

## Human ontogeny – notes for Human biology course

### Auxology

- the study of all aspects of human physical growth
- a highly multi-disciplinary science involving: medicine (paediatrics, general practice, endocrinology, physiology, and to a lesser degree other fields); nutrition; genetics; anthropology, anthropometry; socioeconomics, sociology; public health

#### - *auxology studies:*

- the biological aspects of physical growth and development of children and adolescents
- the morphological and physiological changes that occur since the intrauterine stage through early life and that have an effect on the rest of the human life cycle
- within socioeconomic and cultural context
- both in normal and pathological conditions
- by taking in account their environmental, socioeconomic and emotional situations

#### *the main aims of human ontogenic studies:*

- to reveal the structural and functional changes during human development (growth and maturation) from the undifferentiated or immature state to a highly organized, specialized or mature state
- to determine the normal range of these developmental processes

### Ontogeny:

- the origin and the development of an organism
- starts with fertilization and ends with the attainment of an adult state, usually expressed in terms of both maximal body size and sexual maturity

### Human development

As individuals pass through the life stages, four main types of development occur:

- 1) Physical development: progressive changes in size, shape and function of the body till complete maturity; the genetic potentials are translated into functioning adult systems
- 2) Mental development: refers to development of psychical, cognitive and psychosocial characteristics
- 3) Emotional development: refers to children's increasing awareness and control of their feelings and how they react to these feelings in a given situation
- 4) Social development: refers to children's ability to interact with their peers and adults in a socially acceptable way

### Development

- progression of changes from undifferentiated or immature state to a highly organized, specialized or mature state
- a sequence of orderly, often irreversible changes; can occur with or without an increase in size
- results from genetic plans contained within the chromosomes
- the developmental process depends upon a precisely coordinated interaction of genetic and environmental factors
- differentiation: one cell → many cell types and functions, the first cells are totipotent, later differentiation steps generate groups of pluripotent cells, terminal differentiation and dedifferentiation,
- morphogenesis: formation of anatomical structures (physical and chemical), process by which the adult assumes final shape
- **Growth:** quantitative increase in size or mass, a component of development – achieved via increased cell number or size or production of extracellular matrices
- **Maturation:** the process and the state of reaching functional capacity in terms of biological, behavioural and cognitive capacities, a component of development – increasing complexity, a progression of changes

## **Human life cycle**

Life cycle: stages of development (growth and maturation) from conception to death of any organism

- developmentally functional stages
- life cycle begins with fertilization
- then proceeds through prenatal growth and development
- birth
- postnatal growth and development (neonatal stage, infancy, childhood, puberty)
- maturity
- senescence
- ends with death
- - social mammals have three basic stages of postnatal development: infant, juvenile and adult
- - the human life cycle, however, is best described by five stages: infant, child, juvenile, adolescent and adult
- women have a long post-reproductive stage
- the current human pattern evolved after the appearance of *Homo erectus*
- the new life stages of the human life cycle represent feeding and reproductive specializations of the genus *Homo*

*human pattern of growth and development differs markedly from patterns of ontogeny in other primate species:*

- infant dependency
- extended childhood
- juvenile and adolescent stages prior to social and sexual maturation

*these characteristics are advantageous for us, because they provide:*

- an extended period for brain development
- time for the learning and training of technical skills (tool making, food processing)
- time for socialization, play, development of complex social roles and cultural behaviour

## **Prenatal life**

- divided into three-months periods, trimesters

*Prenatal age*

- time elapsed since fertilization
- mean duration is 38 weeks/264 days
  - germinal period: first 2 weeks
  - embryonic period: 2 to 8 weeks
  - foetal period: 2 to 9 months

***First trimester:***

- from fertilization to 3rd month
- embryogenesis (to 8th week): multiplication of a single cell, the fertilized ovum (zygote)
- cellular differentiation: separate groups of cells form germ layers: endo-, meso- and ectoderma
- by the 8th week the embryo has many phenotypic characteristics that may be recognized as human
- cellular growth: hyperplasia (cell division by mitosis) and hypertrophy (enlargement of already existing cells)
- the most active metabolic dynamics of human organism
- embryogenesis: multiplication of a single cell
- cellular differentiation: separate groups of cells from germ layers: endo-, ecto- and mesoderm
- cellular growth: hyperplasia (cell division by mitosis) hypertrophy (enlargement of already existing cells)
- by the 8th week the embryo has many phenotypic characteristics that may be recognized as human, and foetal heartbeat is detectable with ultrasound

### ***Second trimester***

- rapid growth in length and weight
- differentiation of cells into tissues and organs is complete by the start of this trimester: embryo is a foetus

### ***Third trimester:***

- growth in weight takes place at a relatively faster rate
- development and maturation of circulatory, respiratory, digestive systems occur: preparing the foetus for the transition to extra-uterine life
- growth decreases by the end of this trimester: intrauterine space limitation, exchange of substances (nutrition, respiration, metabolic wastes) is blocked (- - -: predicted curve if no restriction takes place)
- from the 28th week: adding body fat
- by the end of this trimester: less active foetus

### ***Germinal period – first 2 weeks after fertilization***

- conception: the union of the male sperm and female ovum
- life starts with a single cell, the fertilized ovum
- segmentation: growth by cell division in the early stages of gestation (with little or no increase in size) – the fertilized egg divides repeatedly into a mass of cells
- the cells differentiate into 2 layers: inner and outer layers – the blastocyst is forming: a thin-walled hollow structure in early embryonic development that contains a cluster of cells called the inner cell mass from which the embryo arises
- implantation: fertilized egg (zygote) attaches to the inner wall of the uterus

### ***Embryonic period***

- gastrulation: the blastula is reorganized into a trilaminar ("three-layered") structure (gastrula)
  - the germ layers: ectoderm, mesoderm and endoderm
- ectoderm: the outermost primary tissue layer that forms first in all animal embryos, it will give rise to the tissues of the nervous system and the structures that form the outer surface such as hair and teeth
- endoderm: the innermost layer, it forms the gut and structures derived from the gut
- mesoderm: the intermediate layer (last to arise evolutionarily), it is important in the formation of almost all organ systems including the muscles, skeleton and connective tissues.
- after these layers form, subpopulations of cells give rise to the organs – every body part develops from these 3 layers

### ***Foetal period – 2 to 9 months***

- growth and development continue dramatically
- 3 months after conception the foetus has become very active, moving its arms and legs, opening and closing its mouth, moving its head
- face, forehead, eyelids, nose, chin, arms, hands, lower limbs are distinguishable, the genitals can be identified as male or female
- Zygote: the initial cell formed when two gamete cells are joined by means of sexual reproduction; in multicellular organisms, it is the earliest developmental stage of the embryo
- Embryo: stage of prenatal development lasting from second to eight week following fertilization, characterized by the rapid differentiation of tissues and the formation of organs
- Foetus: stage of prenatal development lasting from eight week following fertilization to birth

## **Birth**

- transition between life in uterus and independent life of uterine environment
- the most common indicator of inadequate prenatal growth is birth weight (BW)
- low birth weight: less than 2500 grams at birth)
- prematurity: birth before 37 weeks of gestation
- SGA (small for gestation age) neonate: BW less than the P10 for gestation
- causes of low BW: congenital problems, placental insufficiency, maternal conditions: undernutrition, disease, smoking, alcohol consumption, maternal age, socioeconomic status (education, occupation, social prestige)
- other measures of growth at birth: recumbent length (person measured is lying down), circumference of the head, arm, chest, skinfolds
- small sexual dimorphism: boys are a bit longer, heavier and larger headed, have slightly less subcutaneous fat than girls
- physiological weight loss after birth (transient): volume of extracellular water decreases (insufficient renal activity and nutrition)
- body proportions: head circumference 70% of length (30% at maturity), growth of the brain proceeds faster rate than the growth of the body during foetal, infant and childhood growth, relative short limbs: length of limbs become longer relative to body length during growth

## **Infancy: 0 ys: birth – 3 ys: last deciduous tooth emergences**

- neonatal period: birth to 28 days
- physiological weight loss after birth: the volume of extracellular water decreases (insufficient renal activity and nutrition)
- leading causes of neonatal deaths:
  - birth defects
  - disorders related short gestation
  - maternal complications
- most rapid velocity of growth of any of the postnatal stages (rapid velocity during the first year, then very steep deceleration in velocity, continuation of the foetal pattern, peak of growth velocity in the 2. trimester lasts until childhood
- different patterns of growth:
  - lymphoid type: thymus, lymph-nodes, ...
  - neural type: brain, dura, spinal cord, ...
  - general type: body as a whole, respiratory and digestive organs, kidneys, musculature as a whole, ...
  - genital type: testis, ovarium, uterine tube, prostate, seminal vesicles, ...
- mother provides all nourishment to her offspring via lactation until the end of infancy (until the 6th month, no teeth, fluid food)
- deciduous teeth emergency (milk teeth)
- rate and amount of growth in most infants is similar (no ethnic, socioeconomic difference, lactation)
- motor skills (physical ability, motor coordination) develop rapidly: by 7 month: infant can sit, by 8 month: crawl, by 12 month: walk with support, 2 years: walk, turn the pages of a book, 3 years: run, manipulate small objects
- similar progress of changes in problem solving, cognitive abilities of the infant
- brain grows more rapidly than any other tissue or organ

## **Childhood: 3 ys: last deciduous tooth emerged – 7 ys: permanent teeth emergence**

- childhood diet: easy to chew and swallow, low in total volume – immature dentition and small digestive system

- replacement of the deciduous teeth by the emergence of the first permanent teeth (4 first molars and 4 first incisors: sufficient to eat an adult-type diet)
- completion of growth of the brain in weight
- locomotive skills develop and mature
- these features indicate that the physically dependent children is moving on to independence
- moderate growth rate
- mid-growth spurt: at the end of childhood small increase in the velocity of growth

**Prepuberty: 7 ys: permanent teeth emergence – ♀: 10 ys, ♂: 12 ys: growth rate increases again**

- prepubertal individuals those are no longer dependent on their mothers for survival
- juveniles have all the physical and cognitive abilities to provide much of their own food and provide themselves from accidents and disease (street children)
- rate of growth declines: juveniles growth at the slowest rate since birth

**Adolescence: 11-12 ys – 15-16 ys**

- a transitional stage of physical and psychological human development that generally occurs during the period from puberty to legal adulthood
- puberty: the stage of adolescence in which an individual becomes physiologically capable of sexual reproduction
- the reinitiation of activity of the hypothalamic-pituitary-gonadal system of hormone reproduction
- most of the body measurements, inner organs increase in every dimension
- sexual dimorphism in body size, proportions, body composition and shape, deepening of voice in boys
- genitals are developing and secondary sexual characteristics are appearing
- very long transition from puberty to adulthood (full reproductive maturity: 5-8 years (monkey: 3 years): social and sexual maturation takes place
- differences among populations in timing of onset of adolescent maturation stages
- both boys and girls experience adolescent growth spurt (a rapid acceleration in the growth velocity), boys do it 2-3 years later than girls
- different parts of the body do not experience AGS at the same time (foot, hand, leg, arm, stature, trunk)
- size of the spurt and age of peak velocity are not related to final adult height
- permanent tooth eruption completed (almost)
- the onset of puberty is followed within a few months by the appearance of the secondary sexual characteristics (pubic hair, axillary hair, ...)
- usually every child experiences the same sequence in the order of appearance and timing of the secondary sexual characteristics
- PHV: peak height velocity
  - 7-12 cm/yr in boys, 6-11 cm/yr in girls
  - greater in adolescents who experience it earlier
- PWV: peak weight velocity
  - adolescents experience it after PHV
  - greater in boys than in girls

**Adulthood**

- the longest lasting stage in the human life cycle, stretching from age 20 to 50 ys
- the prime adulthood lasts until the end of child-bearing years and is a time of homeostasis in physiology, behaviour and cognition

**Senescence**

- characterized by a decline in the function of many body tissues or systems
- usually begins after the end of child-bearing years and lasts until death