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>9-13</td>
<td>14-16</td>
<td>17-20</td>
</tr>
<tr>
<td>Weight gain/Year</td>
<td>2Kg</td>
<td>3.5Kg</td>
<td>1Kg</td>
</tr>
<tr>
<td>Height gain/year</td>
<td>6-8cms</td>
<td>8-10 cm</td>
<td>2-3 cm</td>
</tr>
<tr>
<td>SMR* stages</td>
<td>1,2</td>
<td>3,4</td>
<td>5</td>
</tr>
</tbody>
</table>

* Sex maturity rating  
Mean pubertal height gain: Boys - 27 cm, girls - 25 cm  
Mean pubertal weight gain: Boys 29kg, girls 24 kg
## POSTNATAL GROWTH
### UPPER SEGMENT TO LOWER SEGMENT RATIO

<table>
<thead>
<tr>
<th>Age</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>1.7</td>
</tr>
<tr>
<td>6m</td>
<td>1.6</td>
</tr>
<tr>
<td>2yr</td>
<td>1.4</td>
</tr>
<tr>
<td>3yr</td>
<td>1.3</td>
</tr>
<tr>
<td>4yr</td>
<td>1.2</td>
</tr>
<tr>
<td>6yr</td>
<td>1.1</td>
</tr>
<tr>
<td>10yr</td>
<td>1.0</td>
</tr>
<tr>
<td>Adults</td>
<td>0.9</td>
</tr>
</tbody>
</table>

>6m age U/L ratio = 1.6 (Age in years × 0.1)
<table>
<thead>
<tr>
<th>Age</th>
<th>Rate of increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth-3m</td>
<td>2cm/m</td>
</tr>
<tr>
<td>4m-6m</td>
<td>1cm/m</td>
</tr>
<tr>
<td>7m-12m</td>
<td>0.5cm/m</td>
</tr>
<tr>
<td>2nd y</td>
<td>1cm/y</td>
</tr>
<tr>
<td>&gt;2y</td>
<td>0.5cm/y</td>
</tr>
<tr>
<td>By 12 y</td>
<td>52 cm</td>
</tr>
</tbody>
</table>
POSTNATAL GROWTH
CHEST CIRCUMFERENCE (CC)

Birth: $HC > CC$
1 year: $HC = CC$
> 1 year: $HC < CC$
POSTNATAL GROWTH: ARM SPAN (AS)

<table>
<thead>
<tr>
<th>Age</th>
<th>Height Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 5 y</td>
<td>Ht  2cm &gt; arm span</td>
</tr>
<tr>
<td>5-10 y</td>
<td>Ht  1cm &gt; arm span</td>
</tr>
<tr>
<td>10 y</td>
<td>Ht  = arm span</td>
</tr>
<tr>
<td>Adults</td>
<td>Ht  2cm &lt; arm span</td>
</tr>
</tbody>
</table>
POSTNATAL GROWTH: SKELETAL MATURATION

• Steady in childhood, accelerates at puberty
• Closely correlates with sexual maturation
• Maturity indicated by epiphyseal closure
• Complete in boys at 22 y, girls at 18 y

Preferred areas for bone age estimation by radiography

Birth-3m      knee and ankle
3-9 m         Shoulder
1-13 y        Hands and wrists
12-14 y       Elbow and hip
### POSTNATAL GROWTH – DENTITION

<table>
<thead>
<tr>
<th>Primary teeth (20)</th>
<th>Age at eruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisors</td>
<td>5m to 8m</td>
</tr>
<tr>
<td>Lateral incisors</td>
<td>7m to 11m</td>
</tr>
<tr>
<td>Canines</td>
<td>16m to 20m</td>
</tr>
<tr>
<td>I Molar</td>
<td>10m to 16m</td>
</tr>
<tr>
<td>II Molar</td>
<td>20m to 30m</td>
</tr>
</tbody>
</table>

**Approximate assessment**

Expected number of teeth = Age in months - 6
# POSTNATAL GROWTH – DENTITION

<table>
<thead>
<tr>
<th>Permanent teeth (32)</th>
<th>Age at eruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>I molars</td>
<td>6 to 7 y</td>
</tr>
<tr>
<td>Incisors</td>
<td>6 to 8 y</td>
</tr>
<tr>
<td>Canines</td>
<td>9 to 12 y</td>
</tr>
<tr>
<td>Premolars</td>
<td>9 to 12 y</td>
</tr>
<tr>
<td>II Molar</td>
<td>12 y</td>
</tr>
<tr>
<td>III Molar</td>
<td>≥ 18 y</td>
</tr>
</tbody>
</table>
GROWTH STANDARDS

• Norms of growth represented as tables or charts
• Derived from large cohort of healthy children by cross sectional or longitudinal studies
• Tables are useful as easy ready references
GROWTH CHARTS

• Superior to tables to diagnose early deviations in growth
• Distance growth charts reveal the growth acquired till the date of last evaluation
HEIGHT VELOCITY CHARTS

• Height velocity: Rate of height increment per unit time and
• Indicates periods of acceleration, deceleration and steadiness
• Most useful for early identification of growth faltering
DISTANCE GROWTH CHARTS

• Growth parameters are presented in graphical manner
• Age along the X axis and measurements in the Y axis
• Charts have 5 or 7 percentile curves representing the distribution of the growth parameters
GROWTH PARAMETERS IN GROWTH CHARTS

- Weight for age
- Height/length for age
- Head circumference for age
- Weight for length/height
- Body mass index

Each parameter separate for boys (Blue) & girls (pink)
PLOTTING HEIGHT ON A GROWTH CHART

- 8 years old boy,
- Height: 120 cm,
- Draw an imaginary line along the X-axis till the age (8y) of the child.
- Then extend the imaginary line along the Y-axis till the height (116 cm) of the child.
- Mark the point
RECOMMENDED GROWTH CHARTS

WHO, derived from MGRS study 0-5 years

Revised IAP Growth charts, 2015

Height, weight, HC for 0-5 y
Weight for height for 0-5 y

Height, weight, BMI for 5-18 y
WHO GROWTH CHARTS - 2006

• Ideal growth charts that provide data on how children should grow
• Internationally usable standard growth charts
• Multi-center Growth Reference Study (MGRS) from 5 Continents.
• Study sites – US, Brazil, Ghana, Oman, Norway, India.
WHO GROWTH CHARTS - 2006

• Derived from children raised under optimal conditions for growth such as:
  – Exclusive breast feeding
  – Healthy environment
  – Minimal infection
  – Nonsmoking mothers
STATISTICS USED IN DESCRIBING GROWTH

• Normal: Healthy.
• Median: Value above and below which 50% of observations lie.
• Mode: Value having highest number of observations.
• Mean: The average value of observations.
• Standard deviation or Z score: The extent to which observed values cluster near the mean.
NORMAL DISTRIBUTION (GAUSSIAN) CURVE

• Symmetrical bell shaped curve in which 50% of the observations lie above & 50% below a central line which is the 50th percentile or median

• Values below 3rd (-2SD) and above 97th (+2SD) percentile are abnormal.
UNDERSTANDING OF PERCENTILES

- 8 years old boy,
- Height: 120 cm,
- 10\textsuperscript{th} percentile for his age and sex
- 10\% of boys aged 8y in the reference populations are shorter and 90\% are taller than the index child
THANK YOU