SECONDARY SEX CHARACTERISTICS

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INTRODUCTION

SEXUAL DIMORPHISM is a phenotypic / physical difference between males and females of the same species. Examples of such differences include differences in morphology, ornamentation, and behavior etc. It is a phenomenon associated not only with human being but with other primates, creatures other than primates & even in some plants too.

Some of these differentiating characteristics are present by birth while some are destined to develop later – at certain age of the individual's life. Former set of physical / phenotypic characteristics are mostly **primary** in nature while the later are usually **secondary** in nature.

Before going on the details of such phenomenon, it is necessary to present a brief review of different periods of the human lifespan.

DIVISION OF AGE (AS PER ĀYURVEDA)

MALES			FEMALES		
STAGES		**SPAN**	**STAGES**		**SPAN**
Childhood (बाल्यावस्था)		Since Birth to 16th year	**Childhood (बाल्यावस्था)**		Since Birth to 16th year
			1.	Bālā (**बाला**)	Since Birth to 10th year
			2.	Kumārī (**कुमारी**)	Since 11th to 12th year
			3.	Rajomatī (**रजोमती**)	Since 13th to 16th year
Middle age (मध्यमावस्था)		Since 17th year to 60th / 70th year	**Middle age (मध्यमावस्था)**		Since 17th to 50th year
1.	Vriddhi (**वृद्धि**)	Since 17th year to 20th year	1.	Yuvatī (**युवती**)	Since 17th to 40th year
2.	Yuvā (**युवा**)	Since 21th year to 30th / 34th year	2.	**Praudḥā**	Since 41th to 50th year

2.	Yuvā (युवा)	Since 21th year to 30th / 34th year	2.	Praudḥā (प्रौढा)	Since 41th to 50th year
3.	Dhātu maturity (सर्वधातु सम्पुर्णता)	Since 31st / 35st year to 40th / 60th year	3.	Vrḍdhā (वृद्धा)	50th year & onwards
4.	Begining Of Decline (क्षय प्रारम्भ)	Since 41st to 70th years (as per Suśruta only)			
Old age (वृद्धावस्था)		Since 61st / 71st years to Death	**Old age (वृद्धावस्था)**		50th year & onwards

Table 1- DIVISION OF AVERAGE AGE IN HUMAN BEINGS (AS PER ĀYURVEDA)

DIVISION OF AGE (AS PER MODERN ORTHODOX MEDICAL SYSTEM)		
STAGE	**SUB – STAGE**	**SPAN**
Infancy	Infancy	Since Birth to 18th month
Toddlerhood	Toddlerhood	Since 18th month to 3rd year
Childhood	Early Childhood	Since 4th to 6th year
	Middle Childhood / Preadolescence	Since 7th to 11th year
	Late Childhood / Adolescence	Since 12th to 20th year
Adulthood	Young Adulthood	Since 21st to 40th year
	Middle Adulthood	Since 40th to 65th year
	Late Adulthood / Old age	65th year & onwards

Table 2- AVERAGE DIVISION OF AGE IN HUMAN BEINGS (AS PER WESTERN ORTHODOX MEDICAL SYSTEM)

PUBERTY is the beginning of **adolescence**. It is the period which links childhood to adulthood. But when is puberty, exactly? The hormonal changes begin as early as 8 years old. But the physical changes don't

are not going to discuss the controversial details here due the topic adherence). Since, this is a stage which overlaps with LATE BĀLYĀVASTHĀ & EARLY MADHYAMĀVASTHĀ hence not mentioned in the above table (table 1).

Historically, the term **PUBERTY** has been heavily associated with teenagers and the onset of adolescent development. However, the start of puberty has had somewhat of an increase in **preadolescence** (particularly in females, as seen with early and precocious puberty), and **adolescence** has had an occasional extension beyond the teenage years (typically males) compared to previous generations. These changes have made it more difficult to rigidly define the time frame in which adolescence occurs.

The first clear sign of **puberty for girls** is the **thelarche** (pronounced THEL-ark-ee) i.e. beginnings of breast development, around the age of 12 yrs. There is also an overall **growth spurt** that begins around 10½ yrs., peaks at 12 yrs., and begins to slow around 14 yrs. of age (all are mean values). But the main mark of puberty is **menarche** (pronounced MEN-ark-ee; **प्रथम् रजोदर्शन**) i.e. the first menstrual period. Usually, it tends to happen between 12 yrs. and 13 yrs. of age.

The first mark of **puberty in boys** is the start of testes growth around the age of 13 yrs., and penis growth around 14 yrs. The growth spurt for boys tends to begin at 12½ yrs., peak at 14 yrs., and slows by 16 yrs (all are mean values).

Wheather this stage of life is referred to as either **puberty** or **vayah – sandhi**, it doesn't matter. The important fact is that during this phase, **development of secondary sexual characteristics** start & get completed during the entire phase of **ADOLESCENCE**.

PRIMARY AND SECONDARY SEX CHARACTERISTICS

"PRIMARY SEX CHARACTERISTICS " refer to phenotypic / physical characteristics present in the human body that are directly involved in reproductive function: namely the gonads and their accessory structures. The development of primary sex characteristics happens to the foetus in the womb.

"SECONDARY SEX CHARA CTERISTICS" refer to physical characteristics that are typically associated with **"males"/"men"** and **"females"/"women"** but are not necessarily related to reproductive function. Examples would include facial hair growth and deepening of the voice in men, and growth of breasts and increased fat deposits around the hips in women. They are believed to be the product of **SEXUAL SELECTION** for traits which give an individual an advantage over its rivals in courtship and aggressive interactions. Well known secondary s ex characteristics include

Manes of male lions.
Long feathers of male peacocks .
Horns in many goats and antelopes.
Male birds and fish of many species have brighter coloration or other external ornaments.
Differences in size between sexes are also considered secondary sexual characteristics.
Petals & sepals of flowers.
In humans, enlarged breasts of females and facial hair and Adam's apple on males.

IMPORTANCE / SIGNIFICANCE OF SECONDORY SEXUAL DEVELOPMENTS

The concept of **SEXUAL SELECTION** was introduced by **CHARLES DARWIN** in 1859 in his book **ON THE ORIGIN OF SPECIES** (although the phenomenon is known since immemorable dates but first clear cut use of this term by him). This theory is a significant offshoot of his main theory of **NATURAL SELECTION**.

The sexual selection concept arises from the observation that many animals (including human too) develop features whose function is not to help individuals survive, but help them to maximize their reproductive success. This can be realized in two different ways:

By making themselves attractive to the opposite sex (**intersexual selection** i.e. selection between the sexes); or
By intimidating, deterring or defeating same-sex rivals (**intrasexual selection** i.e. selection within a given sex).

Thus, sexual selection takes two major forms:

Intersexual selection (also known as **'mate choice'** or **'female choice'**) in which males compete with each other to be chosen by females; and
Intrasexual* selection** (also known as **'male–male competition'**) in which members of the less limited sex (typically males) compete aggressively among themselves for access to the limiting sex. The ***limiting sex is the sex which has the higher parental investment, which therefore faces the most pressure to make a good mate decision.

SECONDARY SEX CHARACTERISTICS IN HUMEN / HUMAN BEING

MALE

Growth of **body hair** , including underarm, abdominal, chest, and pubic hair. Loss of scalp hair androgenic alopecia can also occur .
Greater mass of thigh muscles in front of the femur, rather than behind it (as is typical in mature females).
Growth of **facial hair** .
Enlargement **of larynx (Adam's apple)** and deepening of **voice** .
Increased **stature** ; adult males are taller than adult females, on average .
Heavier **skull** and **bone** structure .
Increased **muscle** mass and strength .
Larger hands and feet than w omen, prepubescent boys and girls .
Square face .
Small **waist** , but wider than females .
Broadening of **shoulders** and **chest** ; shoulders wider than hips .
Increased **secretions** of oil and sweat glands, often causing acne and body odor .
Coarsening or rigidity of **skin texture** , due to less subcutaneous fat .
Higher **waist -to -hip ratio** than prepubescent or adult females or prepubescent males, on average .
Lower **body fat percentage** than prepubescent or adult females or prepubescent males, on average .
Enlargement / **growth** of the penis .

FEMALE

Enlargement of **breasts** and erection of **nipples** .
Growth of **body hair** , most prominently **underarm** and **pubic hair** .
Greater development of **thigh muscles** behind the **femur** , rather than in front of it .
Widening of **hips** ; lower **waist to hip ratio** than adult males, on average .
Smaller **hands and feet** than men .
Rounder **face** .
Smaller **waist** than men .
Upper arms approximately 2 cm longer, on average, for a given height .

Changed distribution in weight and fat; more **subcutaneous fat** and **fat** deposits mainly around the buttocks , thighs and hips .

TIMING OF THE ONSET OF PUBERTY i.e. BEGINING OF SECONDARY SEXUAL DEVELOPMENT

The definition of the onset of puberty may depend on perspective (e.g., hormonal versus physical) and purpose (establishing population normal standards, clinical care of early or late pubescent individuals, etc.). A common definition for the onset of puberty is physical changes to a person's body. These physical changes are the first visible signs of neural, hormonal, and gonadal functional changes.

The age at which puberty begins varies between individuals; usually, puberty begins between 10 and 13 years of age. The age at which puberty begins is affected by both genetic factors and by environmental factors such as nutritional state and social circumstances. Variations in such timing due to nutritional status & health are mentioned in Āyurveda as follows:-

- **अर्वागपि यदाहारविशेषादारोगयाच्च पूर्णे भवति इति परिषत् ।।**

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The average age at which puberty begins may be affected by race as well. For example, the average age of menarche in various populations surveyed has ranged from 12 to 18 years. The earliest average onset of puberty is for African-American girls and the latest average onset for high altitude subsistence populations in Asia. Rest fall in between them.

However, much of the higher age averages reflect nutritional limitations more than genetic differences and can change within a few generations with a substantial change in diet. The median age of menarche for a population may be an index of the proportion of undernourished girls in the population, and the width of the spread may reflect unevenness of wealth and food distribution in a population.

THE "SEX HORMONES:" TESTOSTERONE, ESTROGEN, AND PROGESTERONE

The hormones commonly considered to be **"sex hormones"** in the body are testosterone, estrogen, and progesterone. Testosterone is often referred to as a "male" hormone, and estrogen and progesterone are often referred to

as "female" hormones. However, it is interesting to note that no exclusively "male" or "female" hormones have been identified. All hormones characterized to date are present in all people regardless of sex, as are the receptor mechanisms that respond to those hormones.

In fact, the physical observation of the sexes we call "male" and "female" in nature is the result of ***differences in the amounts*** *of individual hormones in the body and* ***differences in their patterns of secretion*** (first *in utero* and then again during puberty) rather than their *presence or absence*. In other words, testosterone, estrogen, and progesterone are produced by men and women, but in differing amounts and in different patterns.

Endocrinologists classify sex hormones as being in the family of **"steroid hormones"**--derivatives of cholesterol that are synthesized mainly by the gonads and, in smaller amounts, the adrenal gland. Steroid hormones are typically classified into five groups of molecules, based primarily on the receptors to which they bind:

* **Androgens,** such as testosterone
* **Estrogens,** such as estrodiol and estrone
* **Progestins,** such as progesterone
* **Glucocorticoids,** such as cortisol
* **Mineralocorticoids,** such as aldosterone

For the purposes of this section, only the androgens, estrogens, and progestins are considered, as they are the hormones mainly responsible for the development "secondary sex characteristics," a term further described below.

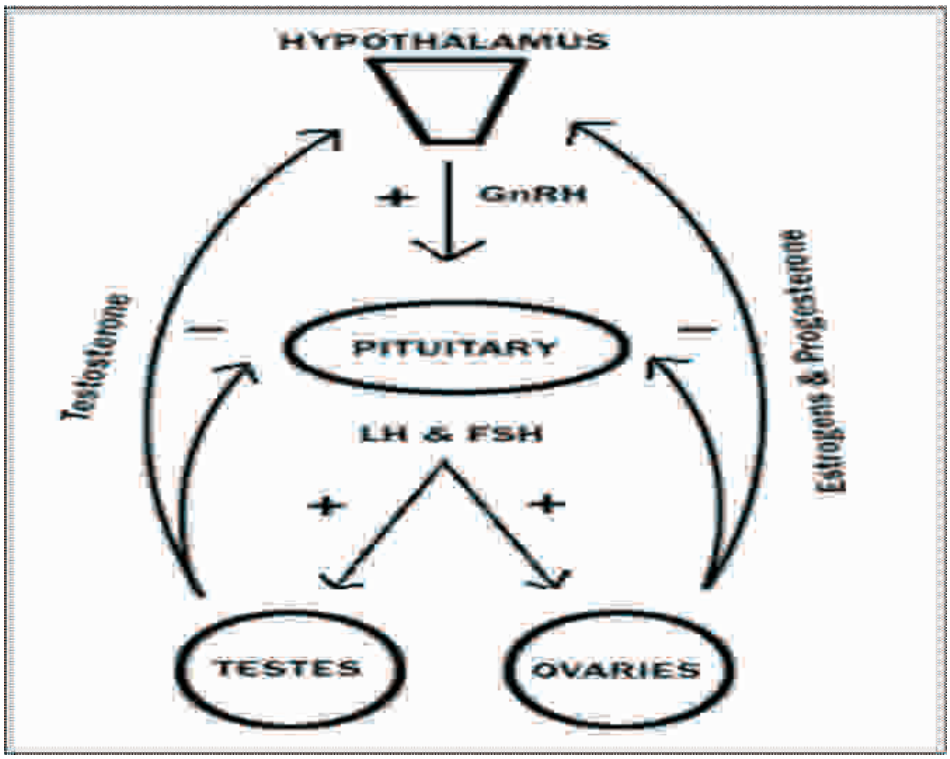
DEVELOPMENTAL PHYSIOLOGY OF SECONDARY SEX CHARACTERISTICS IN HUMAN BEINGS

The development of secondary sex characteristics usually begins at puberty, as the levels and patterns of secretion of the sex hormones in the body begin to change at that time.

The **androgen testosterone** (and its derivative dihydrotestosterone [DHT]) is responsible for producing masculine secondary sex characteristics. **Estrogen** and **progesterone** play a vital role in the menstrual cycle in females. Estrogen is also mainly responsible for producing feminine secondary sex characteristics. Testosterone, estrogen, and progesterone are produced mainly in the **"gonads"** (the testes and the ovaries).

Two other important hormones-- **"luteinizing hormone" (LH)** and **"follicle-stimulating hormone" (FSH)** - stimulate the gonads into secreting sex hormones. LH and FSH are secreted from cells in the **anterior pituitary** gland, and are called **"gonadotropins"** because of their role in stimulating the gonads.

The principle regulator of LH and FSH secretion is **"gonadotropin-releasing hormone" (GnRH)**. GnRH is secreted from the **hypothalamus**. GnRH stimulates secretion of LH and FSH, which in turn stimulates gonadal secretion of the sex steroids testosterone, estrogen and progesterone (see diagram below). In an example of a negative feedback loop, the presence of a certain level of sex steroids then inhibits further secretion of GnRH. Numerous hormones influence GnRH secretion, and feedback control over GnRH and LH/FSH secretion is considerably more complex than depicted in the following diagram.



DISORDERS RELATED TO SECONDARY SEXUAL DEVELOPMENT

PRECOCIOUS PUBERTY

The overall incidence of sexual precocity has been estimated to be 1:5,000 to 1:10,000 children. The female to male ratio is approximately 10:1. The classic definition of sexual precocity is the appearance of secondary sexual characteristics before the age of 8 years in girls, but although controversial, new revised recommendations have redefined precocious puberty. If clinicians follow the revised recommendations, puberty is not considered precocious unless it occurs prior to age 6 years for African-American girls or

Figure 1 - Feedback control over GnRH and LH/FSH secretion

age 7 years for Caucasian girls.

However, many pediatric endocrinologists in the United States routinely evaluate all girls with precocious development prior to the cutoff at age 8 years. Even when puberty occurs between ages 6/7 and 8 years, it is important to consider evaluation of all children. The child may be suffering from a serious CNS disorder associated with precocious puberty. In addition, psychosexual maturation remains concordant with chronological age, and unfortunately early physical sexual maturation at any age places these young girls at a high risk for sexual abuse. Clinicians should routinely screen children with early development for sexual abuse.

The appearance of the secondary sexual characteristics of precocity results from increased sex steroid production. This increase may be secondary to aberrant gonadotropin stimulation or intrinsic disease of the ovary or adrenals.

True precocious puberty, also known as complete precocious puberty, refers to puberty that appears early and either progresses through each of the pubertal landmarks including menarche or, in the absence of treatment, would likely progress through each of these stages.

Incomplete precocious puberty refers to the appearance of one phase of the pubertal process: thelarche, adrenarche, or menarche.

Isolated precocious thelarche, isolated precocious adrenarche, and isolated menarche are the three forms of incomplete precocious puberty.

DELAYED PUBERTY

In general , **the absence of thelarche by age 13 years for girls signifies an abnormality, and remains the definition of pubertal delay** . While some patients present strictly with the absence of the onset of pubertal development, others have abnormalities in the tempo and sequence of puberty th at has seemingly begun on time.

The American Academy of Pediatrics and the American College of Obstetricians and Gynecologists have jointly published guidelines in terms of evaluation of delayed development. They recommend evaluation of girls who have not had menarche within 3 years of thelarche. This recommendation is based on the fact that most girls have menarche between 2 and 3 years after thelarche.

These guidelines also recommend evaluation of girls with the following characteristics:

No breast development by age 13 years (delayed puberty)
Absence of menarche by age 14 years in the presence of hirsuitism or history or exam suggestive of eating disorder or excessive exercise or an outflow abnormality
Absence of menarche by age 15 years.

Age definitions should be seen only as general guidelines. Rather than require a young woman meet the strict definitions of menarche by age 15 or 16 years to initiate an evaluation for delayed puberty, it has been suggested that all adolescents be followed annually throughout the pubertal process.

The most common causes of abnormal puberty were: **(1) ovarian failure (42%); (2) congenital absence of the uterus and vagina (14%), and (3) constitutional delay of puberty (10%)**. Remaining 34% includes other causes with unknown factors too.

Numerically, more patients with ovarian failure and delayed puberty have a form of **Turner syndrome** than they do with either 46,XX or 46,XY gonadal dysgenesis.

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