Bi7878 General Anthropology I 2nd Nov. 2022

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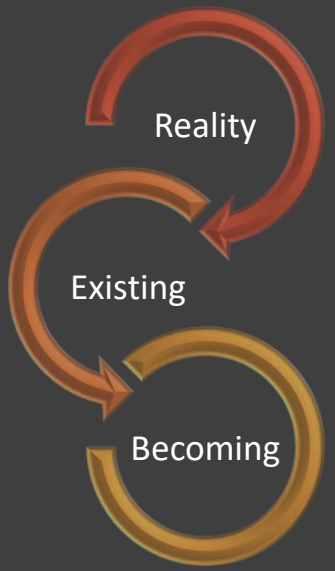
Human ontogeny & Individual Growth

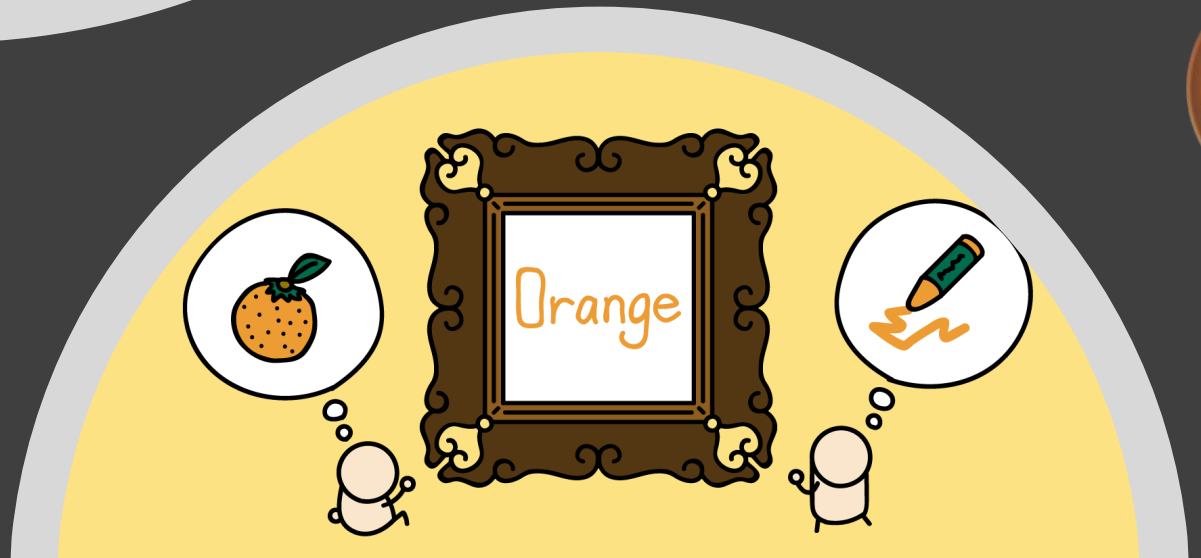
What is the Ontogeny?

- Origination & development of an organism (both physical and psychological)
- **From** the time of fertilization of the egg **to** adult
- Can also be used to refer to '*the study of the entirety of an organism's lifespan*'

Not to be confused with ontology!

- Metaphysics, which is a branch of Philosophy
- Science of being & related concepts as:





Basic concepts

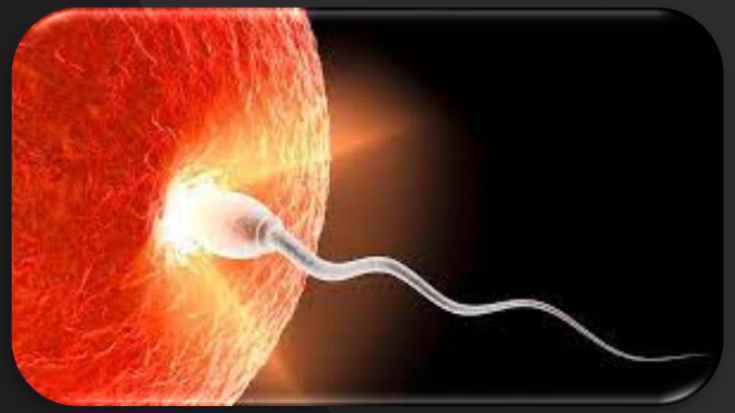
1. Growth
2. Development
3. Maturation

1. Growth

- Increase in the size of the body or its parts
- length, dimensions, weight, volume
- Recorded in measurements units
- Expressed and displayed in graphs

Basic concepts

1. Growth
2. Development
3. Maturation



2. Development

- Process of changes
- Quantitative or qualitative
- Transformation of organism

from undifferentiated & immature **into** a highly specialized, mature and adult form (Bogin 1999)

- Systematic changes of an individual

between conception **&** death (Sigelman & Rider 2009)

Different types of development

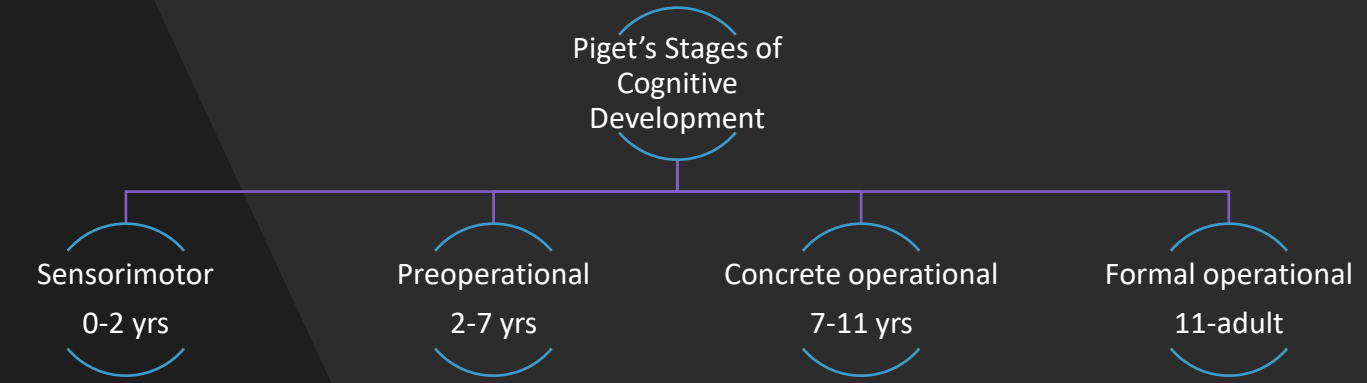
1. Physical development
2. Cognitive development
3. Psychosocial development

- The first and most basic of the three development types
- Includes height, weight, muscle tone, reflexes and balance
- But also things like the onset of puberty and a monitoring of appropriate vital signs

Different types of development

1. Physical development
2. Cognitive development
3. Psychosocial development

Development of mental skills, from basic perception of the different senses to speech and complex thought

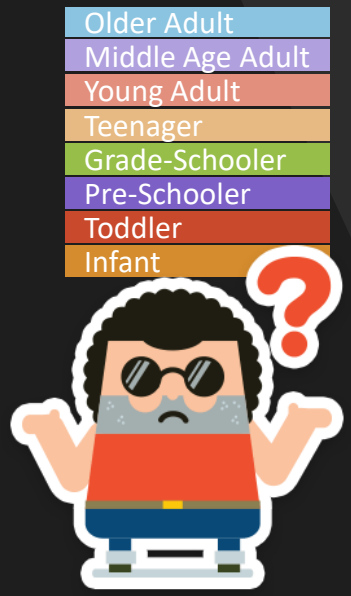


Woolfolk 2010

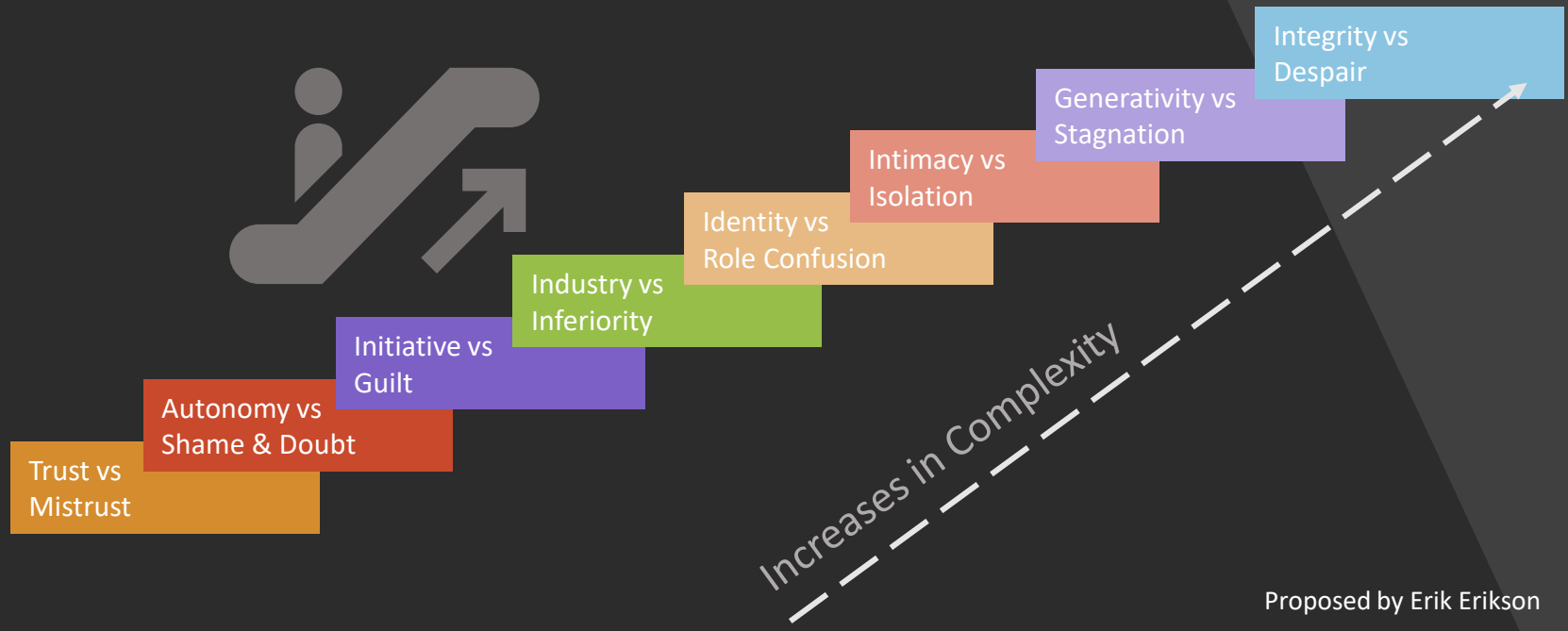
Different types of development

1. Physical development
2. Cognitive development
3. Psychosocial development

Changes in personal and interpersonal aspects of development as: motivations, emotions, personality traits, interpersonal relationships, social roles in the family and wider society



Stages of Psychosocial Development



Proposed by Erik Erikson

Basic concepts

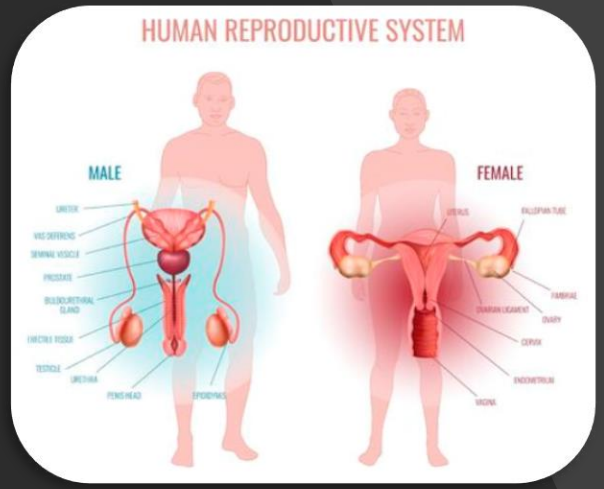
1. Growth
2. Development
3. Maturation

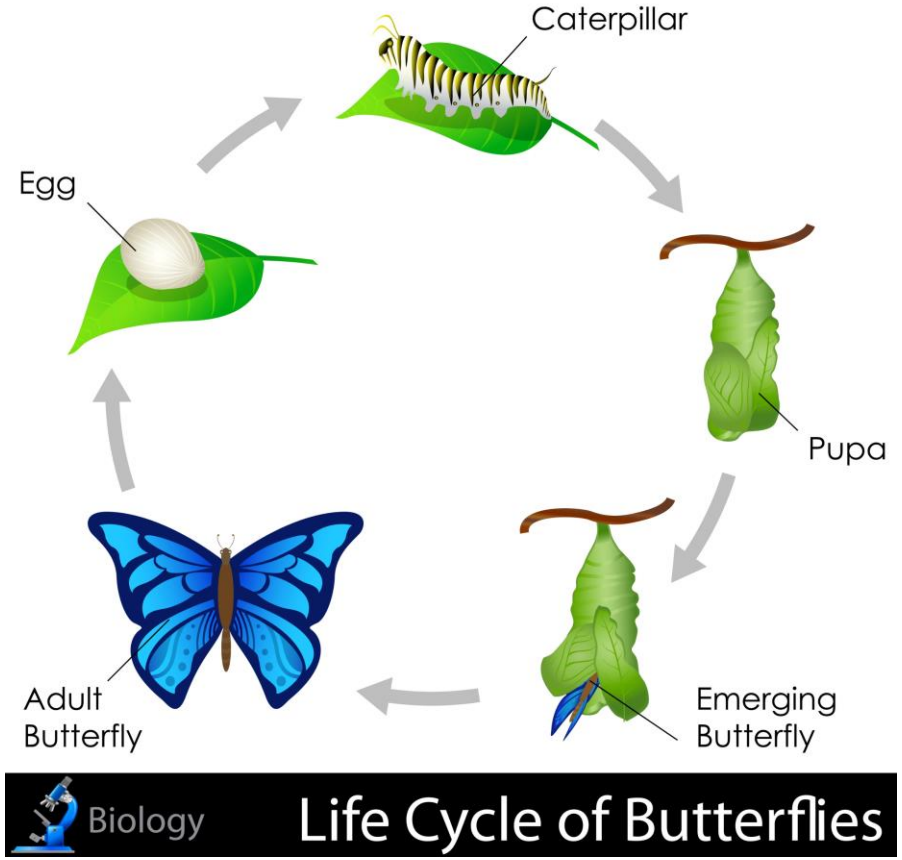
3. Maturation

- Functional capacity

Sexual maturation = achievement of a fully functional reproductive system

Skeletal maturation = achievement of a fully ossified adult skeleton (Bogin 1999)



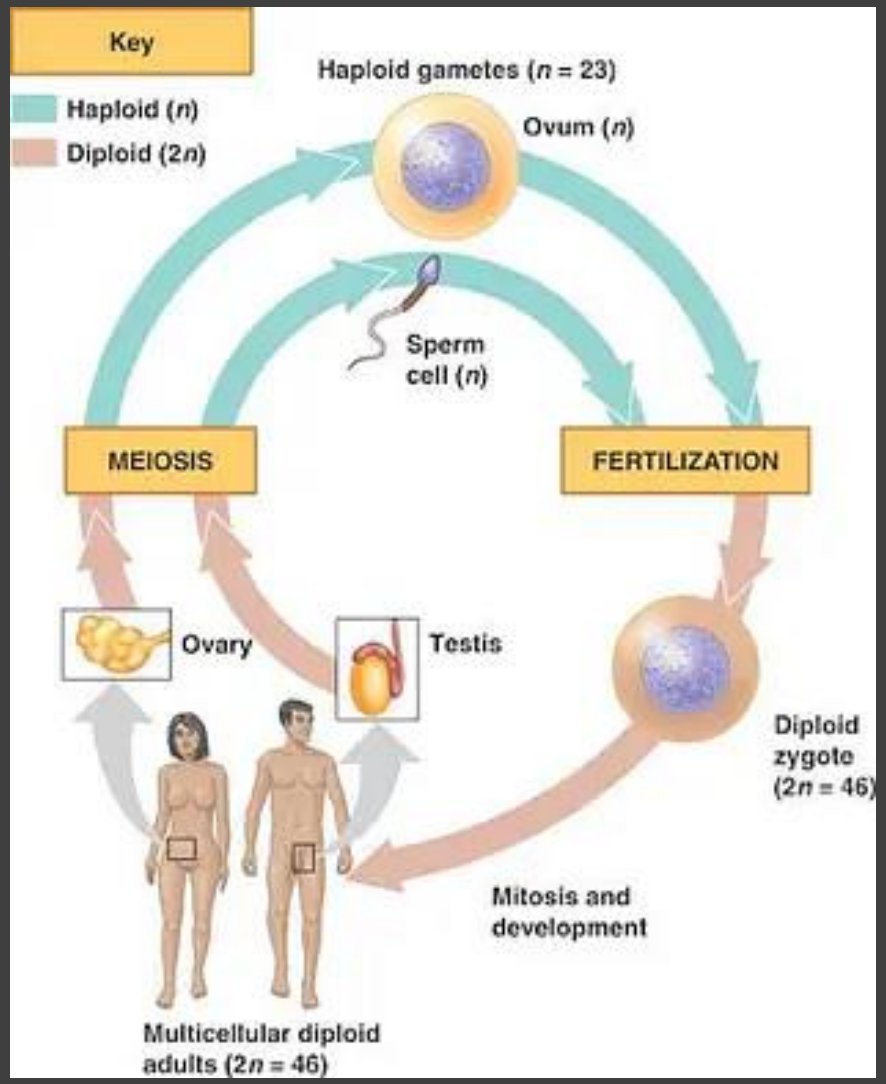


Life cycle

Proposed by Erik Erikson

The period of one generation of an organism from the creation of the organism to its reproduction

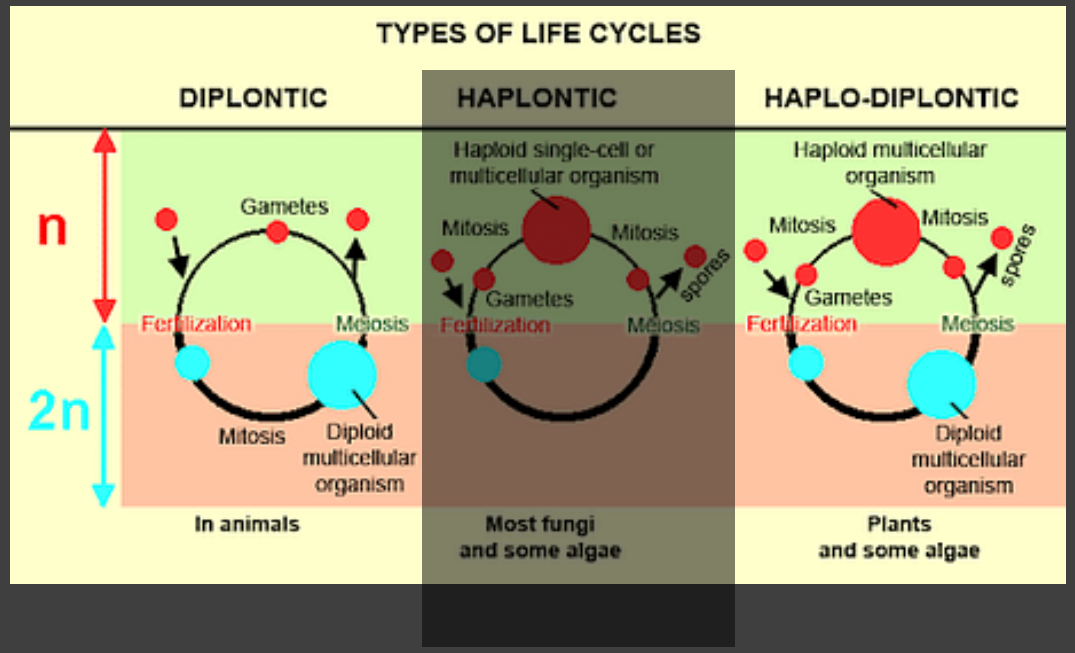
What is a Life Cycle?



- Refers to ‘the biological changes an organism goes through in its life span’
- More precisely ‘the changes happening to an organism from its birth till its next generation
- These changes or transitions may vary completely from each other
- Might be in the form of sexual or asexual reproduction

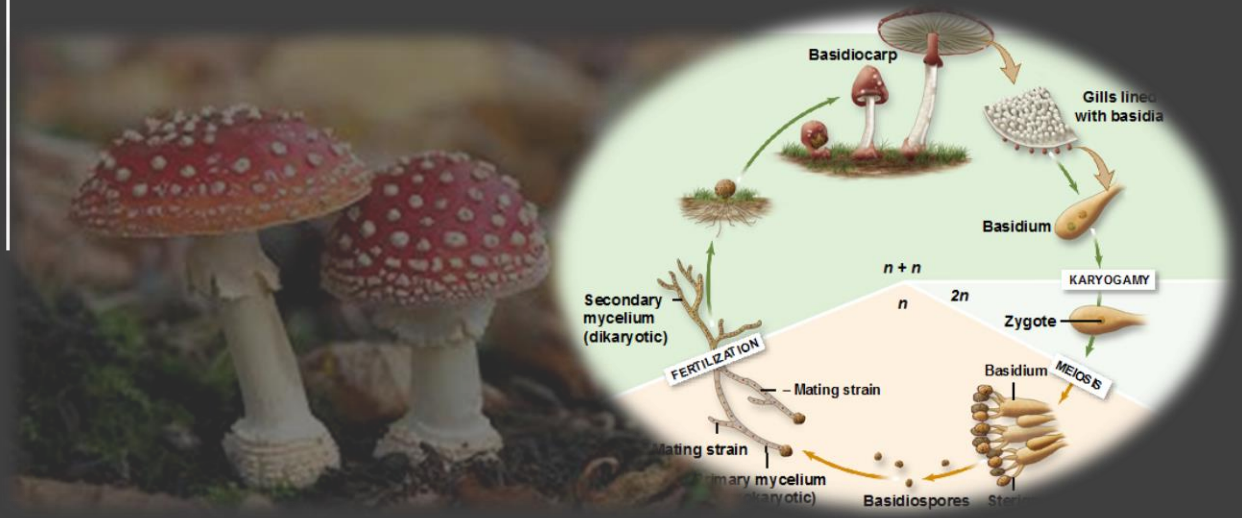
3 Types of Life Cycle

with reference to the ploidy



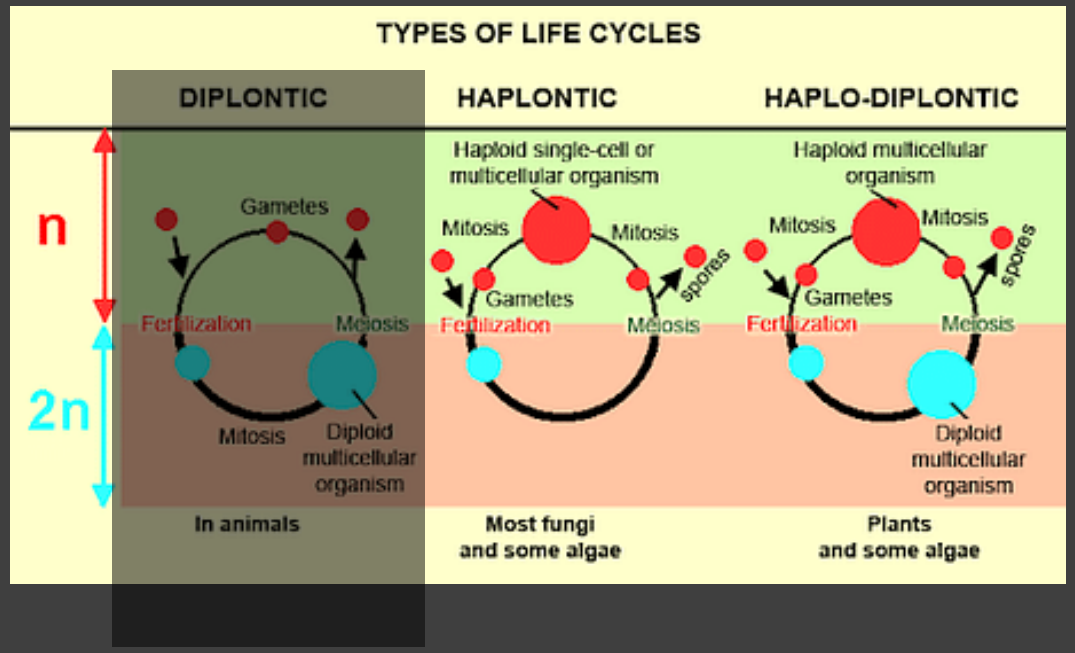
1. Haplontic life cycle

- 23 chromosomes & denoted by n.
- meiosis is of zygotic nature
- haploid is dominant and multicellular
- diploid is a single independent cell



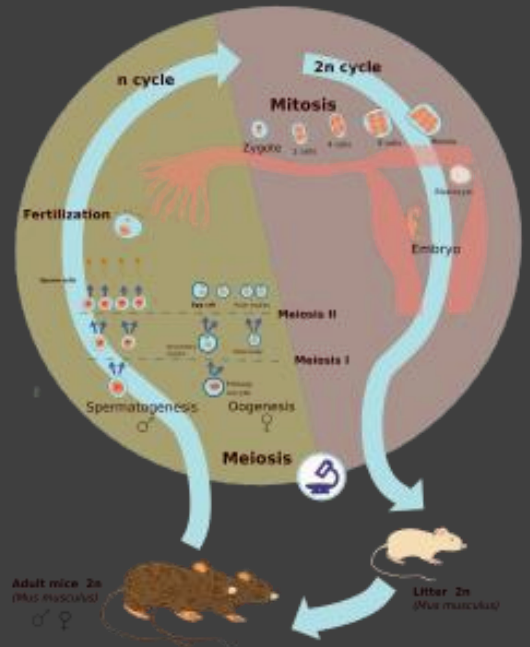
3 Types of Life Cycle

with reference to the ploidy



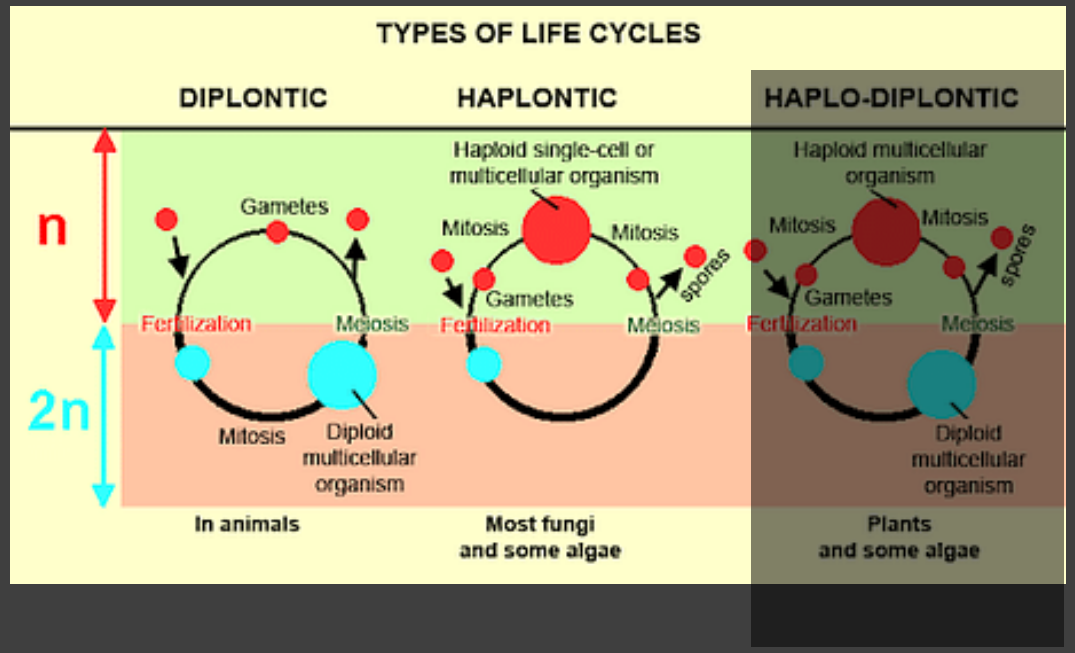
2. Diplontic life cycle

- 46 chromosomes present & denoted as 2n
- mitosis is observed here
- diploid sporophyte is in charge here
- observed in Angiosperms and Gymnosperms



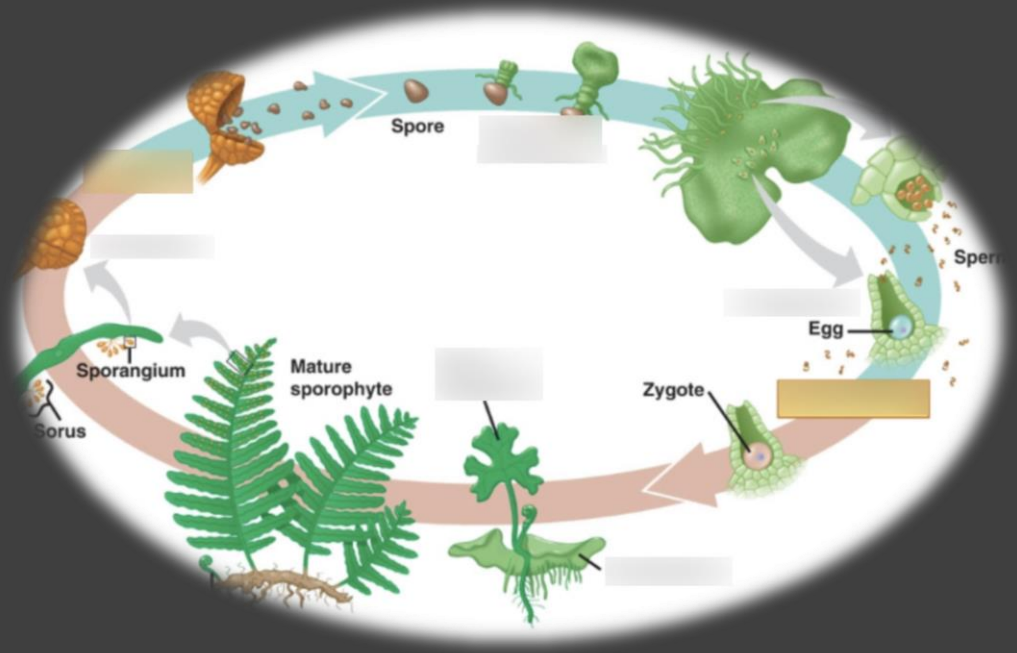
3 Types of Life Cycle

with reference to the ploidy



3. Haplodiplontic life cycle

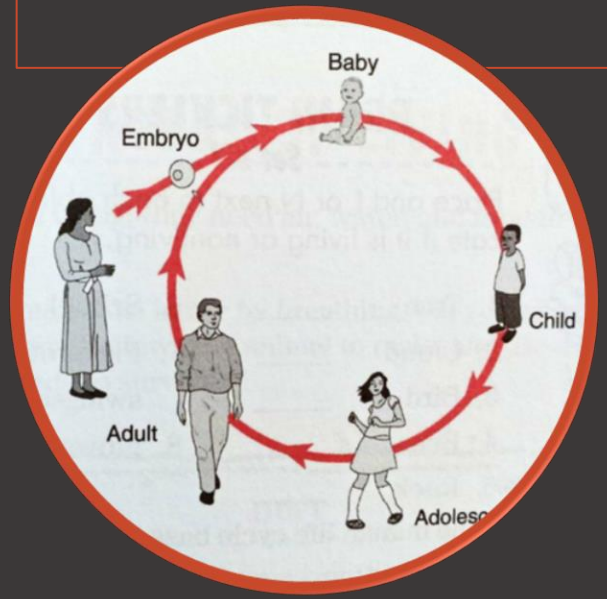
- multicellular phase
- seen in bryophytes
- also known as the diplobiontic cycle



Comparison of human and eel life cycle

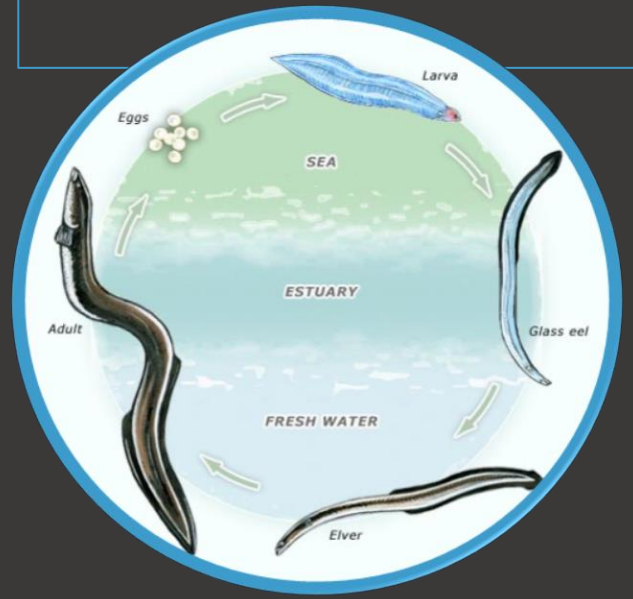
Human

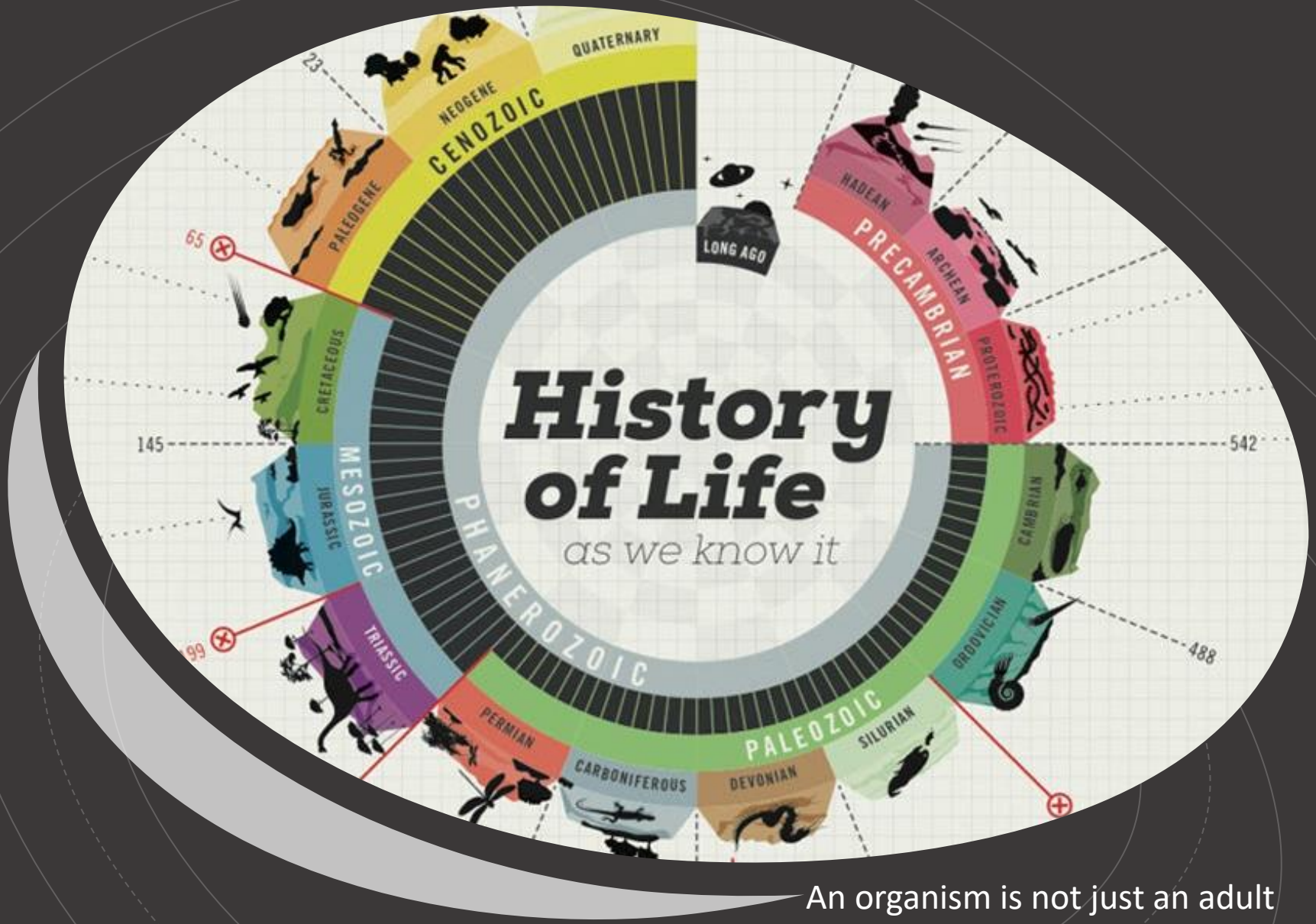
- Sexual reproduction
- Internal fertilization
- Embryo develops in the mother's body
- No specialized larva
- Born immature → parental care usually up to 16 years or more
- Gradual growth and development
- Repeated reproduction usually only in adulthood
- Produces 0-20 offspring, most surviving to adulthood



Eel

- Sexual reproduction
- External fertilization
- Embryo floats freely 600m under the sea
- Larva swims across the Atlantic Ocean on its own
- No parental care
- Rapid metamorphosis
- Spawns once and then dies
- Produces + 10,000 offspring, most dying before adulthood





Life history theory

An organism is not just an adult
It is the entire life cycle
The way an organism carries out its life cycle is the **life history**

Life history

a theory of biological evolution

- seeks to explain aspects of organisms' anatomy & behavior by reference to the way that their life histories have been shaped by natural selection

Life history

strategey

- "age + stage-specific patterns" & timing of events that make up an organism's life, as:



- These events, depend on the physical & ecological environment of the organism

Life history theory

explains the general features of life cycle

how fast the organism grows?

at what age it matures?

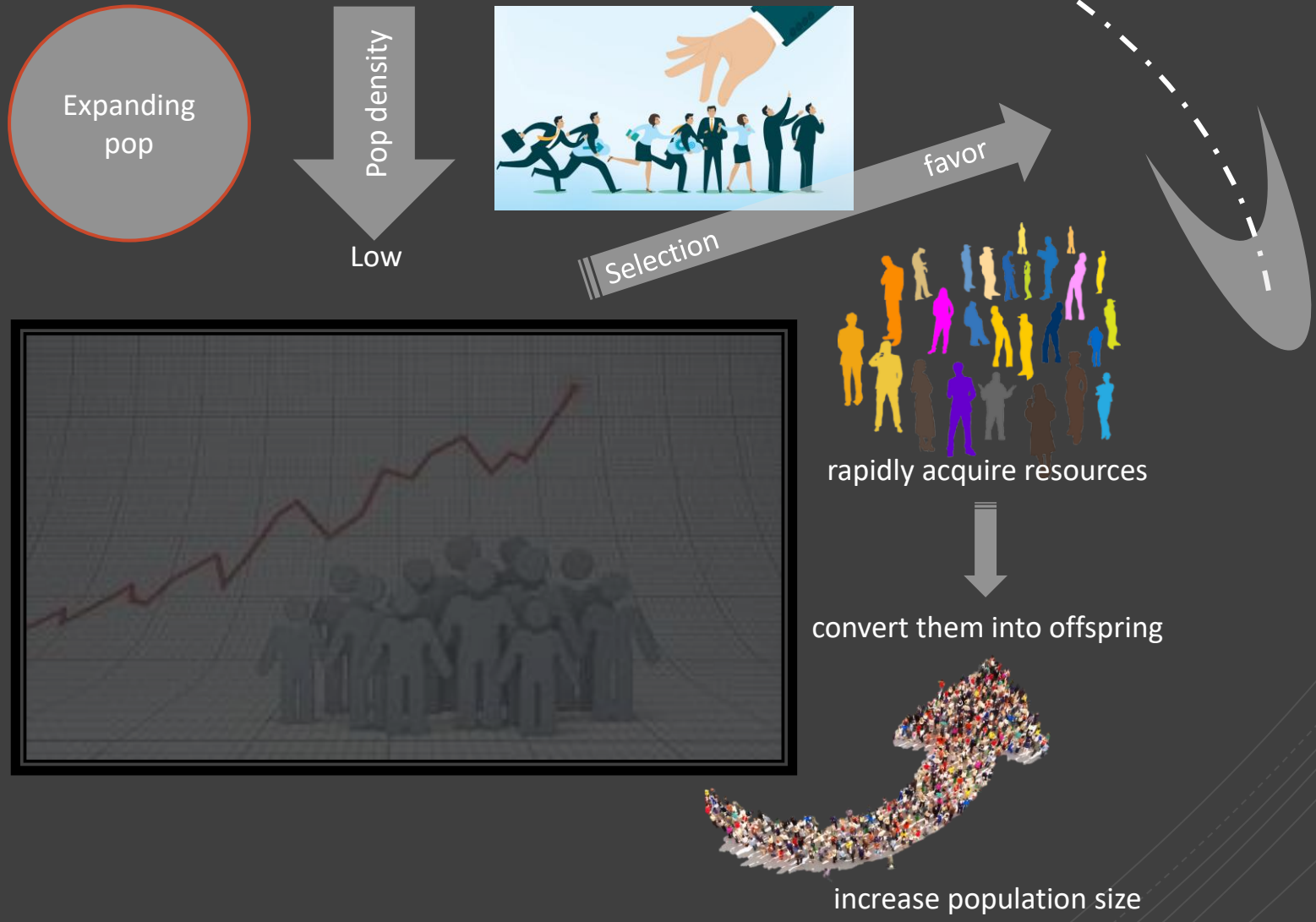
how long it lives?

how often it reproduces?

Life history theory

first articulated by MacArthur and Wilson

initiated on a premise that population density regulates demographic traits



Life history theory

first articulated by MacArthur and Wilson

initiated on a premise that population density regulates demographic traits

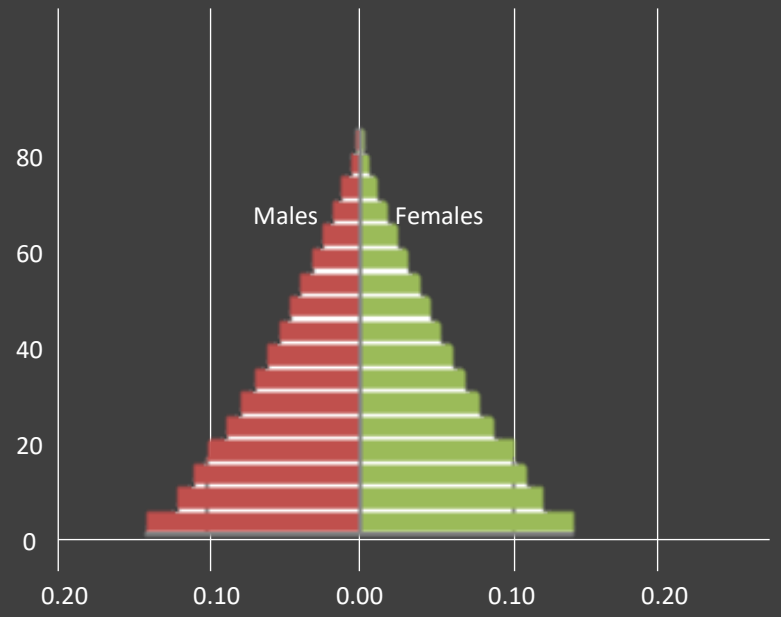
Stable pop

organisms remain close to their carrying capacity

Selection favor

persistence in the face of scarce food

more efficient utilization of food resources.



Life history theory

Models suggest that ------>

evolution of life history strategies depends on heterogeneous mortality among age classes.

CAUSES

external?
density dependent?
interact with environmental factors?

presence of predators?
resource availability?
fluctuating environment?

Life history theory

<u>Production, consumption and redistribution of resources</u>

Human: sharing & redistribution of food within the group (the more concentrated and valuable food) between age categories (pro and post -production age)

The Aché

- Indigenous people of hunter-gatherers
- Living in The forest of eastern Paraguay
- Share food extensively
- Animal prey divided up communally among band members

Social norms --> importance of band-wide distributions

- men are proscribed from eating from their own prey
- wild game is cooked, redistributed in equal portions to resident families, taking into account the size of each family

The Aché: sharing food

Palm starch:

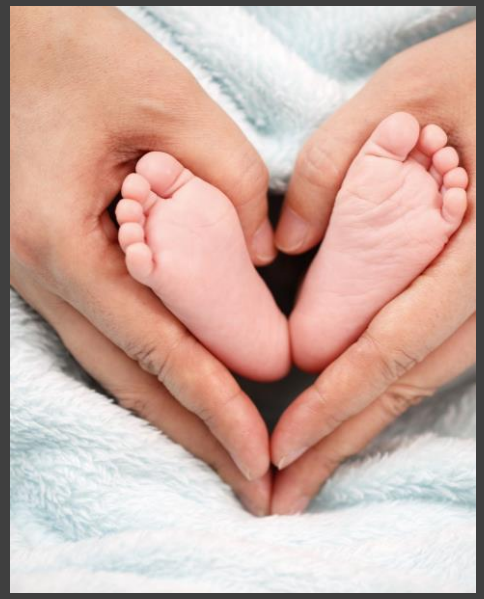
- produced in large batches
- shared in a manner similar to meat
- no taboo against women consuming what they extracted

Honey:

- less widely shared
- large portions saved for absent at the time of extraction

Collected fruits and insect larva:

- less widely shared
- still redistributed to those not present at a collection site



Prenatal & postnatal periods

ontogeny divides 2 periods for placental mammals:

1. **prenatal period** (prenatal development) - from fertilization of an ovum to delivery of fetus
2. **postnatal period** (postnatal development) - from the delivery to death of the individual

Phases of prenatal development

1. pre-embryonic

the first 3 weeks
from fertilization of the ovum

2. embryonic

4^{th} – 8^{th} week
all body organs are constituted
embryo is recognizable human
both in appearance & measures
(2-3 cm from head to tail)

3. fetal

9^{th} week to delivery of fetus
rapid development of organs
some organs enter their function
fetus grows quickly in length
increases its weight gain
in particular during the terminal months

Phases of postnatal development

1. **infancy**: from birth - end of the 1st yr of the age
(the 1st two weeks of infancy = newborn or neonatal period)

2. **childhood**: from 13 month - 12 to 13 yrs
the primary teeth appear & replaced by the secondary or permanent teeth

3. **puberty:** 12-15 yrs (girls) & 13-16 yrs (boys)
secondary sexual characteristics develop

4. **adolescence:** follows the puberty and ends 3-4 yrs after it
the organism reaches sexual but also physical, mental & emotional maturity

5. **adulthood:** developmental changes occur very slowly & are mostly characterized by selective loss of highly specialized cells and tissues

Humans are no exception to biological evolution

New life history stages of growth & development allowing greater flexibility in reproductive strategies

No living species of mammal (even nonhuman primates) has all the characteristics of human growth, development & maturation of Humans

Human life history stages

In common with all mammals, humans share

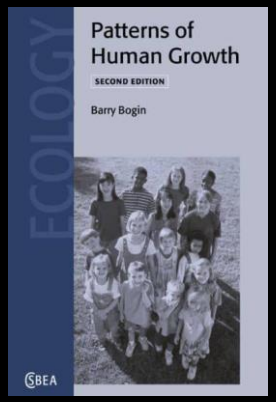
1. “infancy” stage of life history
2. period of feeding by lactation
3. “adulthood” stage
4. period of reproduction

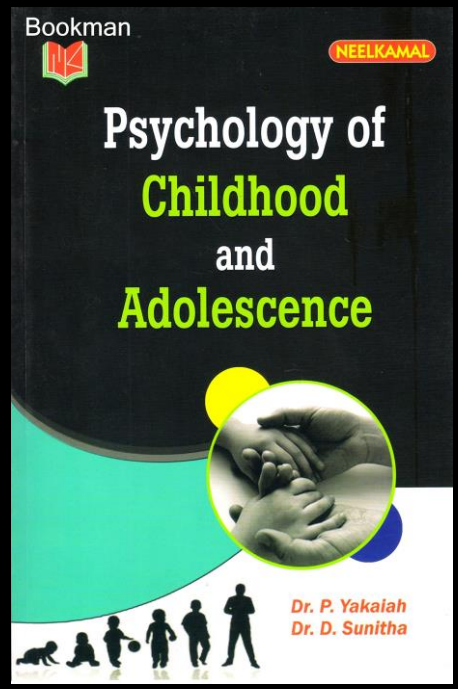
Human life history stages

In common with the social mammals (most primates, elephants, and some carnivores (wolves, lions, hyenas), humans share the:

“juvenile” stage of development, characterized by feeding independence but reproductive immaturity.

Human life history stages

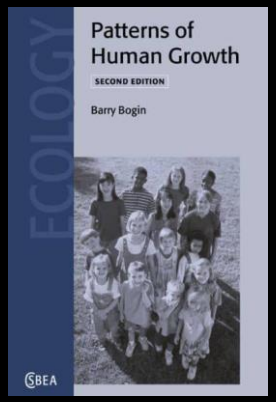


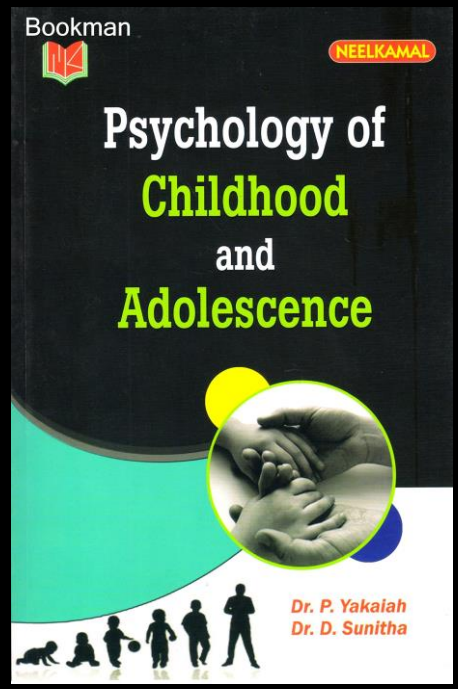


In contrast to all other living species, humans have two unusual periods of development (Bogin, 1999):

1. childhood
2. adolescence

Human life history stages





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Other species of Mammals:

Once weaned individuals have to get their own food

Childhood

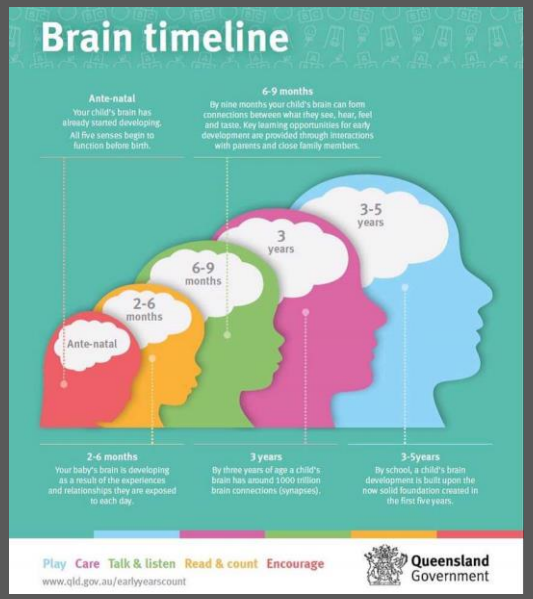
Humans:

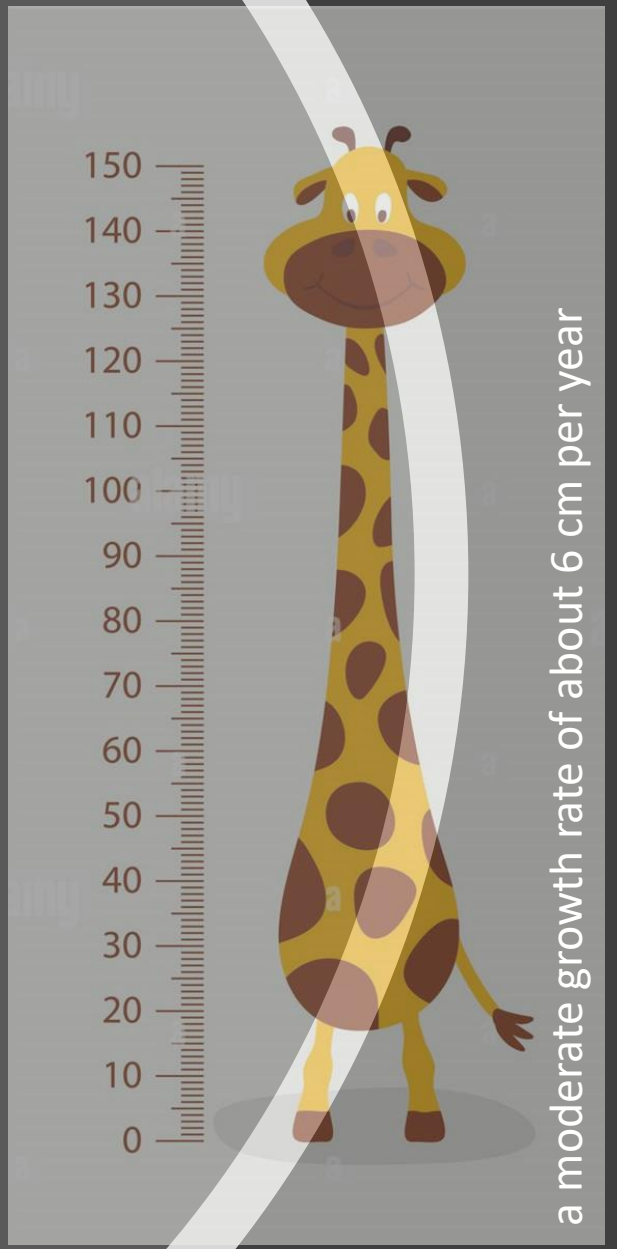
defined as the period of time after infancy
from about the age of 3.0 to 6.9 years
when infants are “weaned”
but still dependent on older people for care & food provisioning

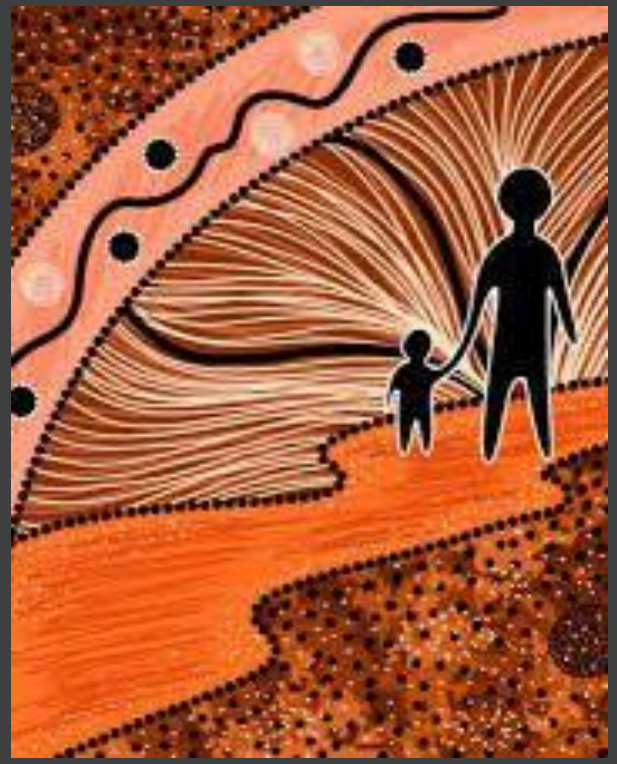
Childhood

ends with the

1. eruption of the 1st permanent molar and incisor teeth
2. virtual completion of brain growth in total weight





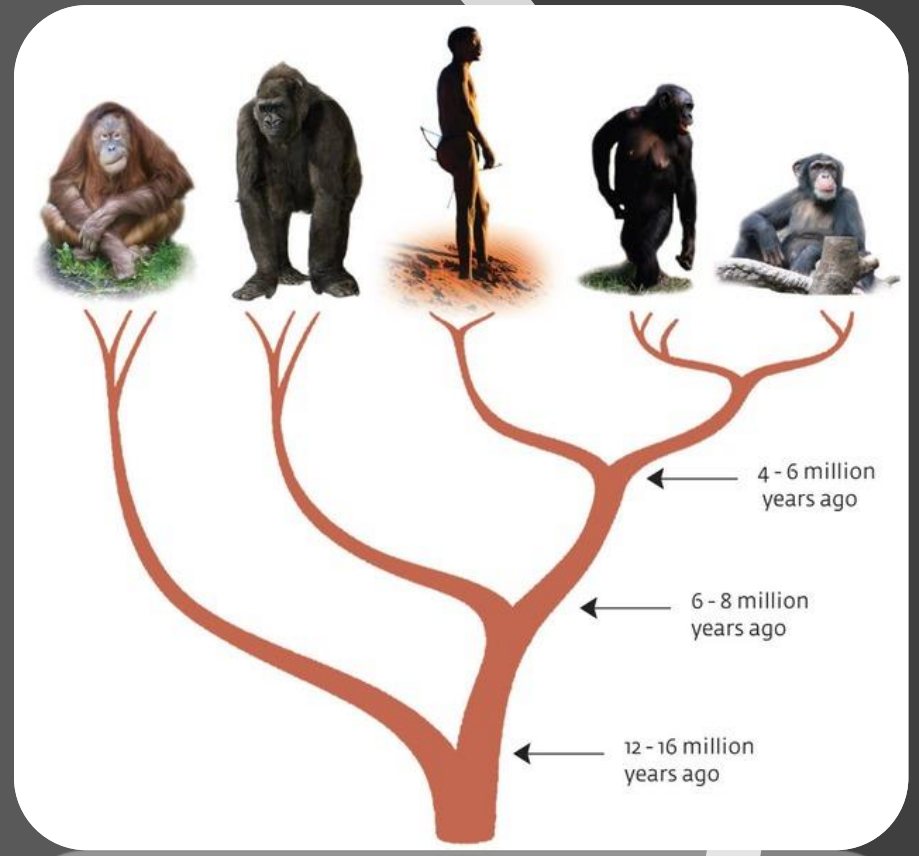


Childhood

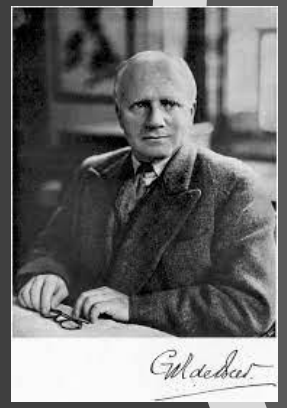
The evolution of childhood may explain the human-specific traits of:

1. relatively early weaning
2. prolonged growth and development between birth and adulthood
3. complex kinship systems
4. language
5. marriage
6. intergenerational transfers of wealth and political power
7. relatively slow aging
8. senescence
9. greater longevity

Childhood



Each of these characteristics of modern humans evolved, mostly likely, at different times since the split between ape and human ancestors occurred about 6–7 million years ago.



Gavin de Beer

concept of “mosaic evolution”

- 1954 originally proposed
- 1975 later applied to the evolution of Australopithecus

childhood is the first piece of the mosaic of human life history evolution, including the evolution of human culture

“adolescence”

the stage of life when
social & sexual maturation
takes place

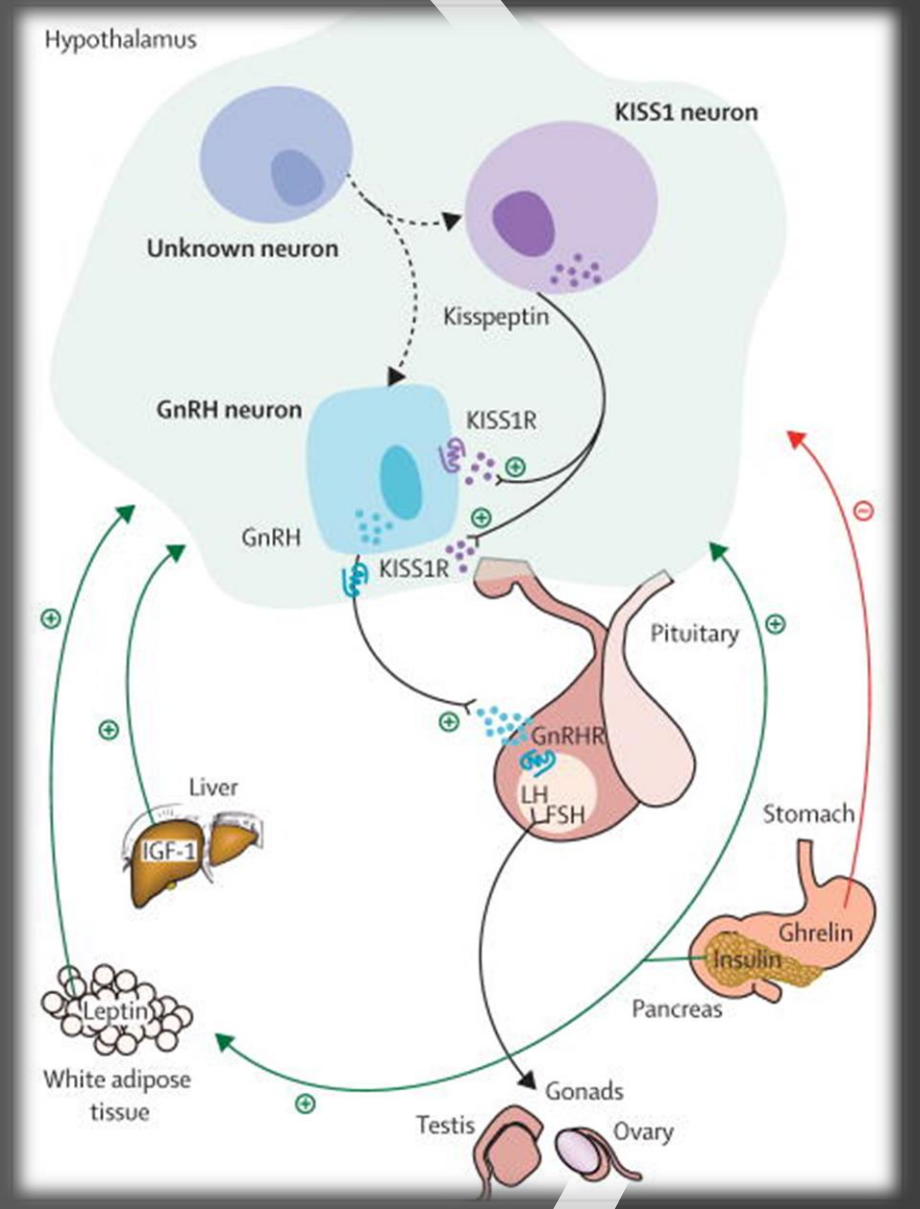
“adolescence”

begins with puberty, or more technically with gonadarche,

is initiation of the adult pattern of activation of the gonadotropin-releasing hormone (GnRH) pulse generator of the hypothalamus

transition from juvenile to adolescent stages requires the:

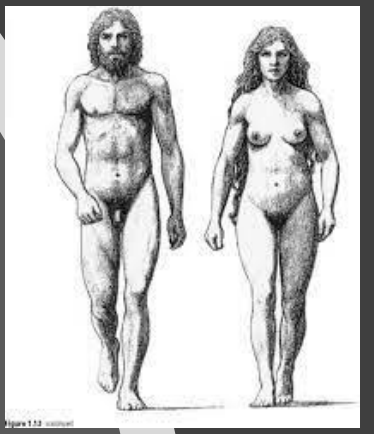
1. renewed production of GnRH
2. its secretion from the hypothalamus in a specific frequency & amplitude of pulses

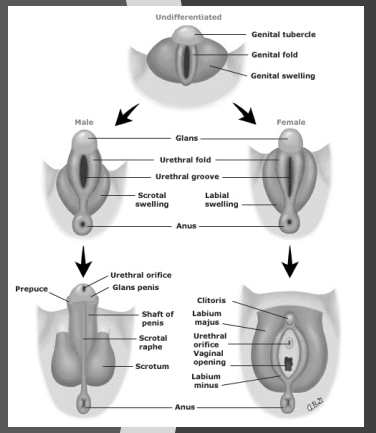


“adolescence”

It also includes development of secondary sexual characteristics:

1. development of the external genitalia
2. sexual dimorphism in body size & composition
3. onset of greater interest & practice of adult patterns of sociosexual & economic behavior



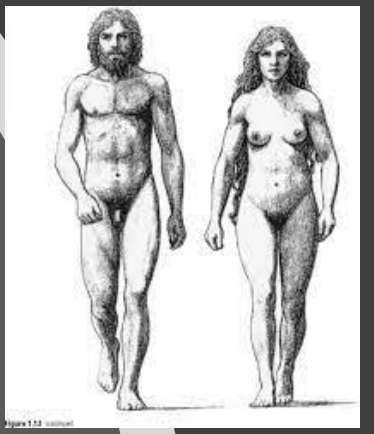


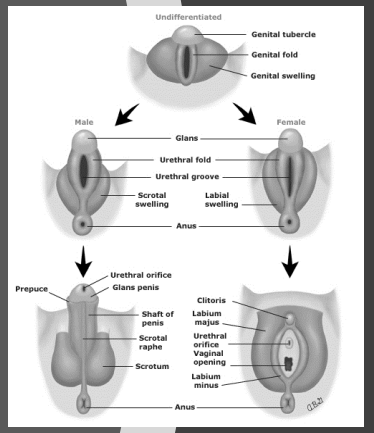
“adolescence”

The adolescent stage also includes development of secondary sexual characteristics, as:

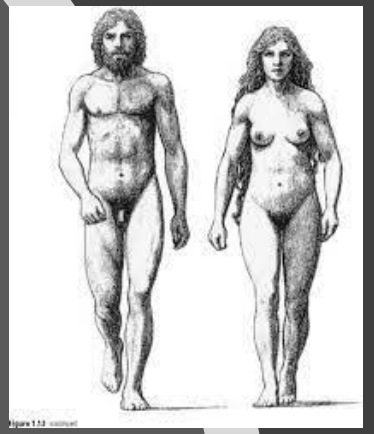
1. development of the external genitalia
2. sexual dimorphism in body size & composition
3. onset of greater interest & practice of adult patterns of sociosexual & economic behavior

Will also occur with puberty in other species of social mammals.





“adolescence”



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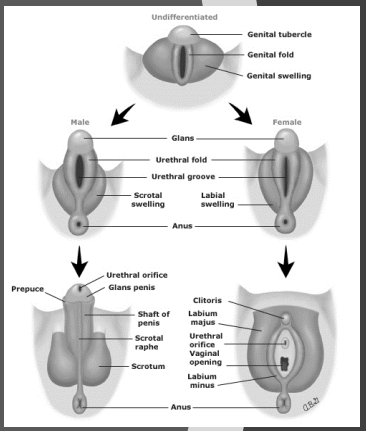
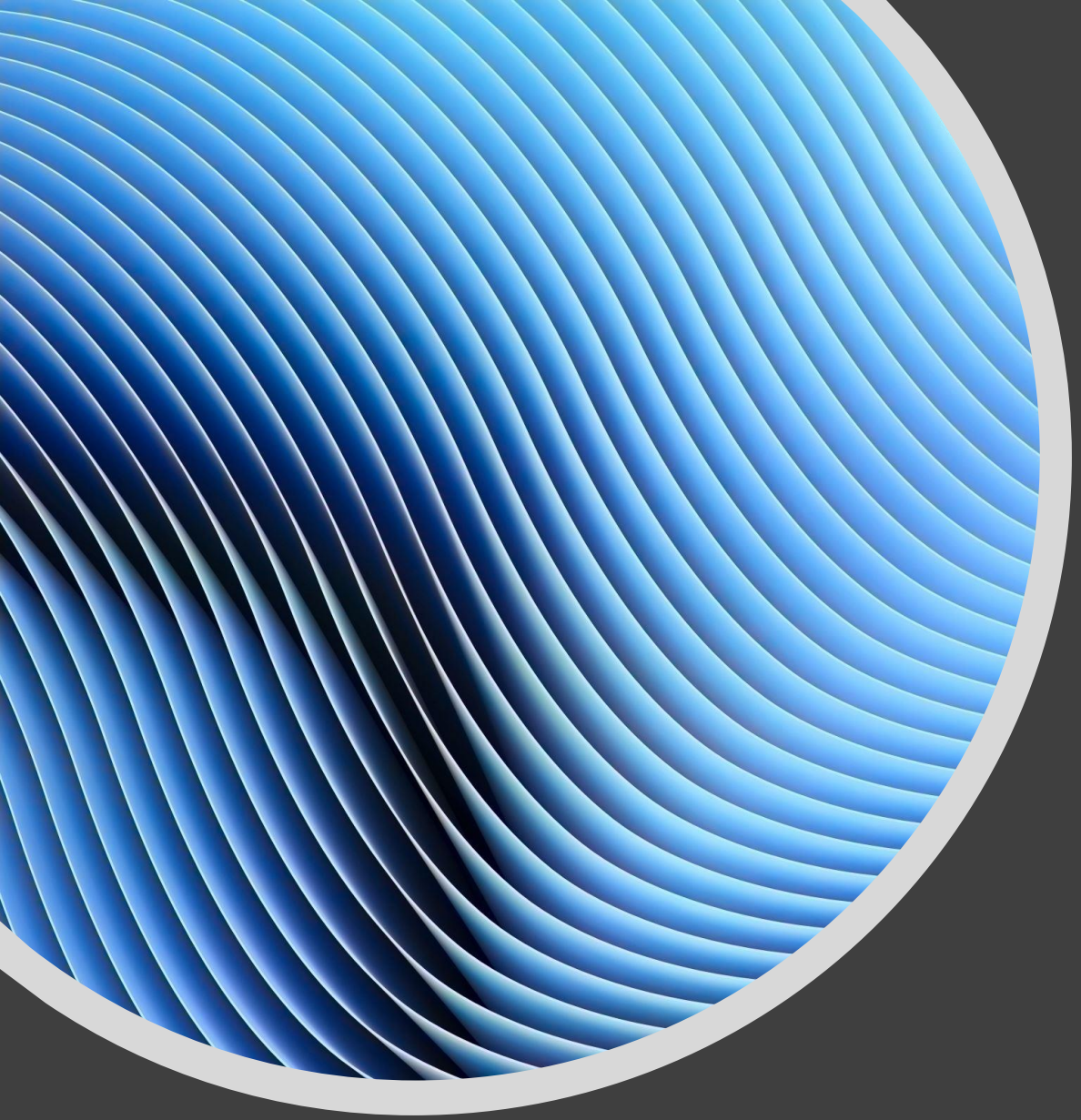


Will also occur with puberty in other species of social mammals.

What makes human adolescence unusual among the primates then?



“adolescence”

1. length of time between age at puberty & age at first birth

2. rapid acceleration in total skeletal growth (growth spurt)

1. length of time between age at puberty & age at first birth

initiate female reproduction:

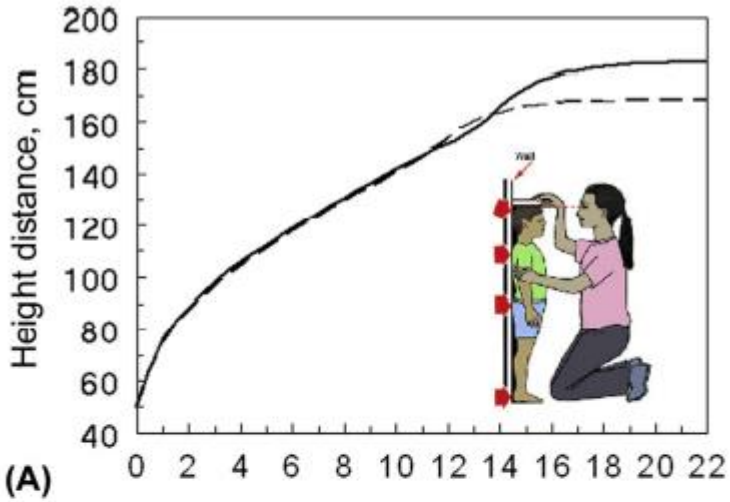
Human: 10 yrs

Chimpanzees: 1–3 yrs after puberty

Reasons:

1. "adolescent infertility": a time of about 3 years after menarche (first menstruation) with absent or infrequent ovulations
2. socio-cultural aspects, marriage, kinship etc.

the duration & intensity of the growth spurt defines human adolescence



2. Rapid acceleration in total skeletal growth (growth spurt)

- velocity of human long bone growth may be 5 times as rapid as that of apes

- other primate species:

no adolescent acceleration in total skeletal growth or a very small increase in growth rate

The Primate Roots of Human Life History

British anatomist Wilfred Le Gros Clark (1895–1971)

defined the Order Primates by 9 categories of traits:

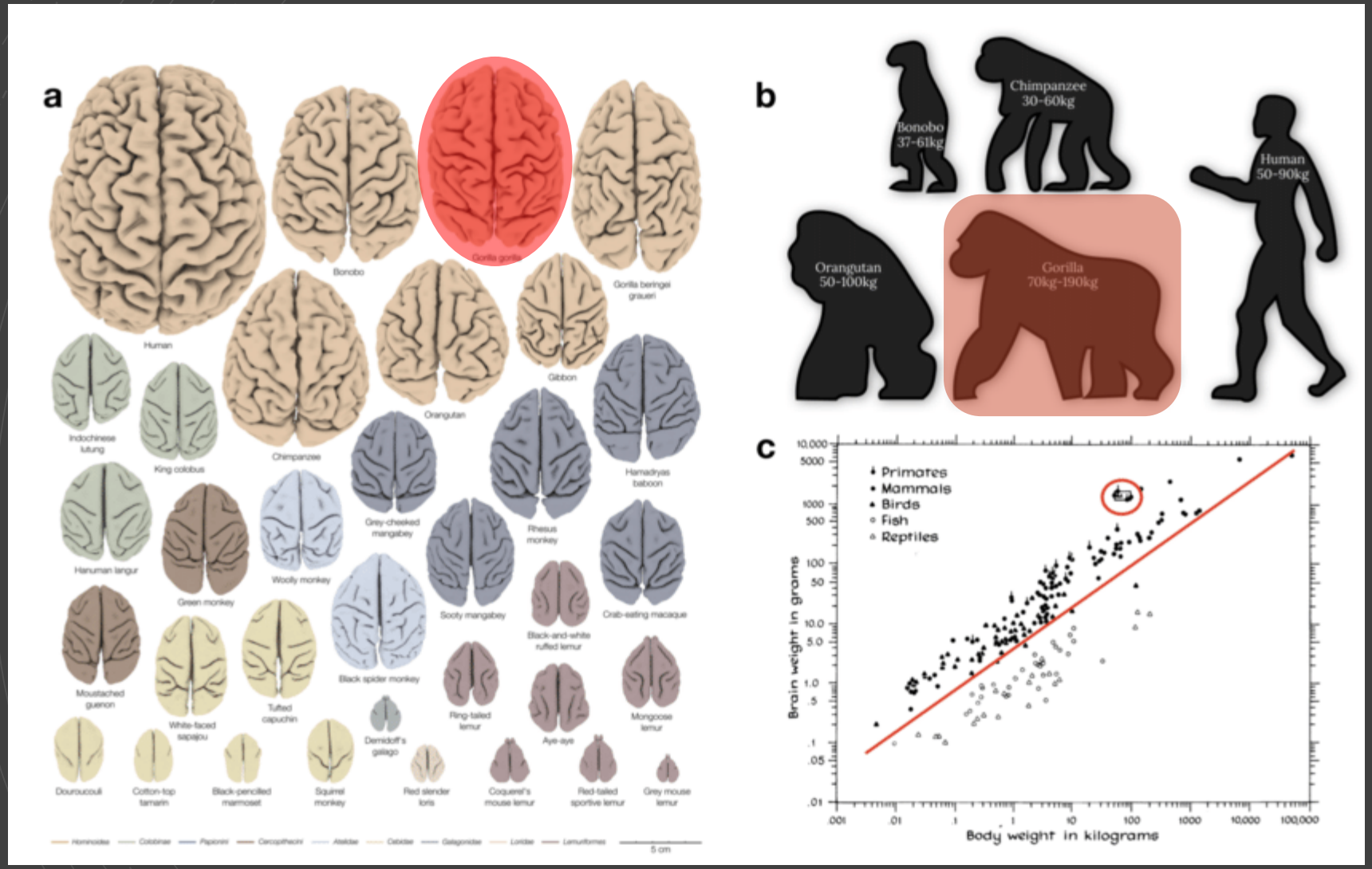
1. generalized limb structure (5 fingers & toes; retention of the clavicle)
2. flexible digits (thumb & large toe)
3. flattened nails & tactile pads that occur at the end of digits
4. less emphasis on the sense of smell
5. reduced muzzle size
6. more dependence on sense of vision (binocular, stereoscopic & color vision)
7. retention of the 4 kinds of mammalian teeth & and a simple cusp pattern of molars

associated with the history of primates (tree-living mammals) specializations for rapid movement in trees and small object feeding (eating insects, flowers, fruits, & seeds)

8. longer gestation and increased vascularization of placental membranes
9. expanded & elaborated **brain**, especially the cerebral cortex

more direct relevance to life history evolution

The brain - the biggest consumer of energy



A comparison of the relationship ‘‘brain weight **&** adult body weight’’ in humans and great apes

The Primate Roots of Human Life History

Longer gestation, more efficient placenta allowing more brain growth & development before birth.

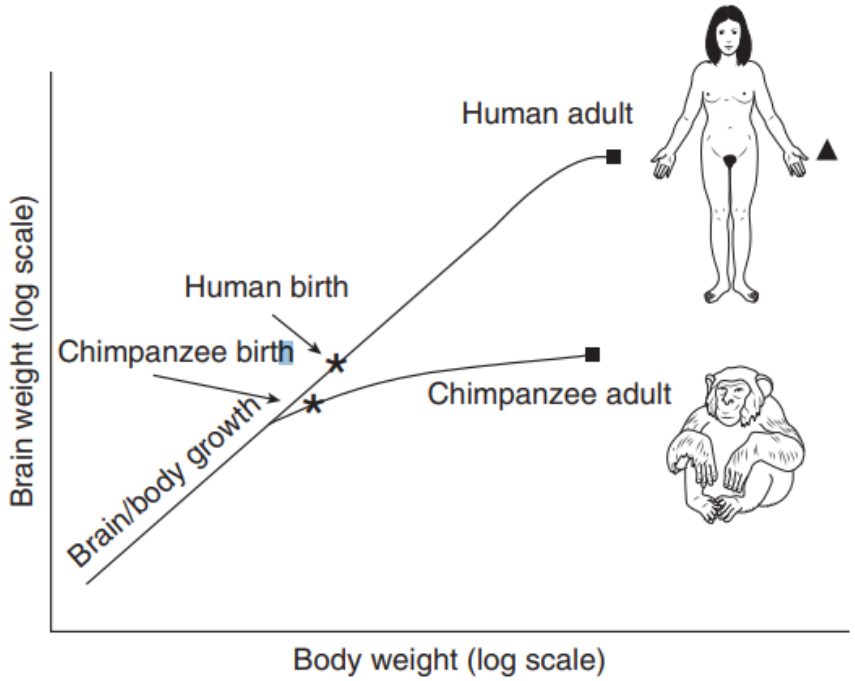
The energy need of a larger brain is a major factor driving life history evolution.

Humans are at the extreme upper end of the range of variation for primate brain size at birth.

Human brain size at birth averages 375 g with a range from 255.0 to 540.0 g.

Chimpanzees average only about 150 g with a range of 109–181 g.

The human advantage in brain size increases rapidly with age so that adult chimpanzee brains average 382 g in contrast to 1350 g for adult humans



Specifics of human life history:

(1) Delivery of a relatively immature newborn

(2) Stage of middle childhood (childhood)

(3) Adrenarche

(4) Adolescence (growth spurt)

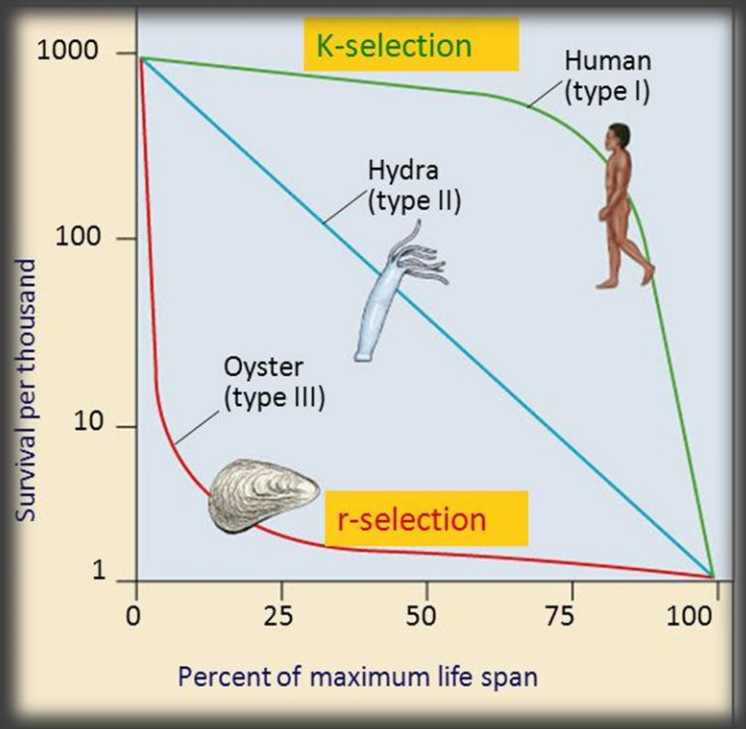
(5) Menopause and post-reproductive age

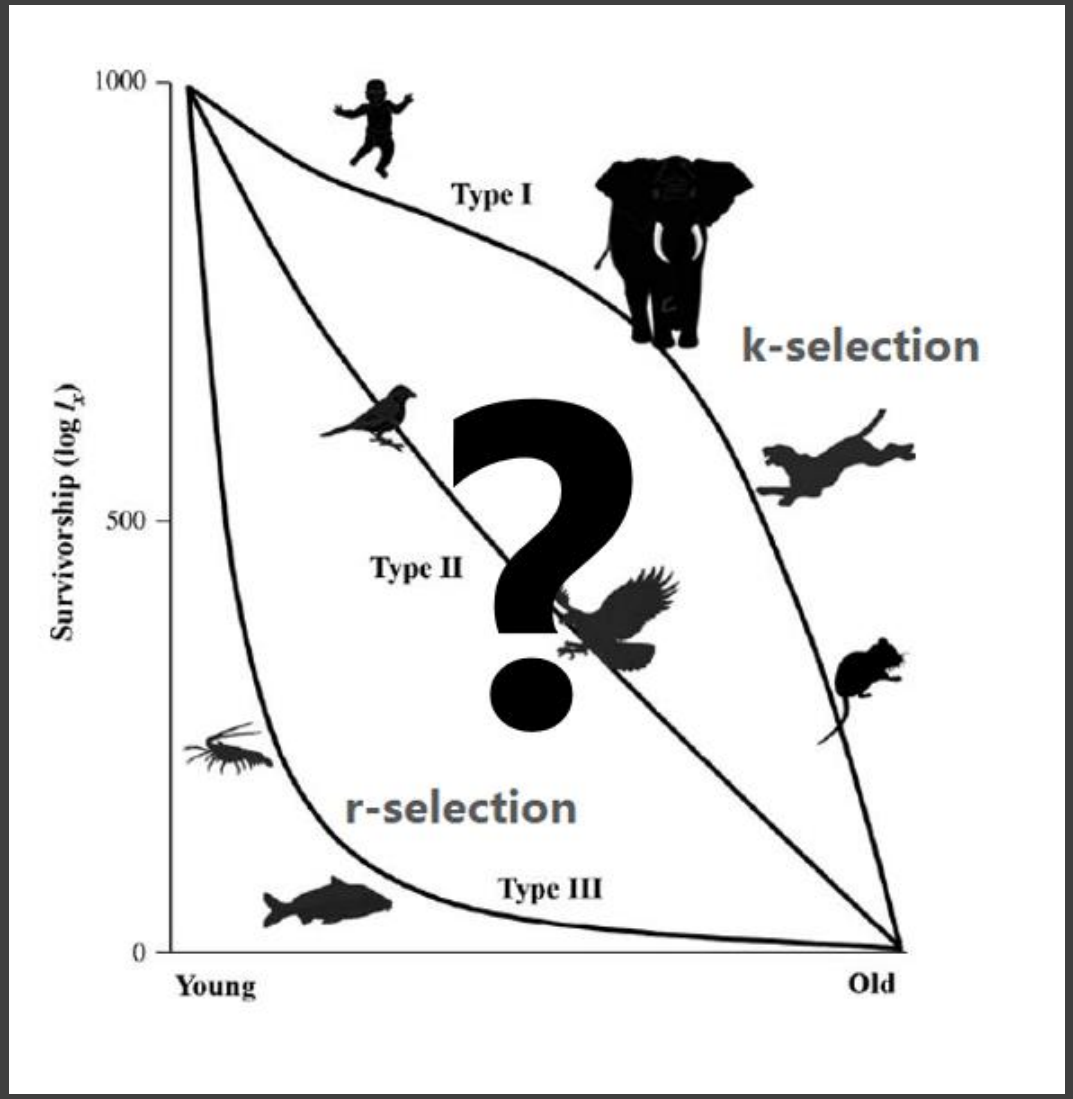
Pianka ER (1970): On r and K selection

Eric R. Pianka (1970)

1. r-strategists

- unpredictable conditions
- emphasis on the number of offspring, regardless of quality & competitiveness
- high mortality offspring
- no or reduced care of offspring
- offspring highly mobile





Pianka ER (1970): On r and K selection

Eric R. Pianka (1970)

2. K-strategists

- in stable predictable conditions
- emphasis on quality of offspring and their competitiveness
- low number of offspring,
- low mortality of offspring, longevity, intensive & long parental care

Population growth rate (calculation)

- doesn't work very well empirically
- hundreds of papers in the 70s,
- according to Joseph L. Graves (2002)
- NONE demonstrated a link between population fluctuation & adaptation

Reasons:

- more complex environments,
- genes have a pleiotropic effect
- a matter of studying individual environmental factors vs. life history traits

Life history theory

- Life cycle signs/properties not only significantly influence the biological fitness of their bearer, but also strongly influence each other

A consequence of long evolutionary tuning and optimization is the fact that changes are almost always in the nature of a choice for something -compromise (trade-off)

- The optimal allocation of resources varies at different stages of its life

- Life history theory is interested in the evolutionary pressures that have shaped the important events of development, growth, reproduction, and aging

Characters

Prenatal Growth Rate

- Weaning age
- Age of sexual maturity
- Adult body size
- Age specific mortality
- Age specific fecundity
- Age of 1st reproduction
- Length of gestation/pregnancy
- Litter size
- Interval btw births
- Sex index of offspring
- Length of life

Compromises in childhood

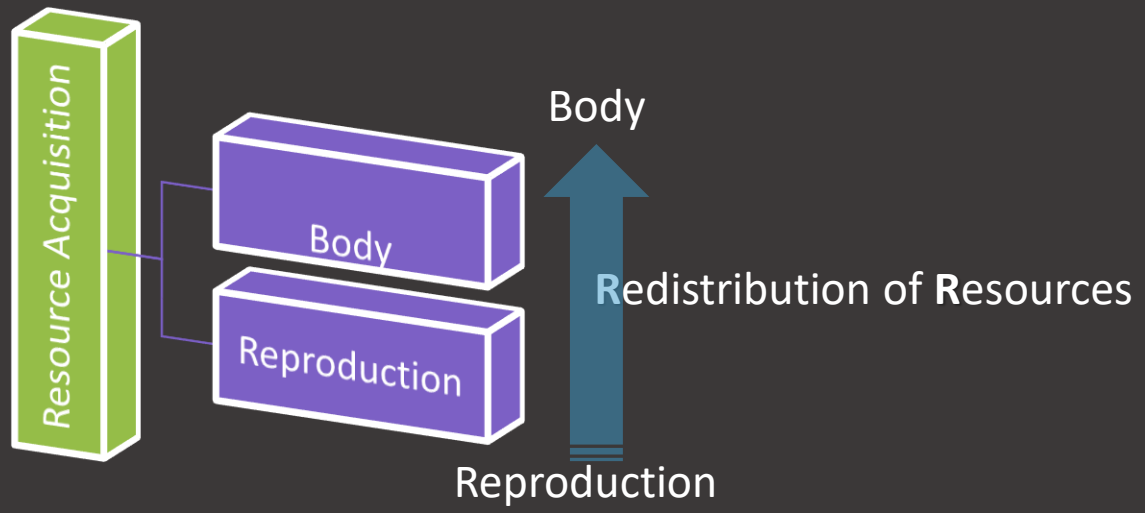
The organism does not choose the life strategy and thus the parameters of the life cycle (if it could, so...), but it is imposed on it by limitations:

A) Internal: genetic disposition, physical parameters of cells ...

B) External: the amount and availability of resources, the presence of predators and parasites, the variability of the environment ...

It distinguishes three basic compromises (trade-offs):

1. Reproduction now or in the future?
2. Quantity or quality of offspring?
3. Further mating vs. care for existing offspring?



Compromises in childhood

- If an organism is exposed to high doses of pathogens , how it grows depends on the amount of resources

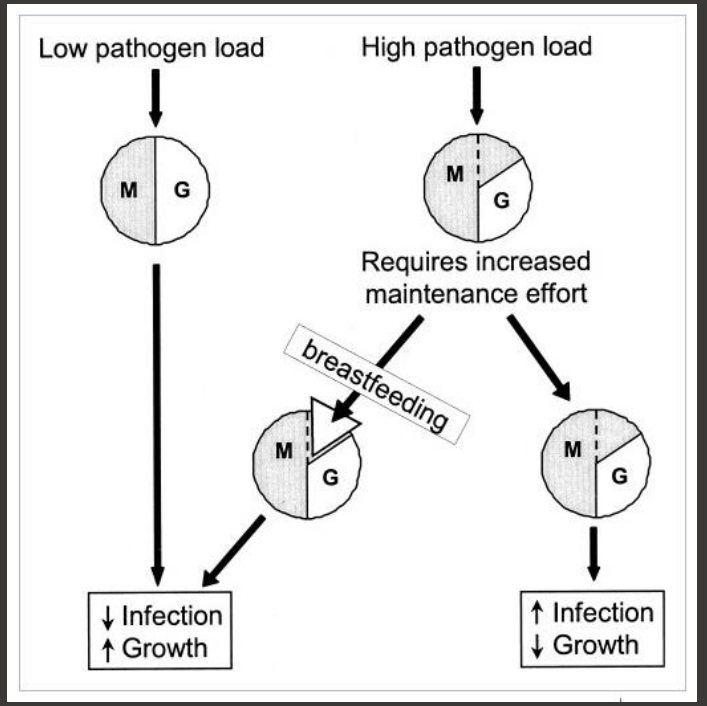
- A very different combination of conditions can mean a similar growth rate and perhaps even the same final state

Thymus – in childhood 2x larger than in adulthood

T-lymphocytes - paracrinely regulate the functions of a number of organs - diffuse peripheral regulation

- increased demands of the immune system can directly modulate the amount of energy taken by growth

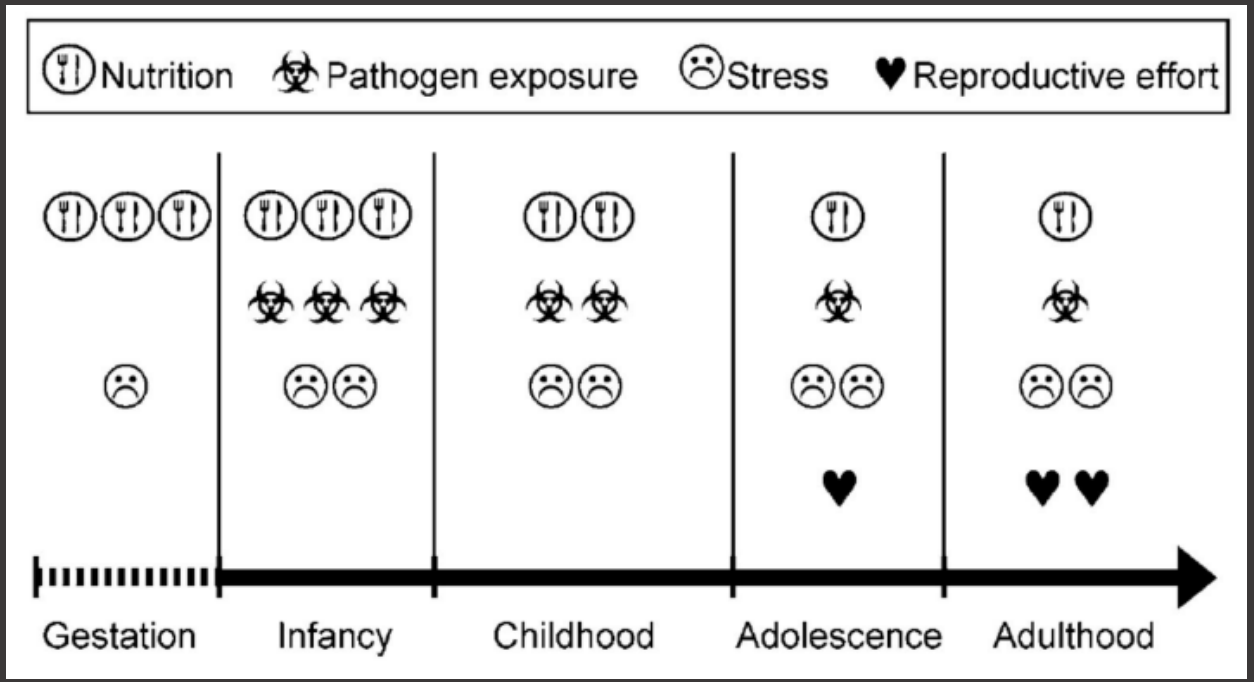
(Stately barons from the village fell like pears in modern wars...)



(McDade 2003)

Compromises in childhood

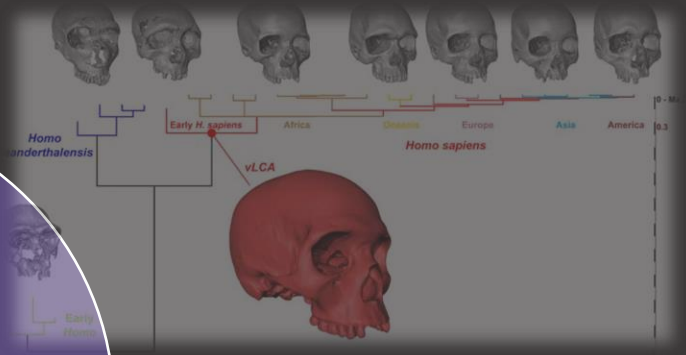
The relative impact of different **ecological factors** on immune function at multiple developmental stages



(McDade 2005)

But not only..

A set of basic biocultural domains affecting human life history:



Phylogeny:
genomic-proteomic-morphology-ethology

Social
Economic
Political

Class, caste, religion, education, occupation, land, possessions

Ecology: nutrition, physical activity, infection, physical environment (high altitude, urban slum, arctic)

Family:
household, kinship, cooperative caretaking

Human life History:

- Stages of growth
- Reproduction
- Trade-offs

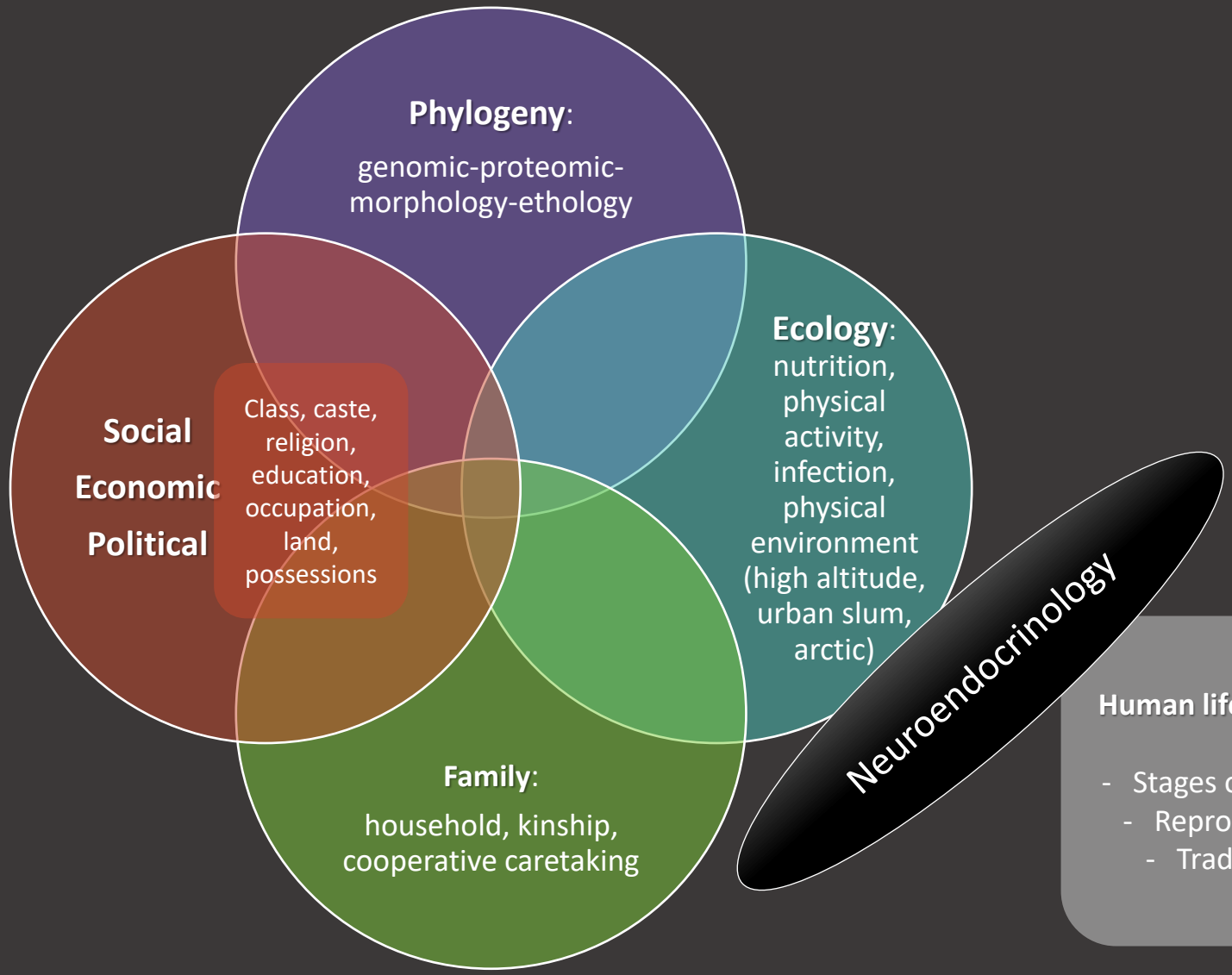
After Bogin et al. 2007

But not only..

The topical domains interact with the phylogenetic domain to create a large range of reaction norms of neuroendocrine production & activity.

Neuroendocrine products (hormones and other agents) have the most direct effect on the:

1. timing of growth,
2. onset and frequency of reproduction,
3. modulation of trade-offs throughout life



Linkage of ontogenetic phases

1. **the mechanisms of postnatal growth and development**

are the means by which the organism achieves phenotype plasticity towards a complex and changing environment (ontogenetic adaptation), important in long-lived organisms

- learning behavior
- body shape
- physiological functions
- Immunity

2. individual sections (manifestations, signs) of ontogenesis

are strongly interconnected, as if the environment had little influence on them

- character of postnatal growth
- development milestones
- morbidity/mortality

Linkage of ontogenetic phases

This can be explained by:

- Life history genetic "program" (?)
- Early (pre/peri/postnatal) settings (prenatal programming) and the cohort effect (?)

Linkage of ontogenetic phases

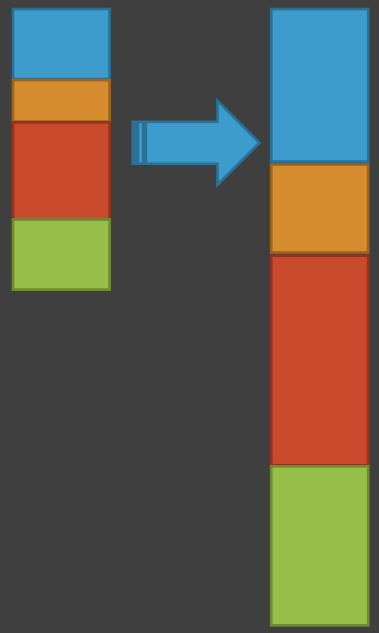
Some dependencies are strongly conservative:

The age of eruption (M1) strongly correlated with:

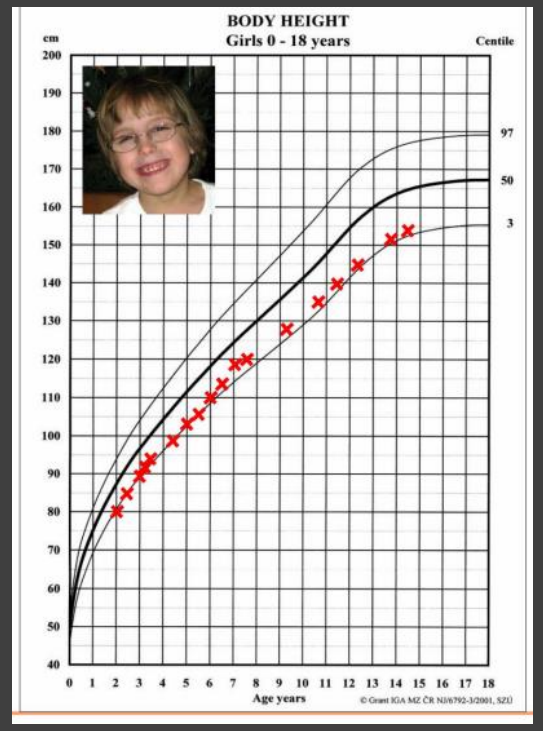
1. adult brain size
(within mammals, between species)

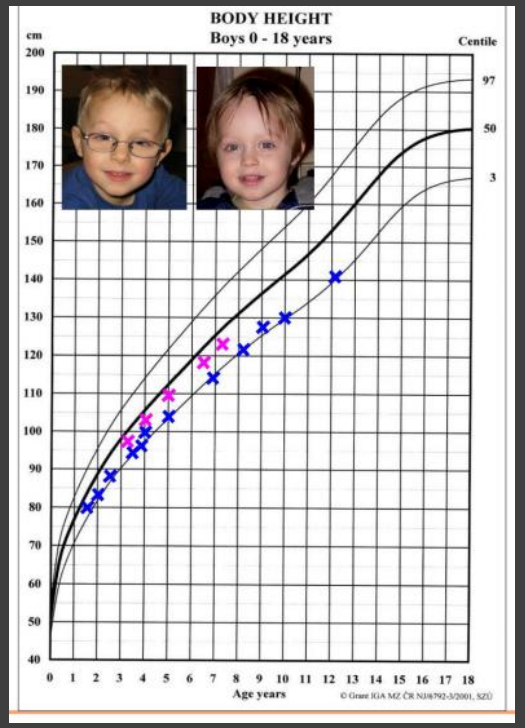
2. age of weaning

3. age of sexual maturity
(for both males and females, r=0.93)



- Life history phasing is tied to some deep, fundamental developmental process, and changes in the timing of one life history event during phylogeny are necessarily accompanied by changes in all others.
- Usable when studying life history during human evolution ‘‘we can't see the stages, but we can see the teeth’’.





Developmental sewerage also within the biological species

- Individual growth trajectories and more
- Constitutional (physiological) variants of the development of the onset of puberty
  - average individual in all growth and development indicators
  - constitutional acceleration of growth and puberty
  - constitutional delay in growth and puberty
  - familial large stature
  - familial short stature

Developmental plasticity

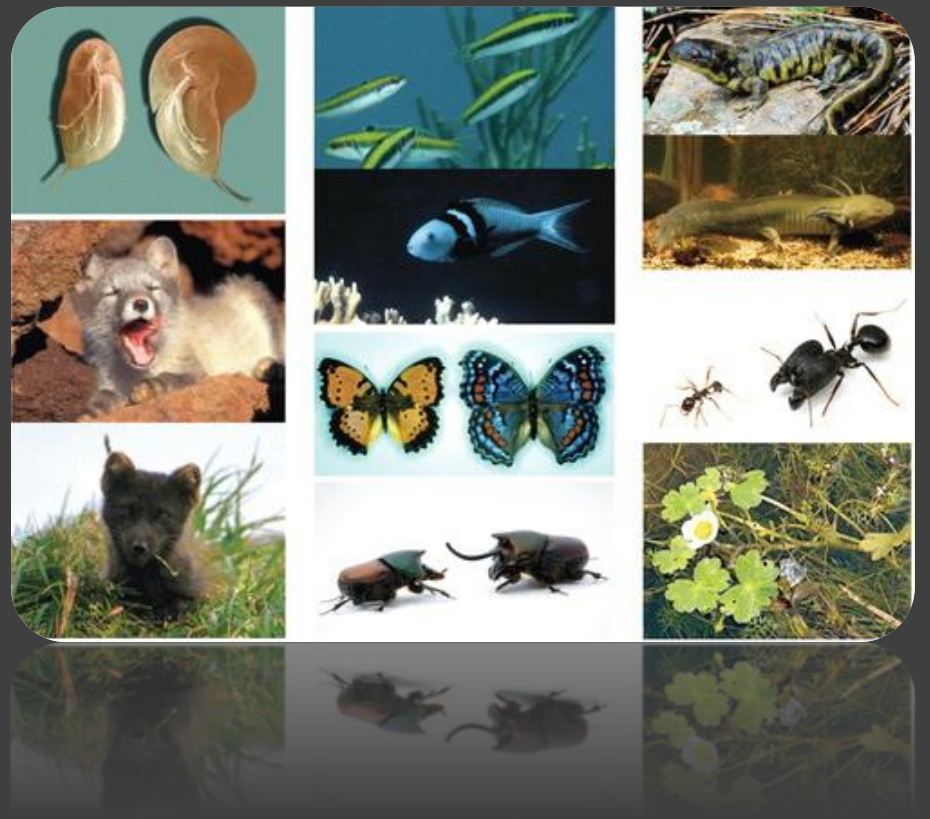
refers to the evolved & ubiquitous ability to adjust phenotypic development in response to environmental cues experienced in the more plastic early stages of development

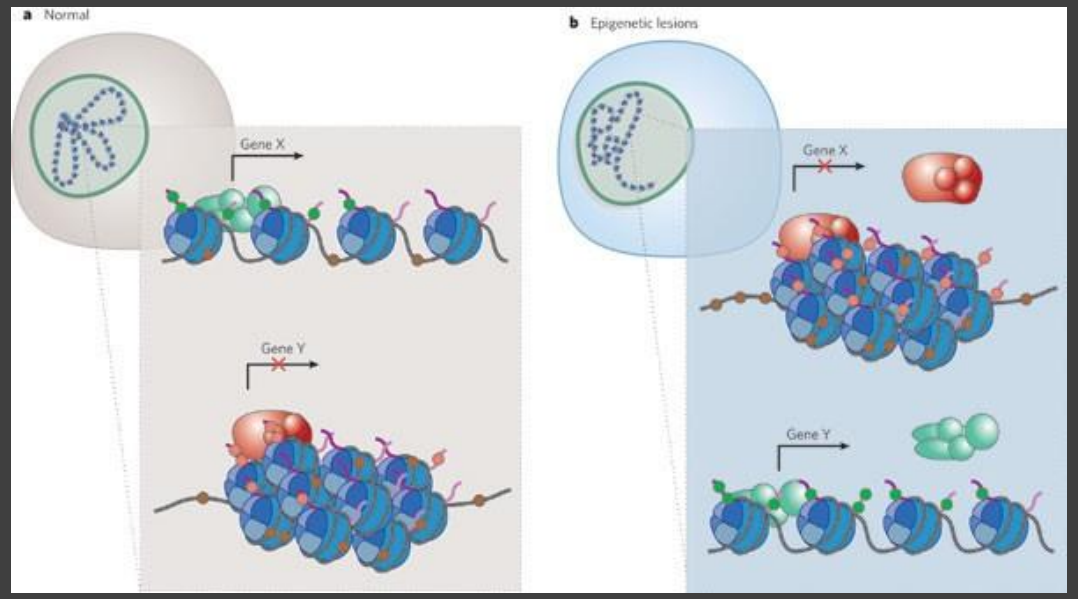
(Bateson et al., 2004)

The growth, development & phenotype setting of vertebrates (size, metabolism, in some cases even sex) is determined by the conditions to which the organism is exposed in the early stages of individual development.

In **mammals**
these processes are hidden & protected in the mother's womb, but they are not necessarily insignificant

In **humans** ,
mainly epidemiological evidence, i.e., the influence of the environment as a disruptor of development & growth, damaging the phenotype:





Phenotypic plasticity and the epigenetics of human disease

Developmental plasticity

1. A body of evidence that many chronic diseases, including their ultimate consequences in mortality in adulthood and old age, arise/establish early in life postnatally or even prenatally.
2. Circumstances that have negligible or only a small effect in childhood can later have fatal consequences

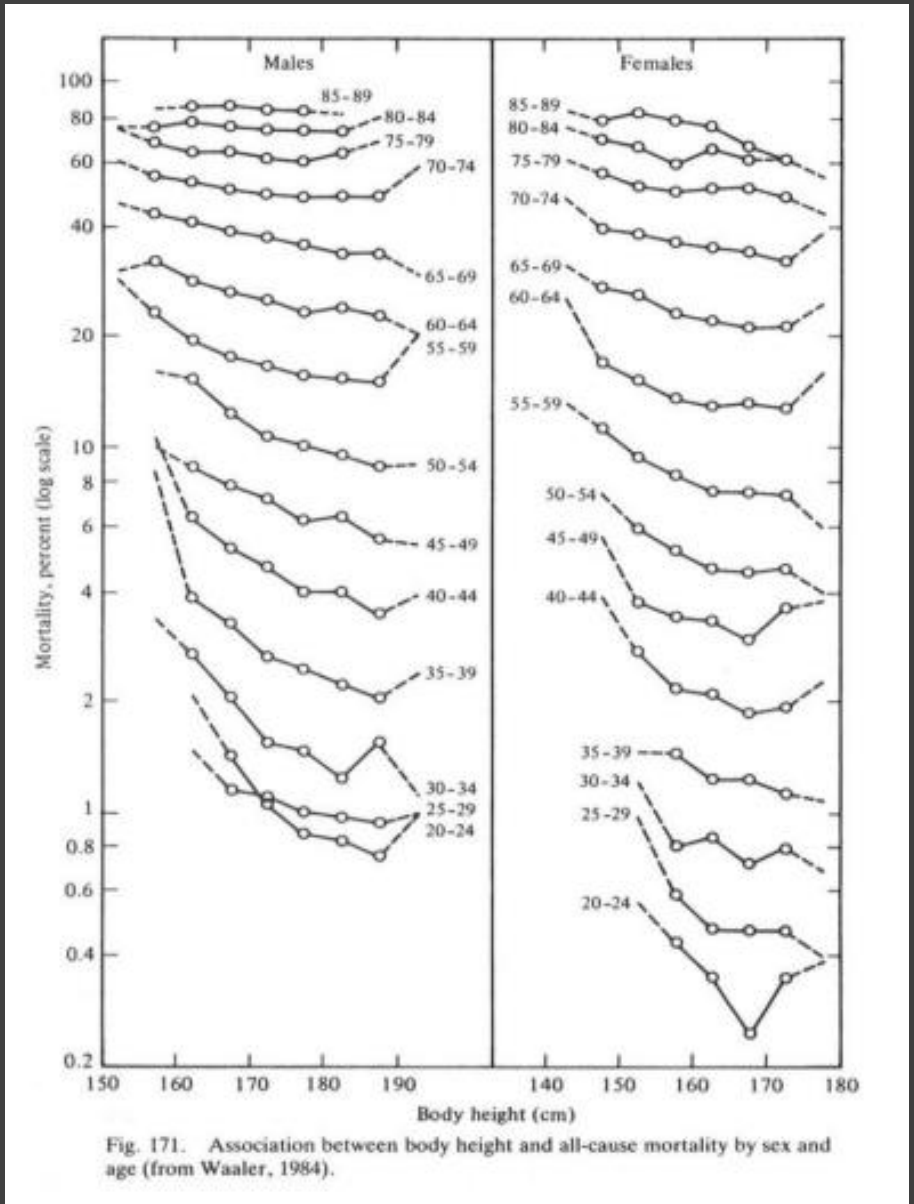


Fig. 171. Association between body height and all-cause mortality by sex and age (from Waaler, 1984).

Growth. Cambridge University Press, Cambridge. Chapter 11, pg 208- Eveleth PB, Tanner JM (1990): Worldwide variation of human 223

Developmental plasticity & mortality

Association between body height & morbidity/mortality

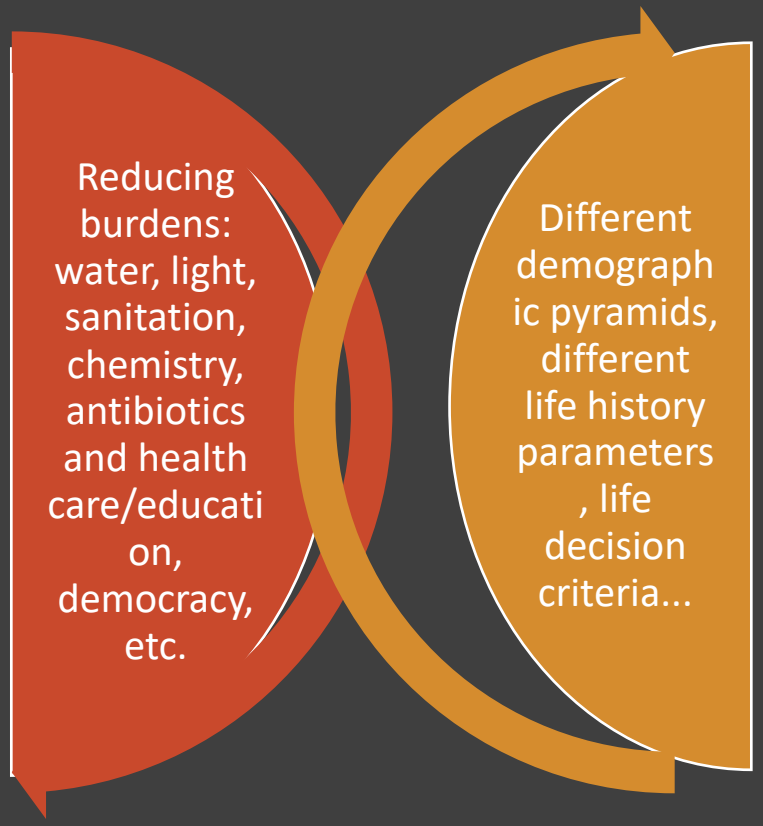
1. Within the population

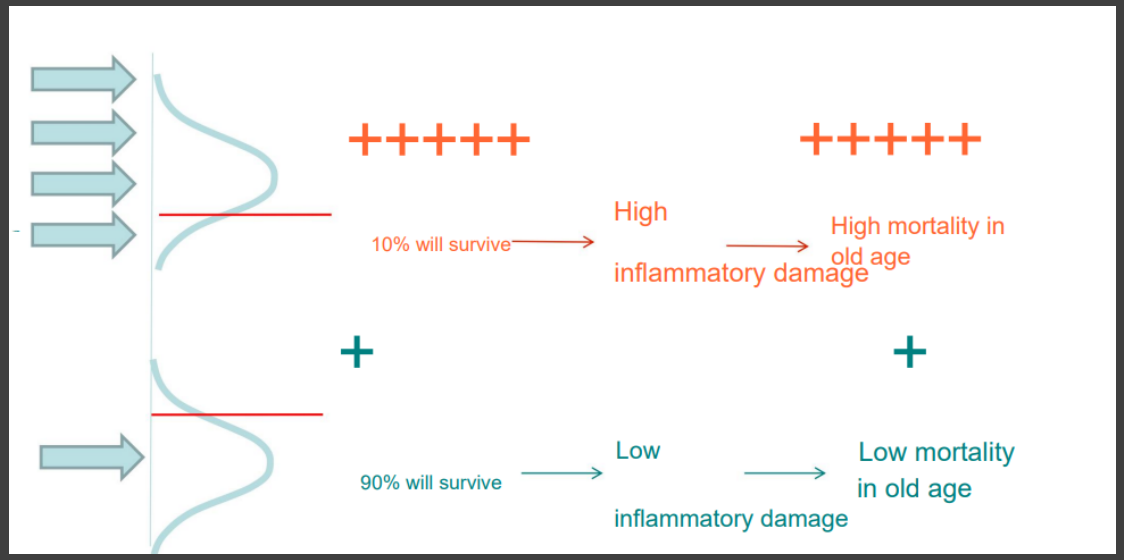
- in all age categories for both sexes, mortality -- with body height
- (Norway): 1.8 million individuals; reduced mortality in older individuals from obstructive pulmonary & cardiovascular diseases)

2. Between populations

- positive dependence of body size (body height) & cancer - Blood pressure at 10&36yrs old
- significantly negatively dependent on birth weight
- (England & Wales): higher incidence of 10-yr-old mortality from cardiovascular disease, children are shorter.

Developmental plasticity & mortality

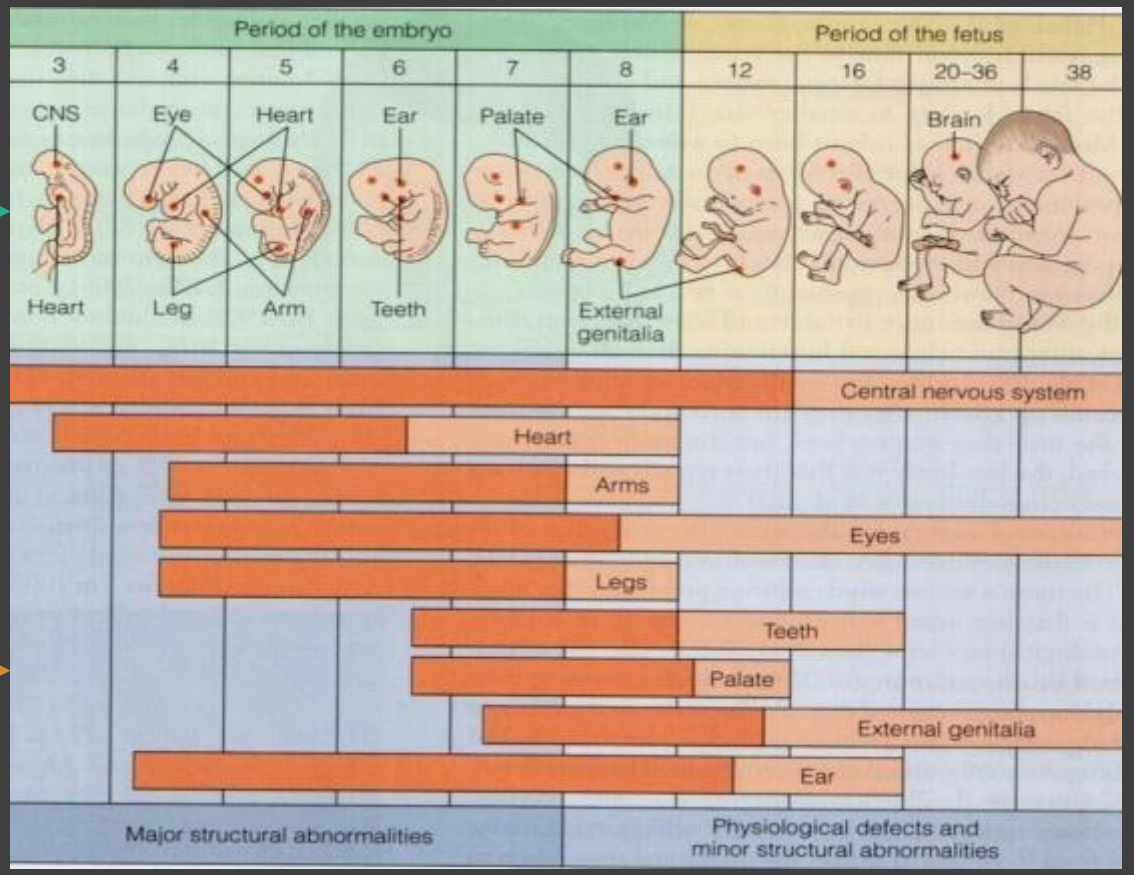




Critical periods of development

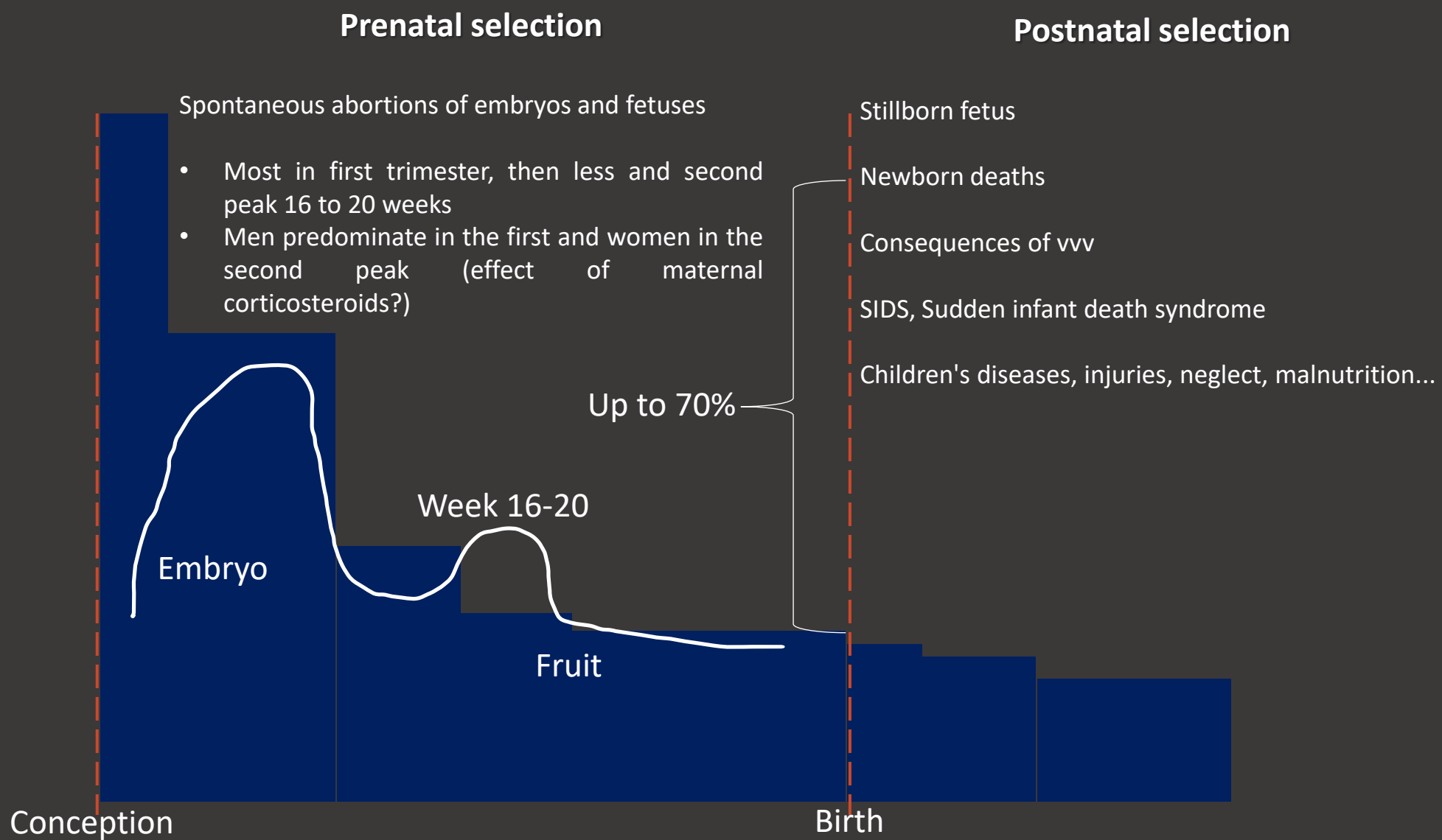
Site of birth defect
(the part of embryo or fetus where damage is most likely to occur)

Severity of defects
(dark orange shading indicates the most highly sensitive period for teratogenic effects)



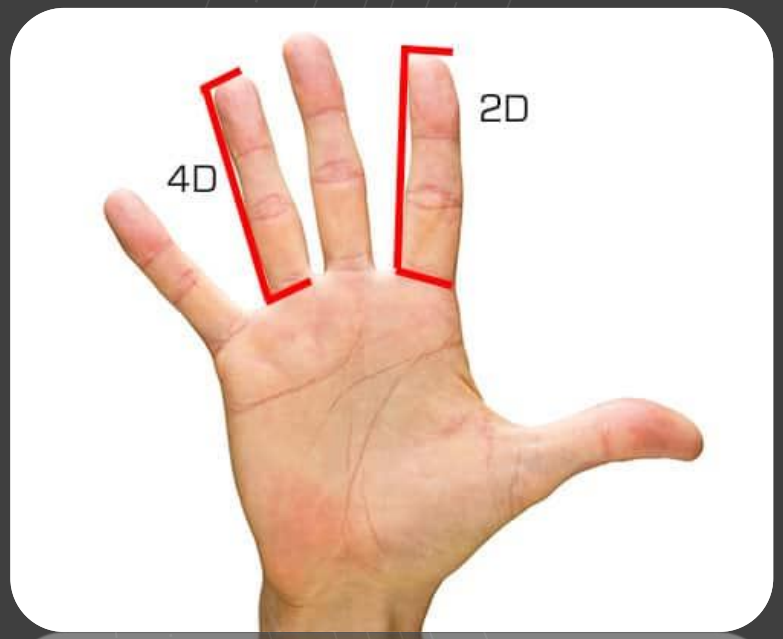
The critical periods of prenatal development. Teratogens are more likely to produce major structural abnormalities during the third through the eighth prenatal week. Note, however, that many organs and body parts remain sensitive to teratogenic agents throughout the 9 month prenatal period
(Moore 1988)

Selection in the first periods of ontogeny



Prenatal epigenetic markers

1. Dermatoglyphs (ridge count)
2. Otoacoustic emission
3. **2D:4D ratio**



- ♂ ♀ different finger proportions
- ♂ 2D shorter than D4
- ♀ 2D is the same length or longer than D4
- 2D:4D ratio correlates with numerous sexually dimorphic behavioral & physiological conditions

- Digit ratios reflect **prenatal exposure to androgen**,
- However! the developmental mechanism underlying sexually dimorphic digit development remains unknown??

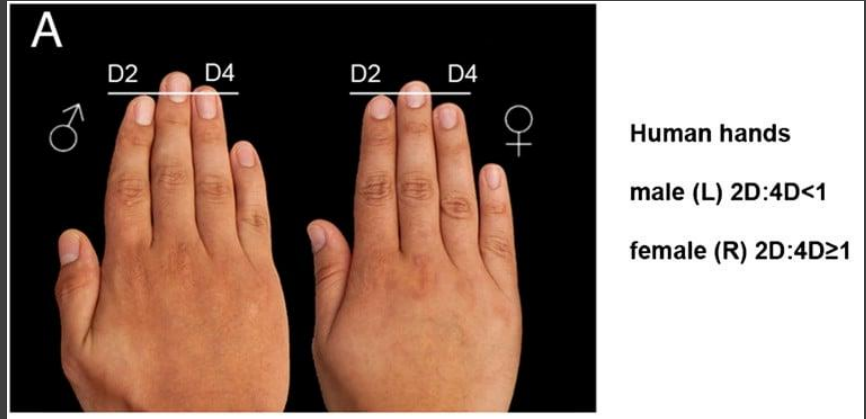
Prenatal epigenetic markers

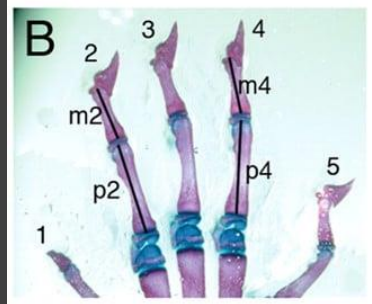
Zheng, Cohn 2011

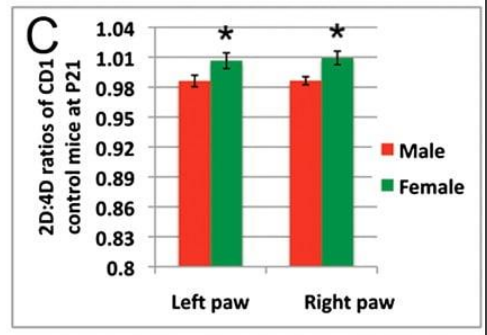
2D:4D ratio in mice is controlled by the balance of androgen to estrogen signaling during a narrow window of digit development.

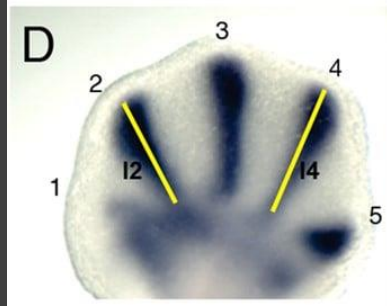
Androgen receptor (AR) and estrogen receptor α (ER-α) activity is higher in digit 4 than in digit 2.

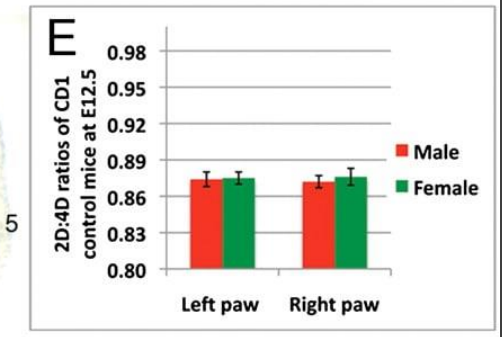
Inactivation of AR decreases growth of digit 4, which causes a higher 2D:4D ratio, whereas inactivation of ER-α increases growth of digit 4, which leads to a lower 2D:4D ratio.

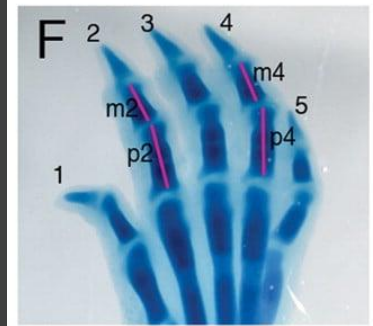


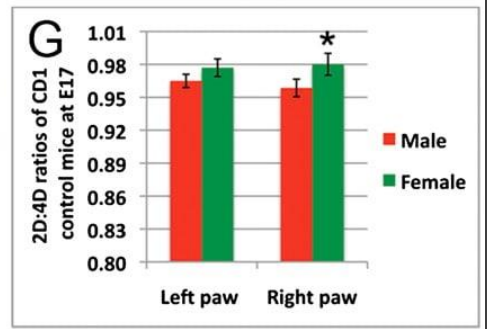










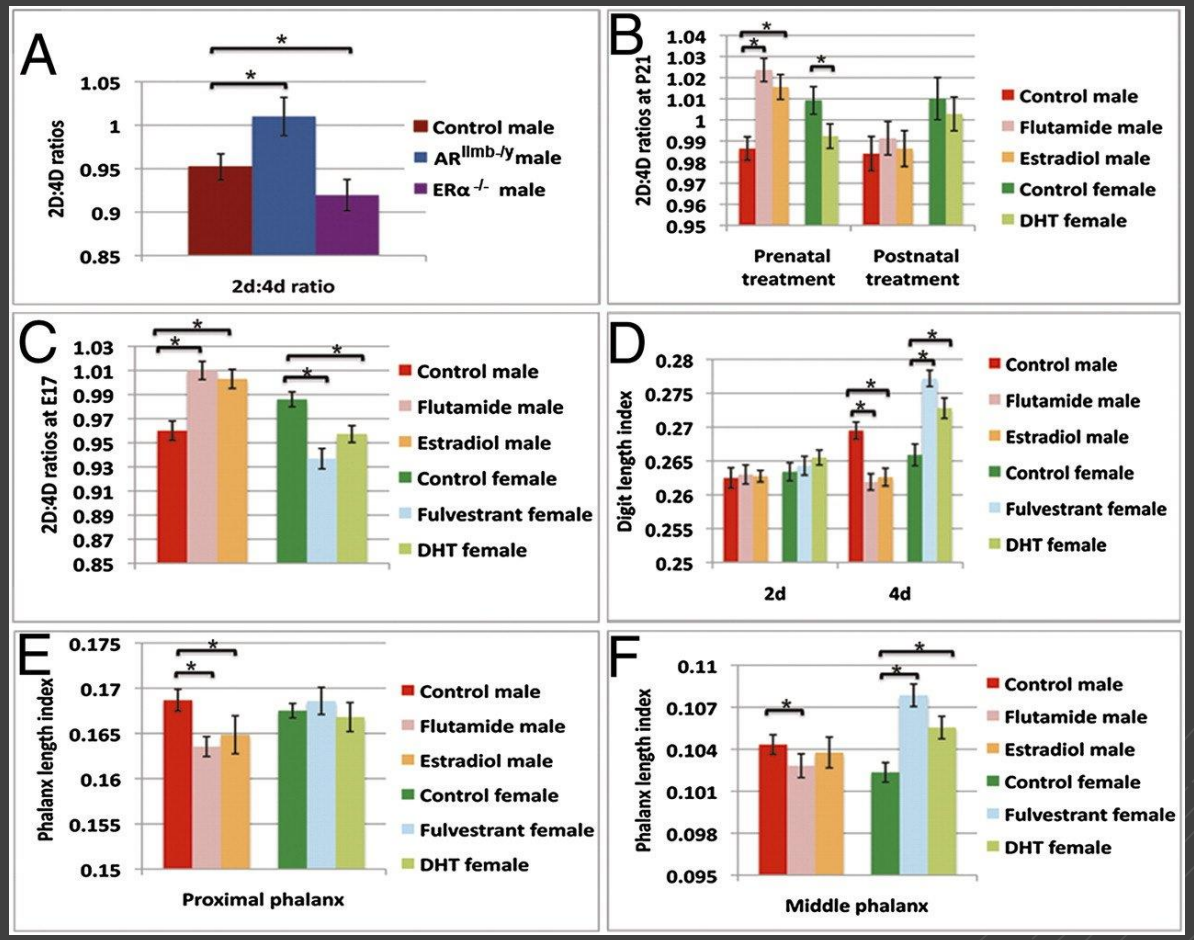


Prenatal epigenetic markers

Zheng, Cohn 2011

addition of androgen has the same effect as inactivation of ER and that addition of estrogen mimics the reduction of AR

Androgen and estrogen differentially regulate the network of genes that controls chondrocyte proliferation, leading to differential growth of 4D in males and females

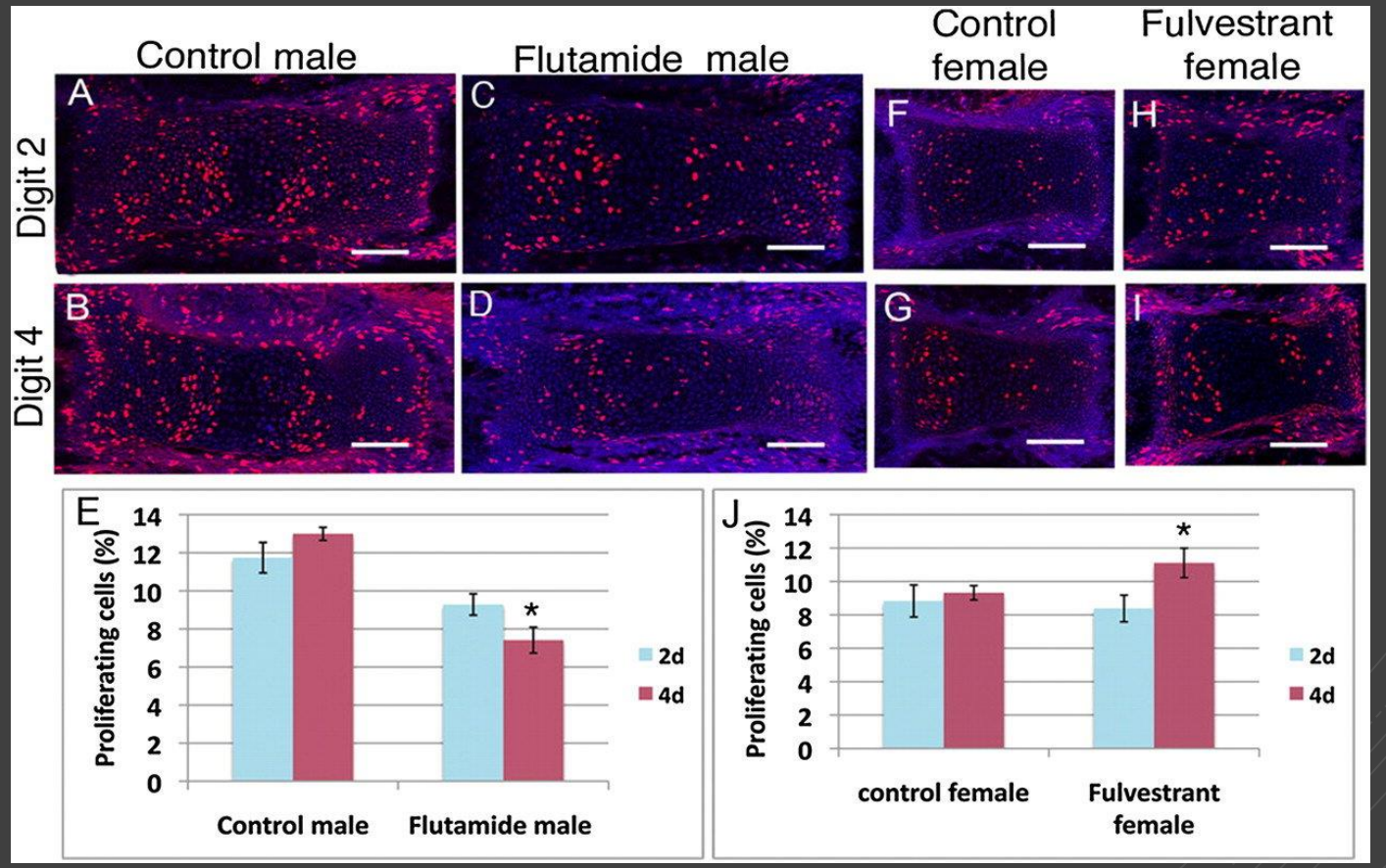


Prenatal epigenetic markers

Zheng, Cohn 2011

provide experimental evidence that the digit ratio is a **lifelong signature of prenatal hormonal exposure**

suggest that the 2D:4D ratio can serve as an **indicator of disrupted endocrine signaling during early development**, which may aid in the identification of fetal origins of adult diseases.



Conclusions

- Environmental influences on prenatal and postnatal growth and development (diet, stress, learning, upbringing, social interaction, microorganisms' immunity, physical load...)
- Ontogeny and its epigenetic processes represent life itself, which realizes the connection between the evolutionary past, the demands of the environment (physical, biotic, social and cultural factors) and other constraints
- Human - a bio-socio-cultural creature, all levels are inextricably linked