The Human Lifecycle
Part 1

by:

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GROWTH AND DEVELOPMENT BEFORE BIRTH

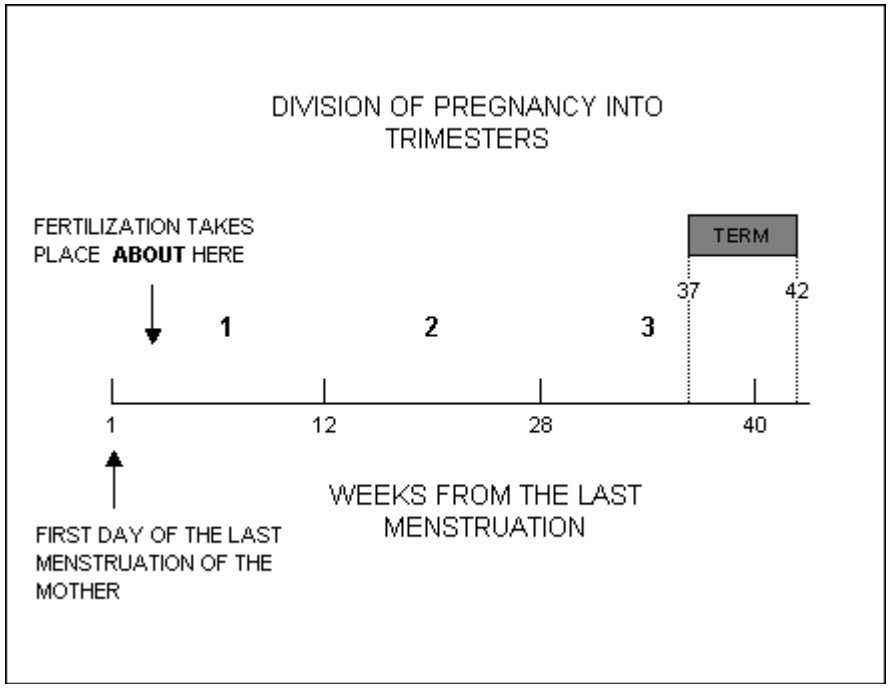
The period of prenatal growth is vitally important to the child's future well being - yet it is the period about which, inevitably, we know least.

Measurement of the duration of pregnancy

"Pregnancy" obviously starts at the moment of conception. This generally occurs round about the time of ovulation. But since ovulation is a symptomless event, and coitus occurs haphazardly throughout most of the menstrual cycle, it is virtually impossible to know when fertilisation occurs. Menstrual cycles, and particularly the length of the first phase of the cycle (the "follicular phase"), are too irregular to make the assumption that ovulation always occurs exactly 2 weeks after the last menstrual period. Clinically, therefore, pregnancy is measured from the only definite date that is generally reasonably easy for the mother to remember in retrospect: the date of the start of her last menstrual period. Obviously for the first two weeks or so of "clinical pregnancy" the mother is not pregnant in any sense of the word, but, as a practical solution, it works extremely well.

Division of pregnancy into trimesters

The duration of pregnancy measured in this way is then, on average, 40 weeks (approximately 9 calendar months). It is divided into 3 "trimesters" ("Trimester" is derived from Latin, meaning a 3-month period). The first trimester is officially from the first day of the last menstrual period of the mother till the end of the 12th week of clinical pregnancy. The second trimester is from the 13th till the 28th week; and the 3rd trimester lasts from the 29th week till the birth of the baby.



These trimesters have different clinical significances. The baby is in the "embryo stage" during the first trimester. This means that it grows very little, but all the organs are developed during this time. It is therefore the time of "organogenesis". If things go wrong during this period (e.g. the mother becomes ill with German measles, or suffers from malnutrition, or takes certain drugs) then the baby might develop malformations of one sort or another.

At the end of the first trimester organogenesis is more or less complete and the individual therefore looks, for the first time, reasonably human (although it can still be confused with a gorilla or chimpanzee embryo at the same stage of development).

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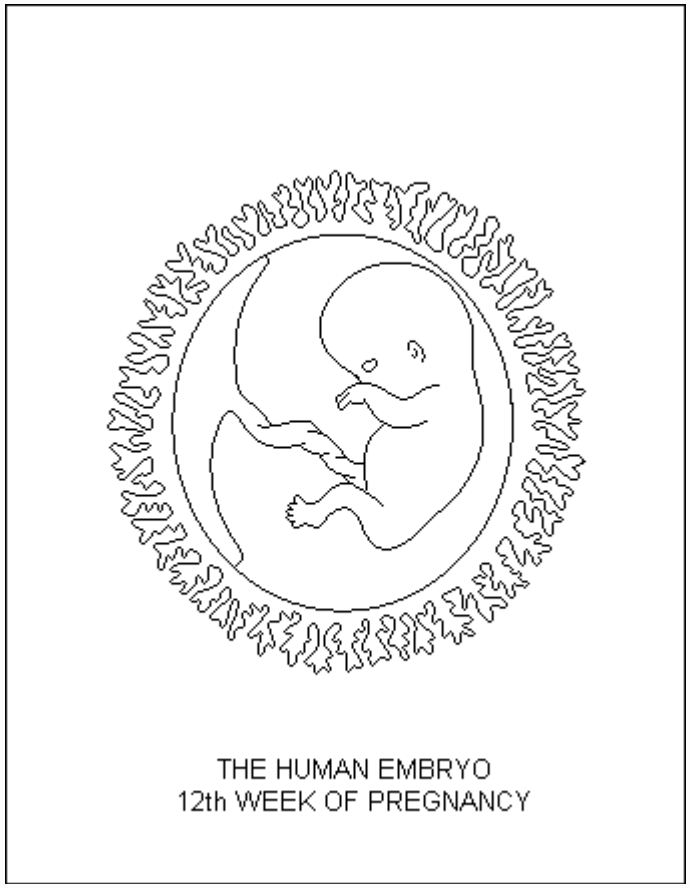


During the second trimester the baby, who is now called a "foetus", starts to grow faster and faster, which it will continue doing till about half way through the 3rd trimester. The rate of growth slows down during the second half of the 3rd trimester, but never stops, unless pregnancy goes on well beyond "term". "Term" is the period between the 37th and 42nd week of pregnancy during which over 70% of babies that make it to the 3rd trimester are born.

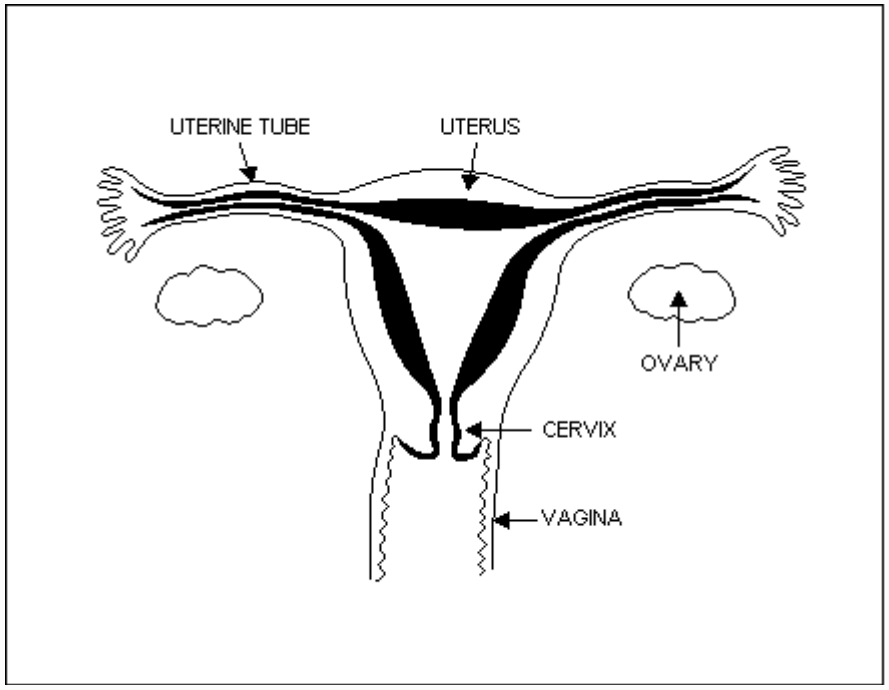
The boundary between the second and third trimesters marks the point at which most foetuses begin to make surfactant in the lungs. This is a soapy material that permits expansion of the lungs if they become filled with air. Surfactant is therefore absolutely essential for air breathing. Thus, in general, foetuses born before the 28th week cannot breathe on their own, and are therefore inviable without medical assistance. Those born after the 28th week stand some chance of survival without special assistance. For legal purposes, therefore, babies born before the 28th week are classified as "abortions" or "miscarriages"; whereas babies born after the 28th week have to be officially registered as "births" (even if born dead).

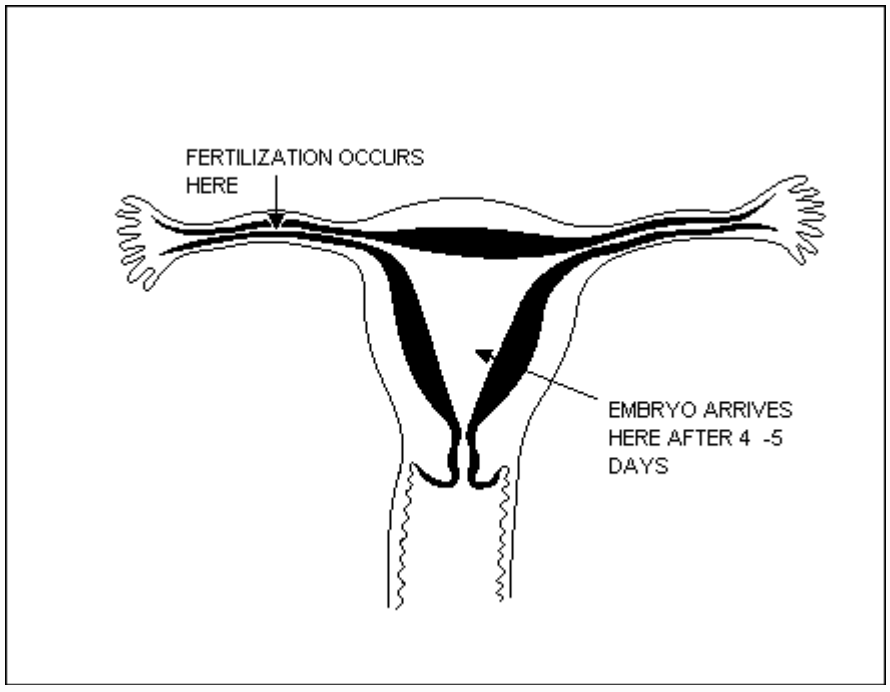
During the first and second thirds (trimesters) of pregnancy we have to rely on cross-sectional studies in order to construct a picture of this early phase of a human life. This is because it is virtually impossible to follow the developmental process of any single embryo/foetus. It is also very difficult, if not impossible, to obtain anything but purely anatomical information about this period of human development. In the first trimester (from the beginning of pregnancy till the 12th week) reliance has to placed on embryos that are aborted (or miscarried) during that time. Spontaneous abortions often involve abnormal embryos, and would not be suitable for the study of normal development. But when pregnancy is terminated artificially (for a variety of reasons, often social) the embryos are presumed to be normal, and it is then reasonable to make inferences about normal development from them. In the second trimester reliance is placed on indirect visualisation (such as echograms), and on foetuses which are expelled from the uterus because, in one way or the other, there was some abnormality. Obviously the possibility of such abnormalities casts some doubt on the

conclusions which can be drawn from this type of investigation. For later foetal life we can study infants born prematurely, making the assumption that these children had been growing normally before birth. Though this may seem a hazardous assumption, it is probably justified if care is taken to exclude certain obvious abnormalities.

The probability of pregnancy

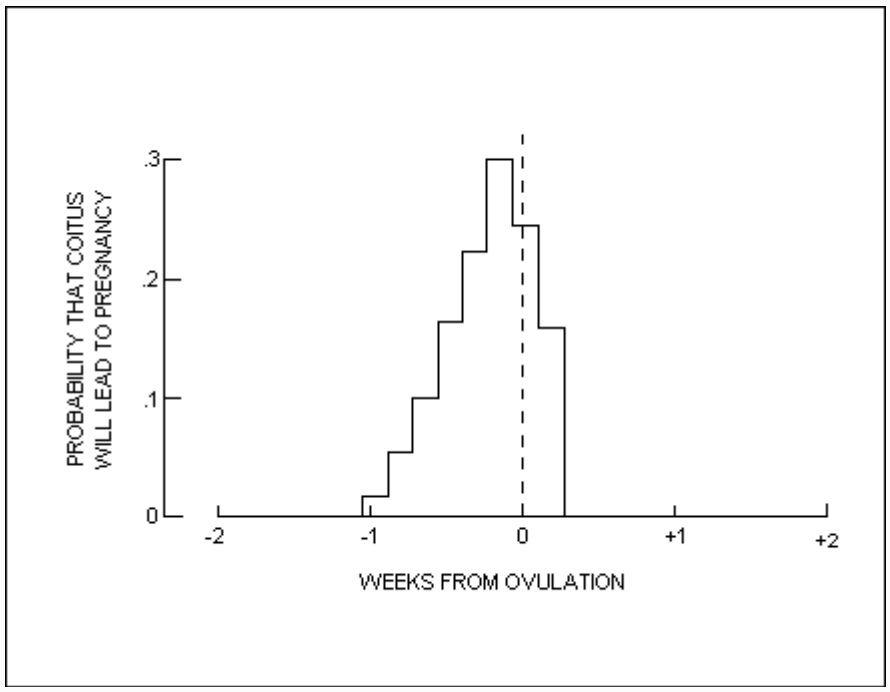
Our ignorance of human development begins at the beginning, for we do not know what forces are responsible for selecting one sperm to fertilise the ovum when some 6 million or so are deposited in the female genital tract during coitus.





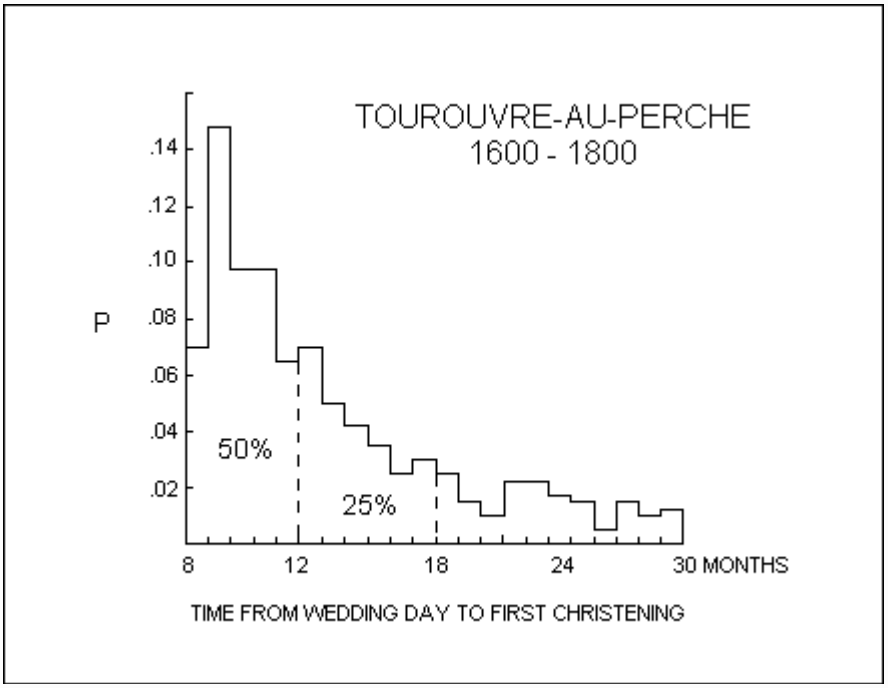
Fertilisation occurs in one of the uterine tubes usually within about 24 hours of ovulation. Sperms usually remain viable in the female genital tract for about 48 hours, but can stay viable for a week.

The ovum also usually remains fertilisable for about 48 hours after ovulation. Artificial insemination studies suggest that if coitus takes place at the most ideal time for fertilisation (viz. during the 24 hours just before ovulation), then the chances of a viable pregnancy are, at best, only about 30%.



The probability of a viable pregnancy falls off rapidly the longer the interval between coitus and ovulation. Coitus at 3 days before ovulation has a 20% probability of causing a viable pregnancy; and coitus 1 week before ovulation has only a 1% probability of causing pregnancy. The probability of pregnancy resulting from coitus on the day of ovulation is about 25%, which falls to 18% on the next day. Coitus from the second day after ovulation onwards cannot result in pregnancy, primarily because the cervix is blocked by a very viscous plug of mucus which prevents the penetration of sperm into the uterus, and partly because the egg is then no longer fertilisable.

Analysis of church registers of marriages and the first christening after such marriages, in the days before the availability of convenient contraceptives, gives an indication of how these probabilities operate in practice.



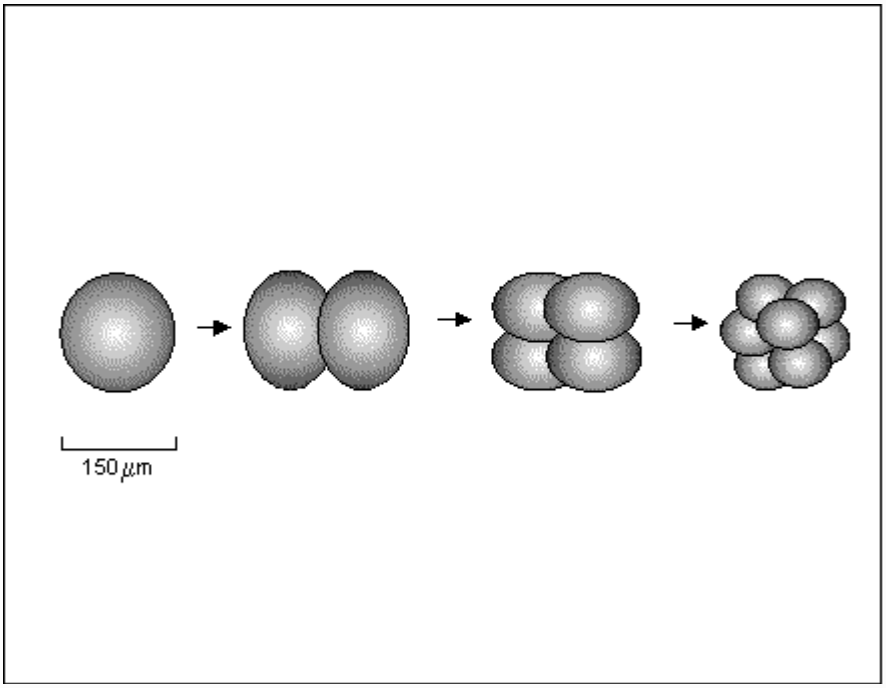
The assumptions that have to be made when analysing these data are that young married couples in 1600-1800 (in a town like Tourouvre-au-Perche) immediately tried to have children when they got married in those days (a not unreasonable assumption). It also has to be assumed that pre-marital sex, with the intention of causing pregnancy, was exceptional (not such a reasonable assumption!). Neither of these assumptions are probably entirely correct. Yet, despite these confounding factors, the data contain a very clear message. Only 50% of brides appear to have become pregnant (and carried the pregnancy more or less to term) within the first 3 months after marriage (and therefore produced babies within a year of the marriage). A further 25% of brides bore babies during the next 6 months. The remaining 25% of first births occurred more than 18 months after marriage, meaning that it took more than 9 months of presumably trying very hard to cause pregnancy for the bride to actually become pregnant.

The important lesson from this data is that one should not be too hasty in declaring a couple infertile simply because they have been trying unsuccessfully to become pregnant for a year. It is not at all unlikely that the couple is perfectly normal and healthy, but that they are simply still waiting for the dice of life to roll a "double six" for them.

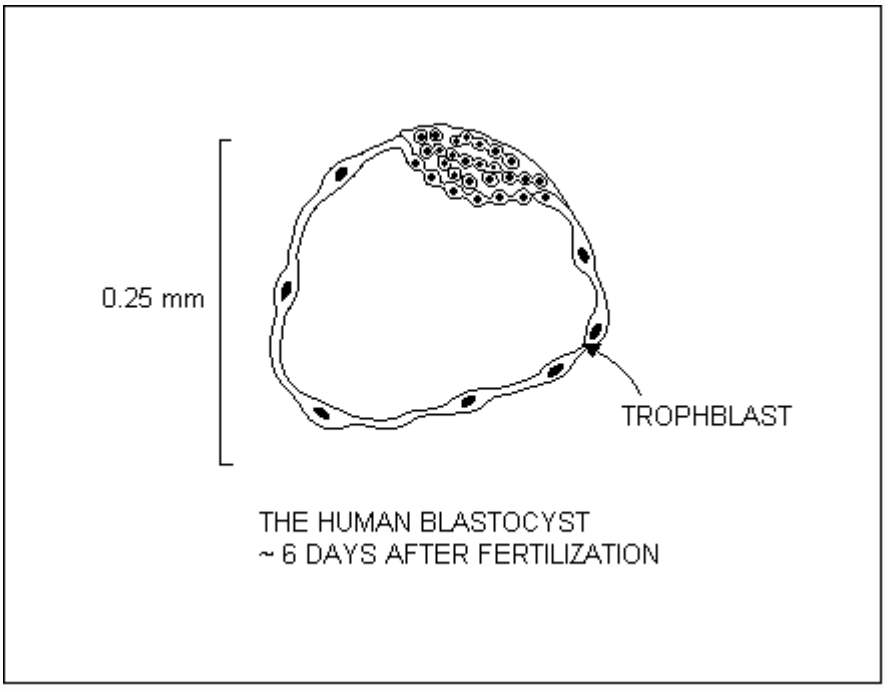
The first trimester

If fertilisation occurs, the fertilised ovum spends 4 - 5 days slowly drifting down the uterine tube towards the uterus.

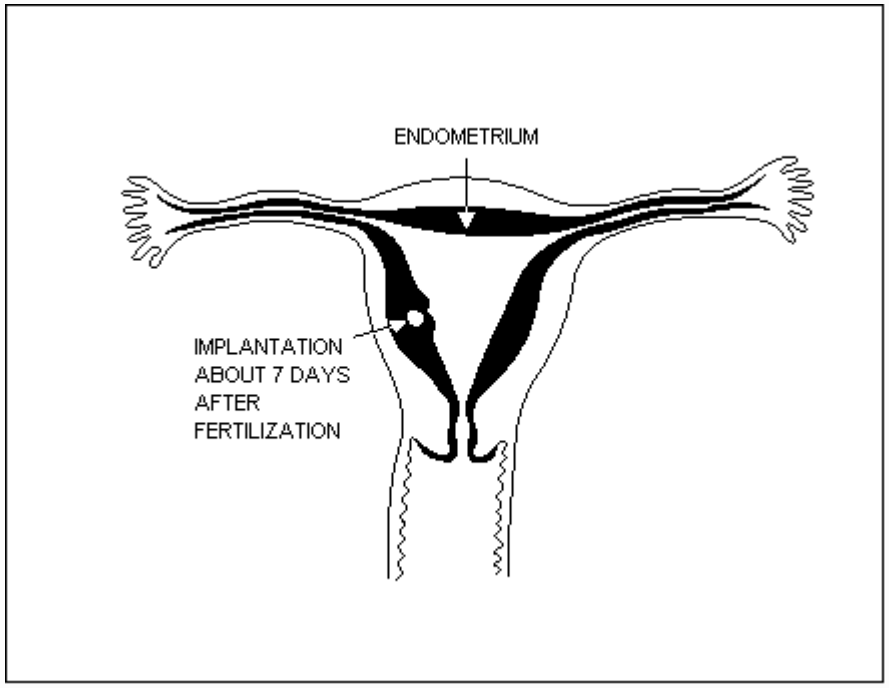
While it does so, it is slowly dividing, first into 2 cells then into 4, then 8, then 16 etc. This is called an exponential progression.



In the human embryo the number of cells doubles about every day or so, and it arrives in the uterine cavity consisting of a hollow ball of some 128 - 264 cells called a blastocyst.



Blastocysts can be washed out of the uterine tubes and implanted into foster mothers, and in animals this technique has been used both for examining the effects of different kinds of uterine environments on development and for transporting the foetuses of large animals by air, while they temporarily packed in the uteri of smaller animals.



After implantation into the uterine endometrium the outer layer of the blastocyst under goes a series of changes which culminate in the formation of the placenta. The inner cell mass, consisting initially of only 8 - 20 cells (out of a total 64 - 128 cells), develops into the embryo proper.

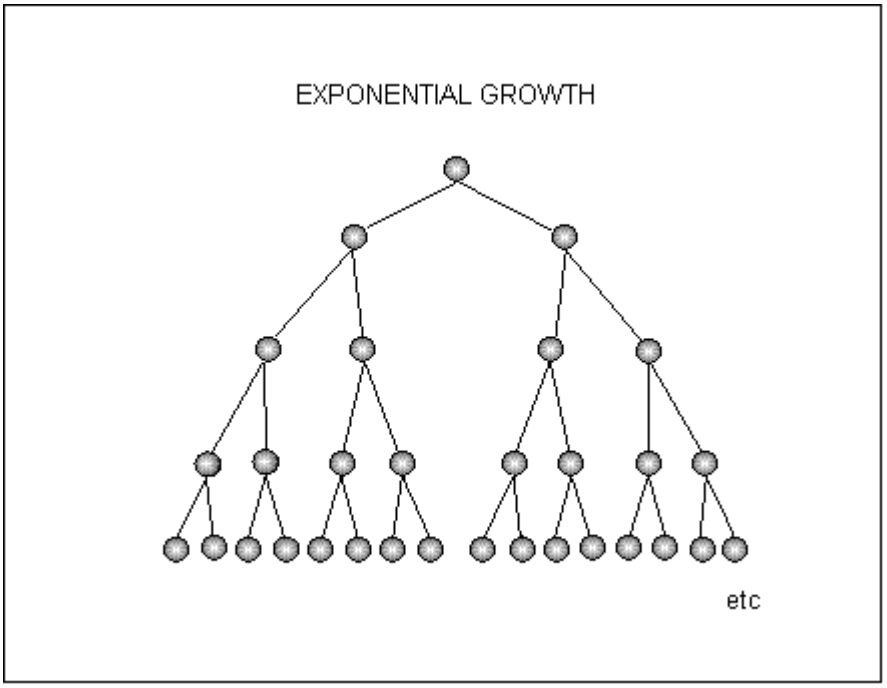
The period of the embryo, starting with the formation of the inner cell mass at about 1 week after conception, is considered to end after about 10 weeks (i.e. the 12th week of pregnancy) when the child, now recognisably human, is called a foetus. At this stage it is about 30 mm long.

Less than half of the ova which are fertilised reach the foetal stage. About 10% never become implanted, and then of those that do, about 50% are spontaneously aborted, usually without the mother knowing that anything unusual has happened.

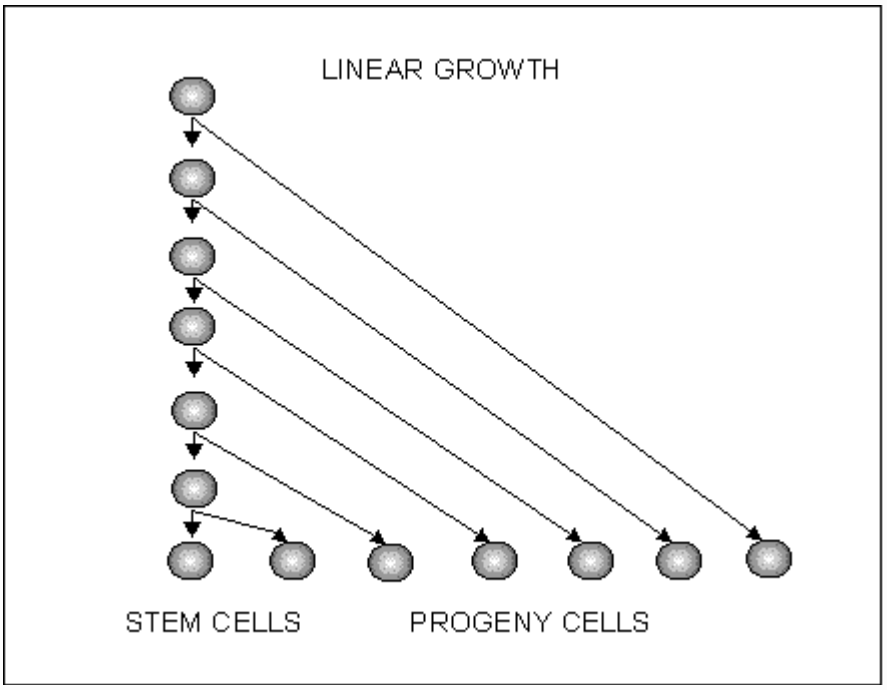
These rejections are due in most cases to abnormalities of development, either of the foetus or of the nutritive surrounding structures. A few lesser abnormalities escape this rejection process in the early stages of pregnancy, and may go on to term, at which stage they may be rejected through not being able to cope with life outside the uterus. A few may live on, such as Down's syndrome to reach adulthood, or even old age (e.g. Turner's syndrome etc.)

Exponential, linear and cancerous cell multiplication

Initially, as we have seen, the number of cells in the developing embryo increases exponentially: that means that each cell division gives rise to 2 daughter cells which in turn each divide. The time between each doubling in the number of cells is called the 'doubling time', which in the human embryo is fairly long at first (12 - 24 h), but becomes shorter (6 - 12 h) after the inner cell mass has begun to differentiate.

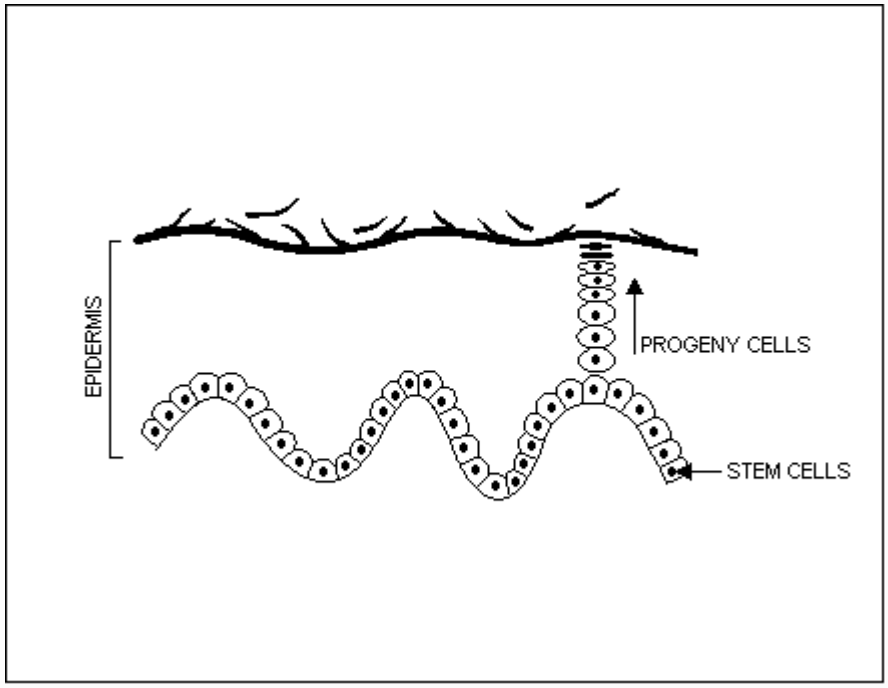


At the same time however there is a gradual decrease in the number of cells which can divide - in other words, increase in cell number is no longer exponential. Instead of each cell division giving rise to 2 equal daughter cells, it is found that only one of the daughter cells retains the capacity for rapid cell division; the other more quiescent cell now shows signs of functional specialisation. The one daughter cell, which goes on to divide again, is called a 'stem cell', since it retains the characteristics of the cell which gave rise to it. The other cell is called a 'progeny cell'. Increase in cell numbers is now linear.

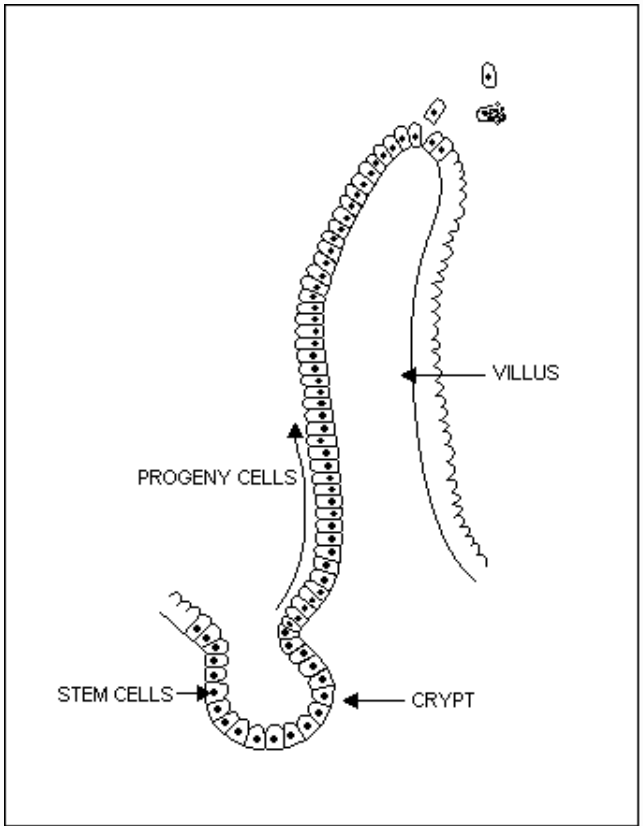


During embryonic development 'progeny cells' may divide (at a later date) and give rise to a second (or third, fourth, fifth etc.,) generation of progeny cells which are progressively more specialised than the earlier generations of 'progeny' cells, which, from the point of view of the later generations, have technically become 'stem cells' in their new setting.

In the adult animal there are small numbers of relatively specialised 'mature stem cells'. They are normally quiescent, and only occasionally feed the progeny pool by cell division, often in response to injury, and consequent wound healing. However, in epithelium the stem cells divide on a regular basis, producing one stem cell which divides again very soon, and a progeny cell that is destined to die within a few days without ever dividing again. In skin epithelium the progeny cells become filled with keratin, lose their nucleus, and eventually flake off as dandruff.

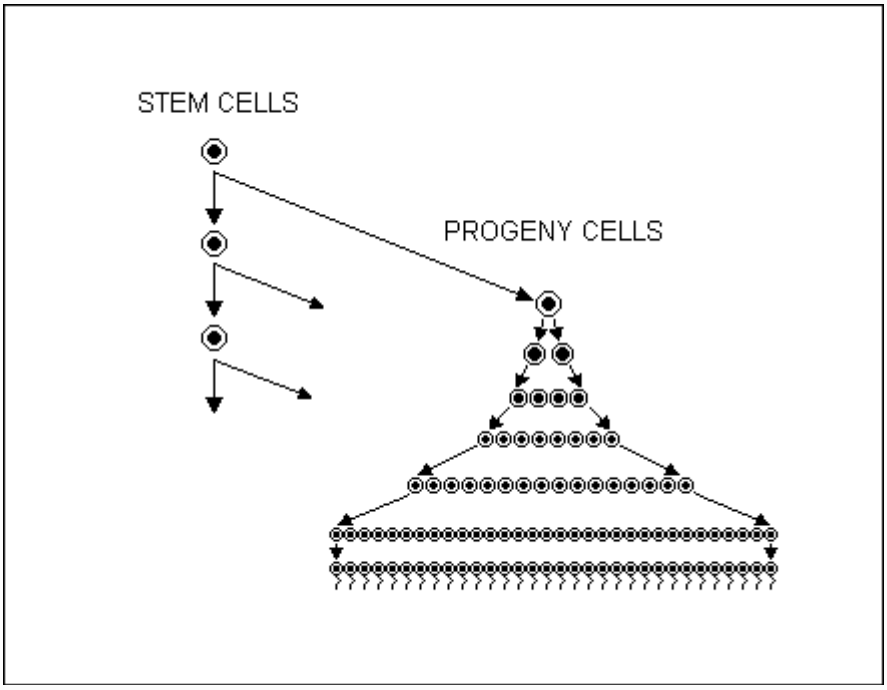


A similar process occurs in the gut and bronchial tree, with stems cells producing one daughter cell that has a very limited life span, while the other retains the mother cell's ability to divide.



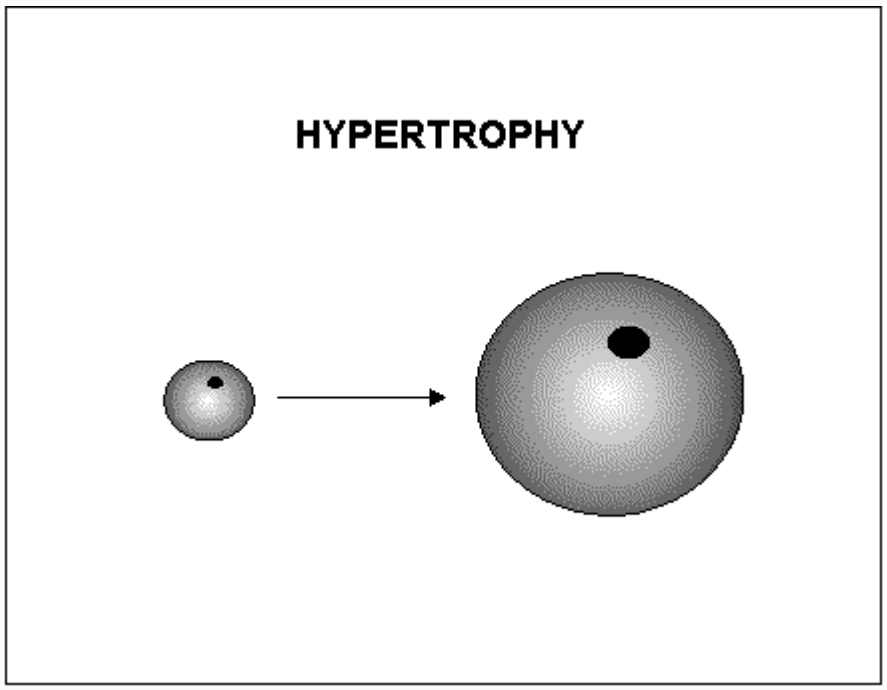
If the cell division in epithelium produces two stem cells (i.e. two identical daughter cells, both of which can divide), the resulting cellular chaos is called a cancer. Cancers seldom undergo mitosis more often than normal stem cells. The reason they form tumours, however, is that the increase in number of cells is exponential and not linear. Thus, if, for argument's sake, normal stem cells divide every day, but a cancer of the same tissue only every week, then in 1 week the normal tissue will have formed 7 cells and the cancer only 2. But after 5 weeks they have produced nearly equal numbers of cells: the normal tissue has formed 35 cells while the cancer has formed 32 cells! At six weeks the cancer consists of 64 cells while the normal tissue has made only 39 cells (most of which will have flaked off as dandruff). It is therefore a mistake to think of cancerous tissue as consisting "rapidly dividing tissue" that should respond to mitosis inhibitors. Cancers can in fact be dividing very slowly, but nevertheless producing rapidly growing tumours!

In tissues such as the bone marrow (where blood cells are formed) and the testes (where spermatozoa are formed) stem cells also divide regularly. The progeny cells in these cases undergo a few, very clearly defined generations of rapid exponential cell division to produce clones of functional cells (which thereafter never divide again, and have a limited life span - 120 days in the case of red blood cells, and not more than a week in the case of sperm cells).



During growth and development one gradually progresses from the stage where the embryo consists entirely of stem cells, capable of exponential growth in numbers to the adult situation where the 'stem cells' that do exist are themselves specialised, and may never be called upon to divided unless there is tissue damage or destruction, or, if a particular tissue is called upon to do extra work, and therefore needs to hypertrophy.

Growth can therefore occur as a result of exponential or linear cell division, or of cell hypertrophy.



In the very early embryo cell division accounts for most of the growth that is seen, but in the later embryo cell hypertrophy becomes an additional source of growth.

Illustrations and website design by Ann Koeslag **(Mail me)**

From Womb to the Tomb

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RATE OF PRE-NATAL GROWTH

All mammalian species start life as a single cell, the fertilised ovum. This cell does not vary much in size whatever the ultimate mass of the adult animal.

Animals differ considerably, however, in the rate at which growth occurs, as shown by the time

taken, from the moment of conception, to reach a mass of 1g. At this stage the embryo is generally recognisably, for the first time, a member of its parents' species, and is then termed a foetus:

hamster	14 days
rabbit	17 days
rat	17œ days
pig	26 days
cat	36 days
human	55 days

This shows that species vary considerably in the rate at which they grow during the embryonic stage of development, and that humans are amongst the slowest developers.

Apart from the growth in mass, animals also differ in the rate at which they progress to maturity (adult physiology). Animals with short gestation periods are nearly always less mature at birth than those born after a longer time in the uterus. Thus the mouse, rabbit, kitten and puppy are born with eyes and ears closed. However, although these species are less mature than the human infant at birth, they are much more mature than the human foetus at the same time from conception. The guinea pig is even more remarkable in that after about 10 weeks' gestation it is born so mature that it runs about and even begins to eat solid food within the next few days.

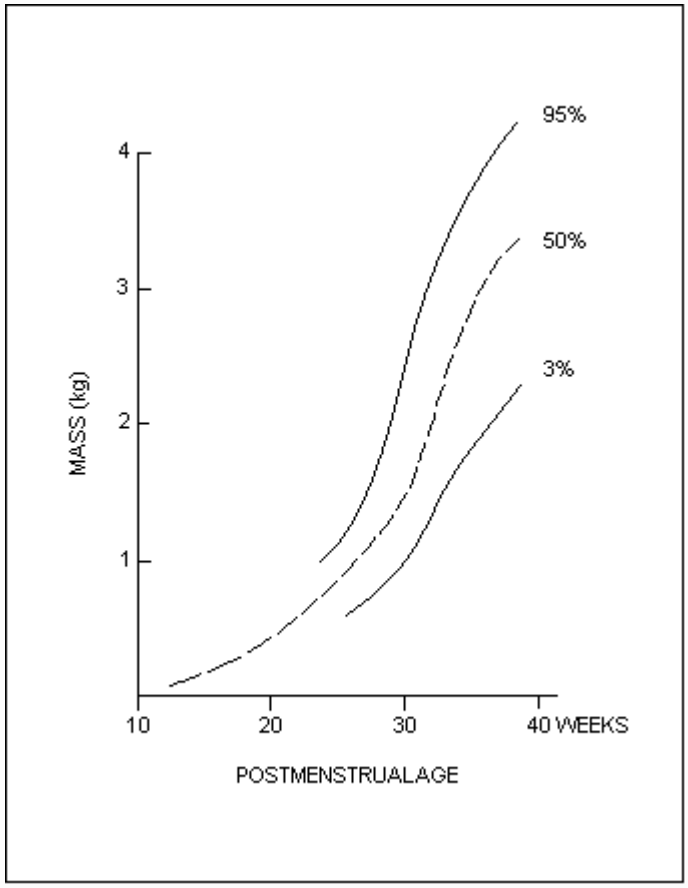
These combinations of rates of growth, maturation and duration of gestation, which must be genetically determined, do not reflect the final size the animal will attain. Thus a hippopotamus with a birth mass of around 33 kg has a shorter gestation than humans, whose mass at birth is a little over 3 kg. Conversely, after spending twice as long *in utero*, a new-born elephant is only the same size as a new-born horse at 65 - 70 kg.

The fertilised human zygote starts to divide, to form first 2 cells then 4 then 8 and so on till 64 cells have been formed. This takes a little less than a week to accomplish. There is no increase in overall size during this time - all that happens is that one largish ovum becomes a ball of the same size but consisting of many small cells.

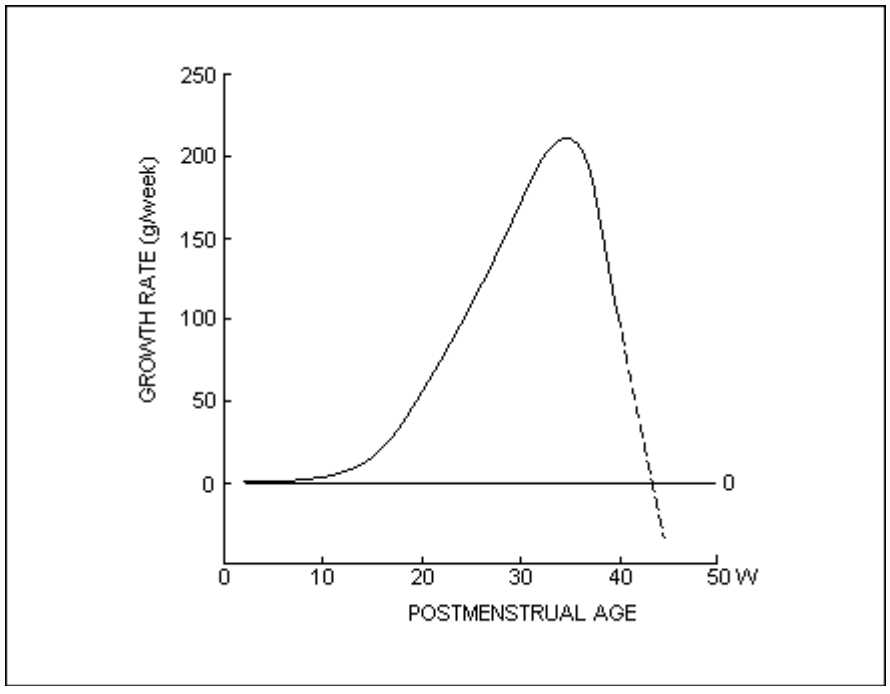
Thereafter there is some growth but it is, in general, very slow. After the 4th week postmenstrual age in the human embryo, there are are only 500 - 600 cells, but the stage (embryonic disc stage) has been set for cell differentiation and the formation of organs and a proper 'animal shape'. There then occurs a very rapid rate of growth - and a 40 times increase in size in 4 days. But since the starting size is so small the gain in mass in g/week is very low.

Although the time between doublings in mass gradually increases, gain in mass in terms of g/week increases with increasing time in the uterus. The graph below depicts the centile lines for normal

intra-uterine growth. The line labelled "50" (the 50th centile) represents the average (or median) for all healthy foetuses. The area between the 3rd and 97th centile lines represents the accepted range of normality. Three percent of foetuses have masses for their age below the 3rd centile, and another 3% have masses for their age above the 97th centile. "The normal range" therefore represents the growth characteristics of 94% of all normal foetuses.



The rate of growth reaches a maximum at about 34 weeks after the mother's last menstrual period.



At that stage the human is growing faster than she will ever grow again (under normal circumstances), for the rest of her life. At that stage she is putting on weight at 200 - 250 g/week, or increasing her mass by 10% per week. Compare that with an increase in mass by 4000% in 4 days at the tender age of 15 days after conception! The rate of growth from about 34 - 36 weeks (after the last menstrual period) slows down, because space in the uterus is becoming limited. Twins slow down earlier, at about the time that their combined mass is that of a 34 - 36 week singleton. If the pregnancy continues beyond the usual 42 weeks, there may even be a loss of mass for the foetus, and peri-natal mortality increases markedly. Babies held back in this way grow rapidly after birth, so that large babies often grow more slowly post-natally than small babies. This slowing down mechanism allows genetically large babies to develop in the uteri of small mothers.

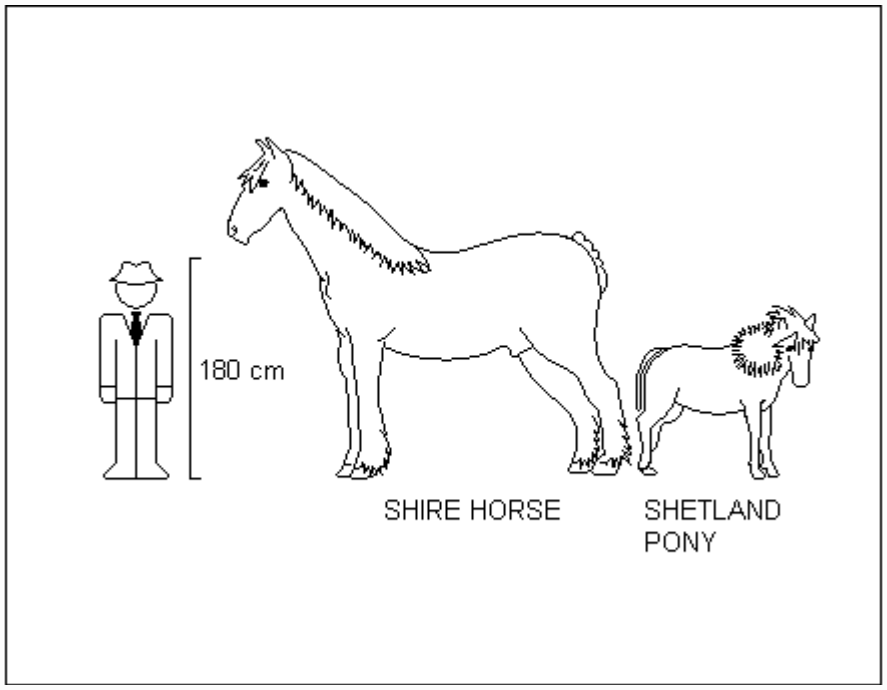
VARIATIONS IN PRE-NATAL GROWTH

Seen in its broad biological context intra-uterine growth and development occurs at a rate which is species-specific and therefore genetically determined. No matter how you may manipulate nutrition and the intra-uterine environment, you will not be able to induce the foetus of a Pekinese to develop at the same rate as that of a blue whale.

However, within a species, there is room for variation, and it is the scope of this variation, and the factors which influence it which will now occupy us.

Maternal size and embryonic genotype

Who adapts to who? Does the uterus stretch to accommodate whatever is inside it? Or does the uterus dictate the rate and ultimate size of the foetus? Alternatively, does the foetus grow to fill all the available uterine space? In 1938 Walton and Hammond studied the size of the offspring (at birth) of the matings between Shire horses and Shetland ponies.

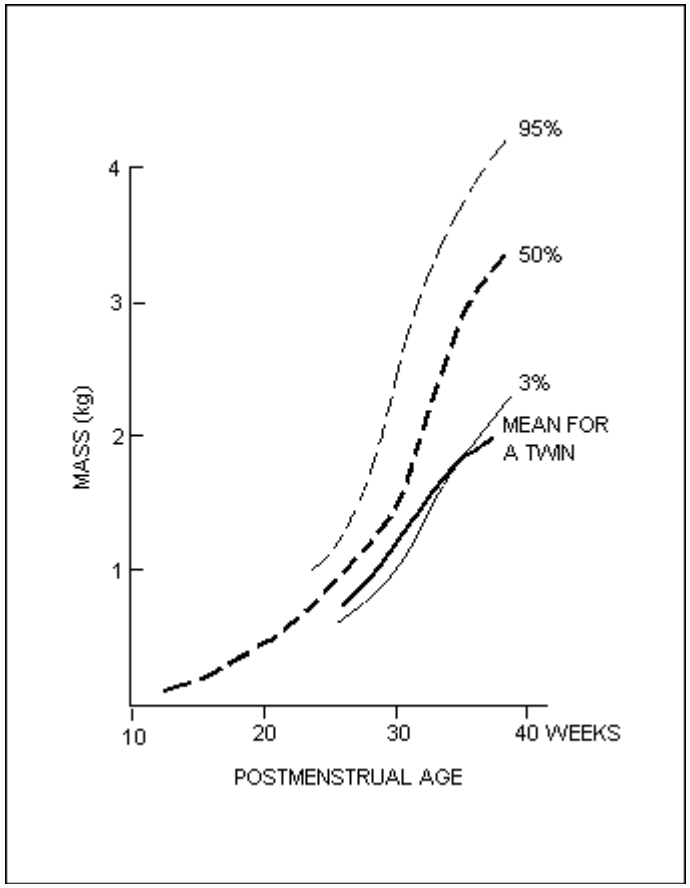


There is approximately a fourfold difference in mass between the mares. Reciprocal crosses, achieved by artificial insemination, provided embryos of substantially identical genotype, but in the

uteri of vastly different sizes.

The hybrid foals born to the Shetland mares were found to be comparable in size to pure-bread Shetlands, while the foals born to the Shire mothers were considerably larger, approaching but not quite equalling the mass of new-born pure-bred Shires. Both types of foal were of normal proportions and were the same size after a few months: the foals born to the Shire mares having grown more slowly than the foals born to the Shetland mares. Similar results have been obtained in cattle and in sheep.

In humans there is also a tendency for small (short) mothers to have small babies, and large (tall) women to have large babies, irrespective of the size of the father and consequent foetal genotype. This effect is however most marked in multiple births.

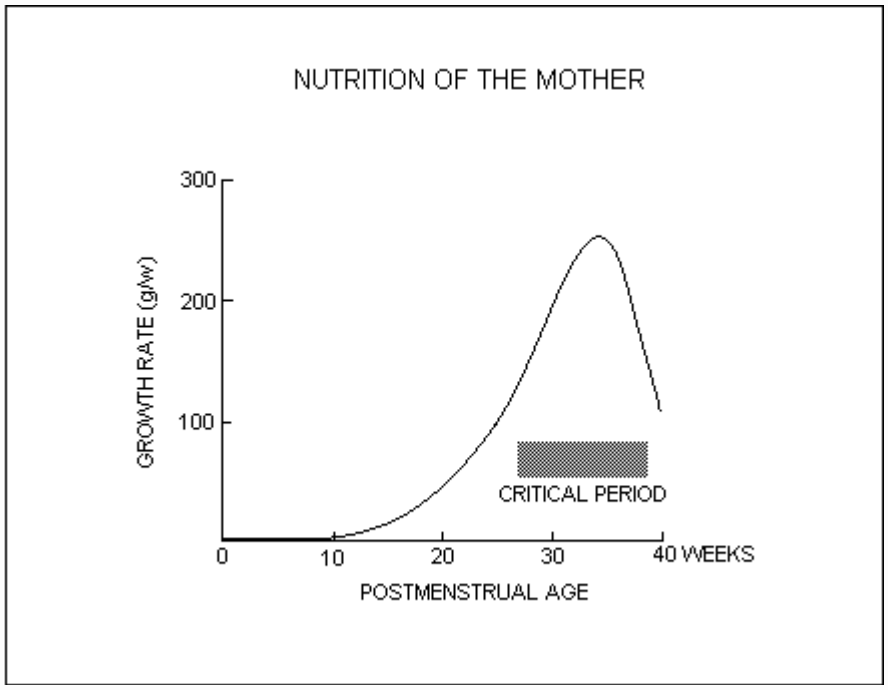


The graph shows the normal growth curves for singletons. The combined mass of twins is usually only a little greater than the mass of a singleton, at the same gestational age, but, more pertinent, is the fact that there can be a considerable discrepancy in size between the 2 members of the twins (the mean difference in birth mass is 300 - 400 g), even if they are monozygous. Most of this difference in size of the twins would appear to be due to the limitation of space for one of the twins in the confines of the uterus.

When compared with singletons, twins show a deficit in size at birth that increases with gestational age. At 33 weeks each twin is, on average, at about the 36th centile for singletons, but at 40 weeks the average size of twins is below the singletons' 5th centile.

Maternal nutrition

Between 32 and 36 weeks of gestation in humans, the foetus gains mass at about 200 - 225 g/week. This matter has obviously to come from the mother, and ultimately from her diet.



It is therefore to be expected that foetuses will grow faster if there is enough food of the correct type, than if there is some limitation in the quantity or quality of the food eaten by the mother. It is however very difficult to obtain clear cut data on this issue for humans, as unsatisfactory nutrition so often goes hand in hand with other factors such as poor maternal health, infections, smoking, and small maternal size etc.

Suffice it to say that mean birth weights for babies is smaller in most developing countries than in Europe, the USA or in Canada. Also, during the 'famine winter' of 1944 -1945 (i.e. the last winter of the World War 2) in Holland, babies were on average 10% smaller by mass than usual. (These babies were affected by maternal malnutrition only during the third trimester. Foetuses whose mothers were exposed to famine during the first and second trimesters were not significantly affected in size, though mal- and undernutrition during the first trimester produced many miscarriages and foetal abnormalities). The size of the foetus seemed to be affected only if the mother's daily food energy intake was less than 6 MJ (normal about 10 MJ).

Maternal age and parity

Birth mass increases with age of the mother:

<20 years	3205 g
20 - 29 yrs	3320 g

30 - 34 yrs	3345 g
>35 years	3375 g

Note these are averages, and give no indication of the spread of actual birth masses in each category.

One must be careful however of attributing these different average birth masses simply to maternal age, since it is not known how much these data are confounded by different social and demographic factors affecting the development of mothers born at different times. There is also a tendency for birth mass increase with increasing parity:

para 0	3230 g
para 1	3355 g
para 2 - 3	3375 g
para >3	3420 g

These too are only averages. There is considerable overlap of birth masses between the categories.

Other factors

1. Boys weigh approximately 100 g more than girls at birth.

2. Social class affects birth mass; the babies of the professional classes were about 100 g greater than those of the unskilled labouring classes in Britain during the 1950's.

3. Smoking is associated with an, on average, 175 g smaller birth mass compared with non-smokers.

ABNORMALITIES IN PRE-NATAL GROWTH

Pre-term babies

The average length of gestation, measured from the first day of the mother's last menstrual period, is 280 days or 40 weeks, but considerable individual variation can occur. Lengths of gestation from 37 - 42 weeks are considered by international agreement to be normal (70% confidence limits).

Babies born between these limits are termed 'Term babies'. Those born before that age are 'pre-term', and those after 'post-term'.

A pre-term baby, even of 28 weeks post-menstrual age, is at not a great disadvantage, if everything else is normal, especially if there is specialised neonatal care available in the form of incubators and qualified nurses. These babies grow very rapidly, at approximately the rate they would have done so *in utero*, and can usually be sent home at about the time that they would have reached 38 - 40 weeks postmenstrual age *in utero*, with a perfectly normal mass, and normal prospects for growth and development in infancy through to puberty.

Low-birth-mass babies

This group is composed of 2 types of babies: those that are pre-term, but of a normal size for their post-menstrual age (this group has been discussed under "pre-term babies: above), and those that are born at the normal time (or before) but are below the 5th centile for mass at their age. Babies in this last group are called "small-for-age babies", see next item.

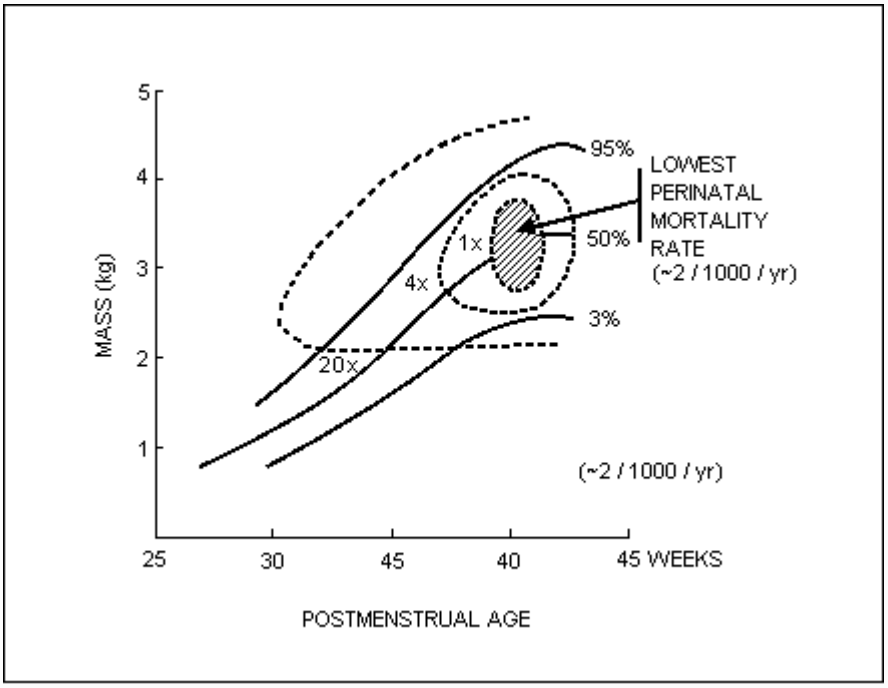
Small-for-age babies

These are babies below the 5th centile for mass at their age. This group is at a distinct disadvantage. Most of these babies grow up to be small children (below the 25th centile) and adults, and many of them show signs of improper development in the form of mental and neurological deficits. Peri-natal mortality is high: 55/1000 in Canada compared to about 10/1000 for all babies in Developed Countries.

PERI-NATAL MORTALITY

Peri-natal mortality rate is defined according to the WHO as the number of deaths which occur between the 28th week of pregnancy and the seventh day after birth, per 1000 live births. The figure for Sweden is less than 10/1000.

The babies most likely to survive the first week of extra-uterine life are those that are born at term (37-42 weeks after the last menstrual period), and who are above average mass:



The figure presents 'contours' of peri-natal mortality on which mortality rates are constant and expressed as a percentage of the average rate (1000 = average peri-natal mortality rate). The data are taken from the 1973 WHO study using results from Cuba, New Zealand and Sweden. The birth mass-for-gestation centiles lines are also shown.

It can be see that the main determinant of a high peri-natal mortality rate is a low birth mass, irrespective of gestational period. A mass of less than 2500 g seems to be particularly critical.

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From Womb to the Tomb

The Human Lifecycle
Part 3

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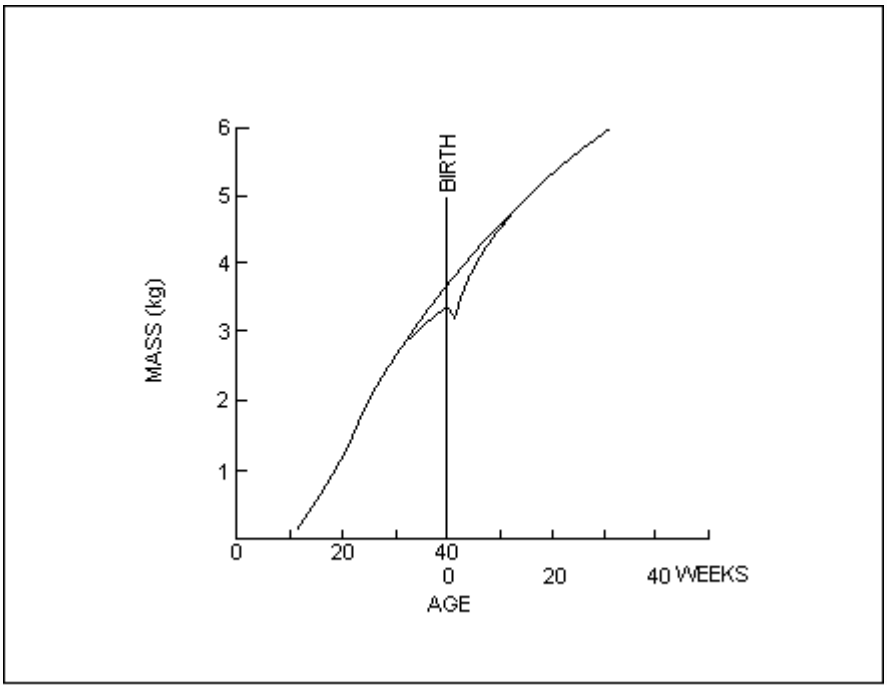
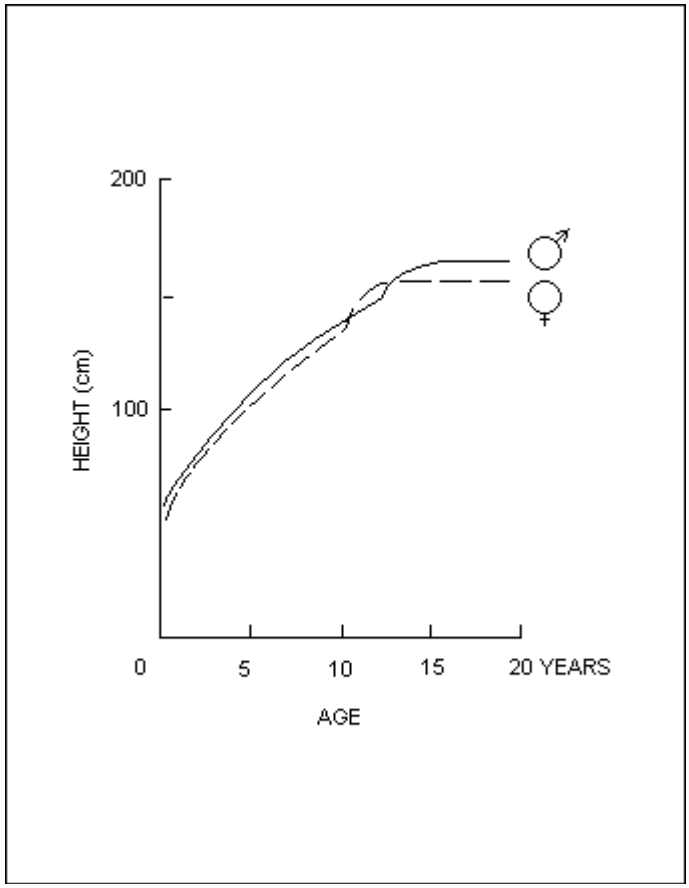
RATE OF PRE-NATAL GROWTH

POST-NATAL GROWTH

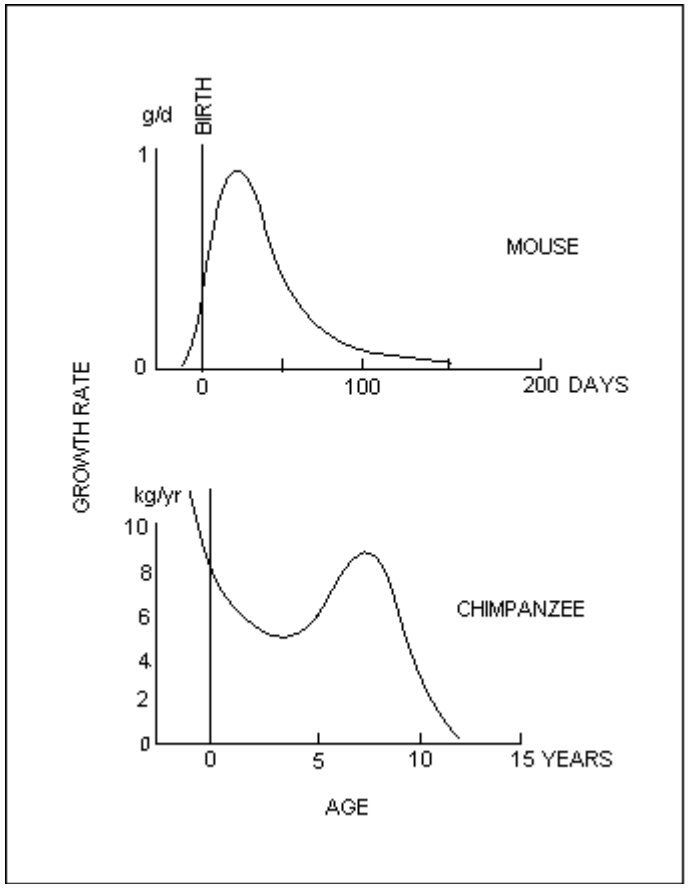
As with pre-natal growth, a child's post-natal growth follows an extraordinarily regular path, so much so that the rate of growth is one of the best indices of a child's general health. Yet, once again, we are almost in total ignorance as to how this normal rate is regulated and controlled.

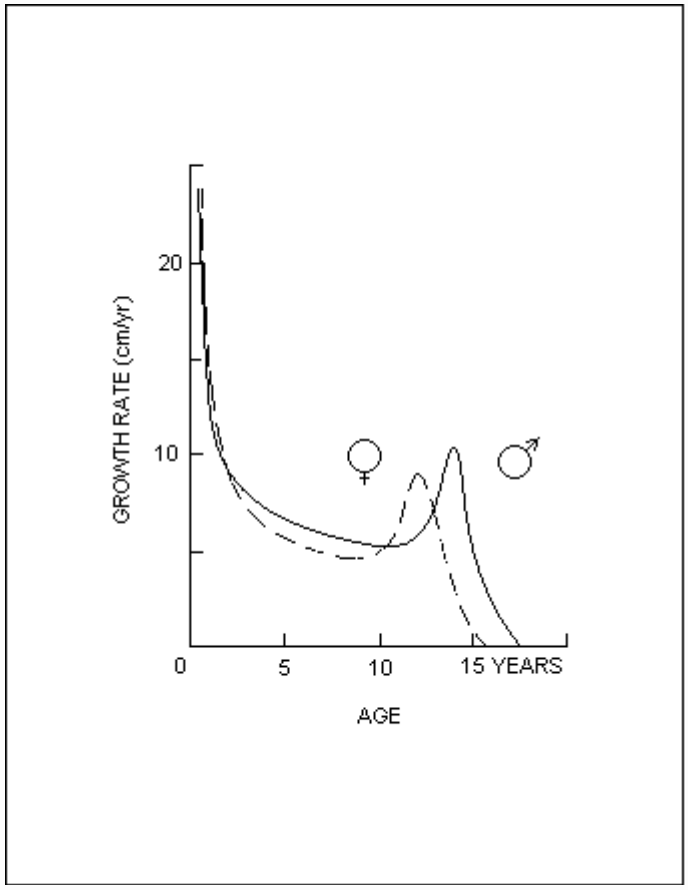
Post-natal growth is merely a continuation of pre-natal growth, with the phenomenon of birth exerting little influence. It is a mere incident in a continuum. True enough, there are major physiological adjustments to the made at birth, when the baby leaves the uterus and has to breathe air and eat his own food, and excrete his own wastes. But all of this does not really affect growth in anything but in an incidental manner.





It can be seen from the graphs that the rate of growth gradually decreases after birth - a process that begins at about the 34th week of intra-uterine life. In most animals this gradual decrease in the rate of growth continues uninterruptedly till growth finally stops altogether, at which stage the organism is usually considered to be adult.

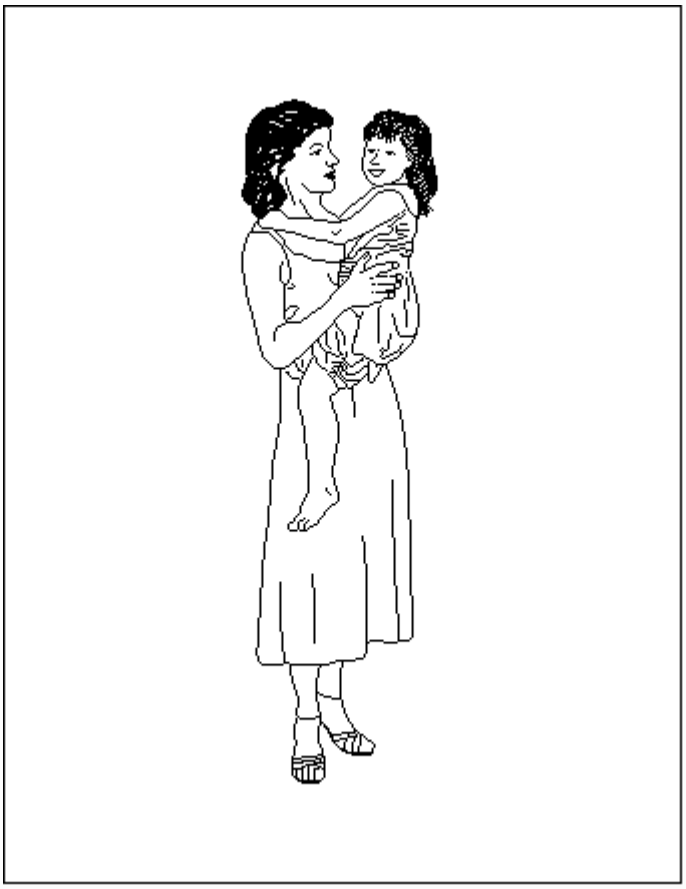




In humans, and in the other primates, the smooth decrease in the rate of post-natal growth is

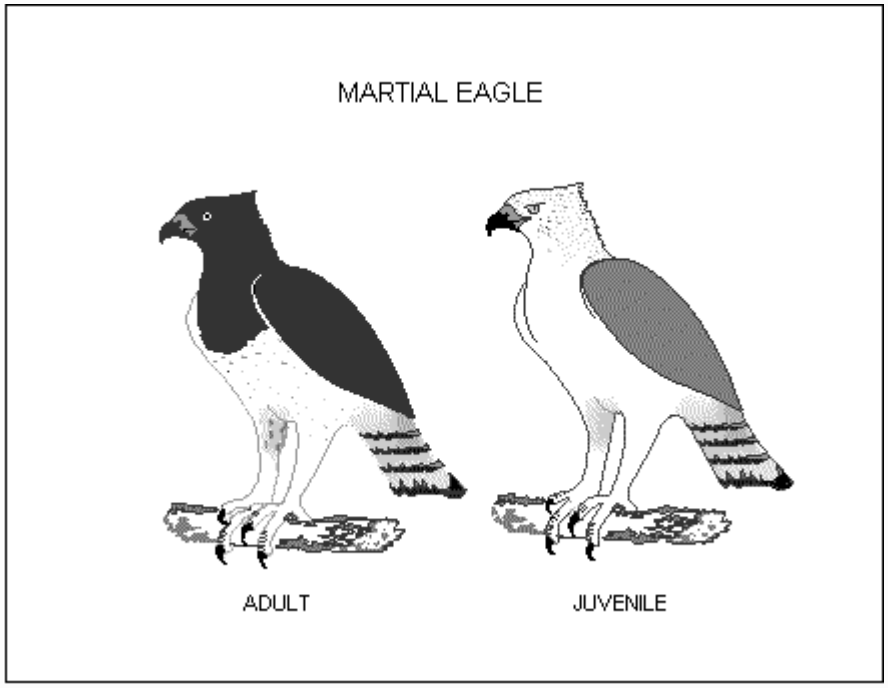
interrupted just before the adult stage is reached, by the so-called adolescent or pubertal growth spurt. As far as is known this is a phenomenon peculiar to the primates.

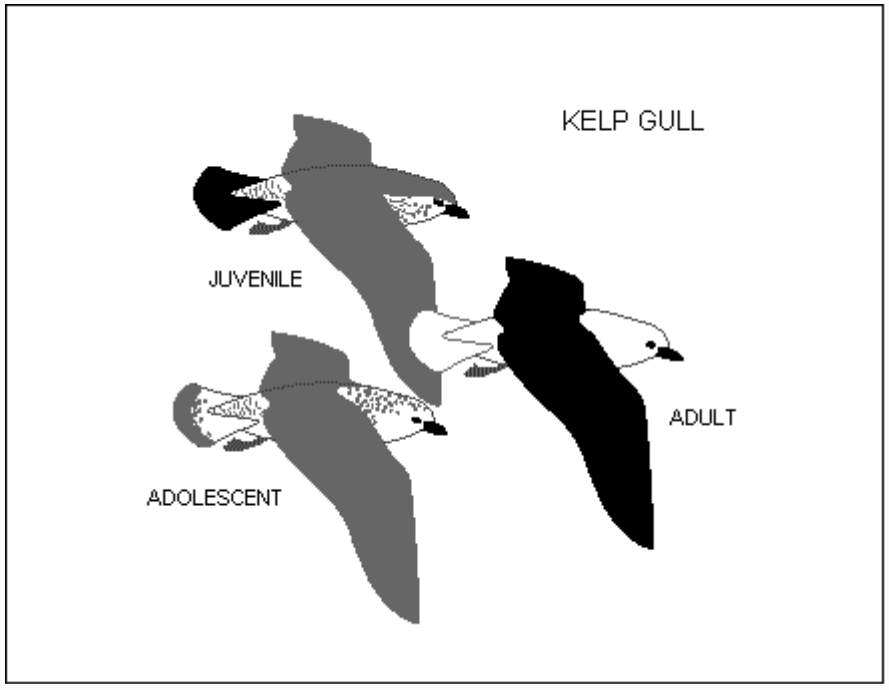
The reason most often given for the pubertal growth spurt in primates is that the adults have to be big and strong enough to carry their infants, whom they look after for a long time. However many other animals also carry their young, and none of these other species have adolescent grow spurts. Furthermore if the adolescent growth spurt is intended to produce an adult who is big and strong enough to pick up and carry not just infants but also quite big children who are already able to walk independently, the spurt would be expected to be more marked in the gender that generally does this carrying of children.



Yet it is nearly always the female of the species who carries the children, and not the male who benefits the most from the additional growth during puberty. So the pubertal growth spurt must serve another function.

Its occurrence, of course, means that 'children' are conspicuous by their short stature relative to the adults. In the other animals the pre-adults are recognisable by their different coloured plumage (birds), fur, or other features.





This age-related-polymorphism is very important in regulating the social interactions of animals; something that we will have to discuss in more detail later on.

Chicks and ducklings - yellow plumage

Wild piglets have stripes

Lion cubs are spotted, as are deer fawns

Dalmatian pups have no spots

Canadian seal pups are white

If subadults are to receive special treatment then they must somehow be recognisably different from adults, just as the males of a species have to be recognisably different from the females if the genders are to come together in an efficient manner for mating purposes.

This notion that we have to display, in considerable detail, who we are to the other members of our species is the recurring and central theme of these essays on "The Human Life Cycle". Old age is therefore not seen as simply a process of becoming increasingly decrepit, but as a well orchestrated succession of signals that denote that the individual is now one of the most senior members of the species.

Old age is accompanied by an ever increasing probability of dying during the ensuing year, but the reasons for that are a separate problem.

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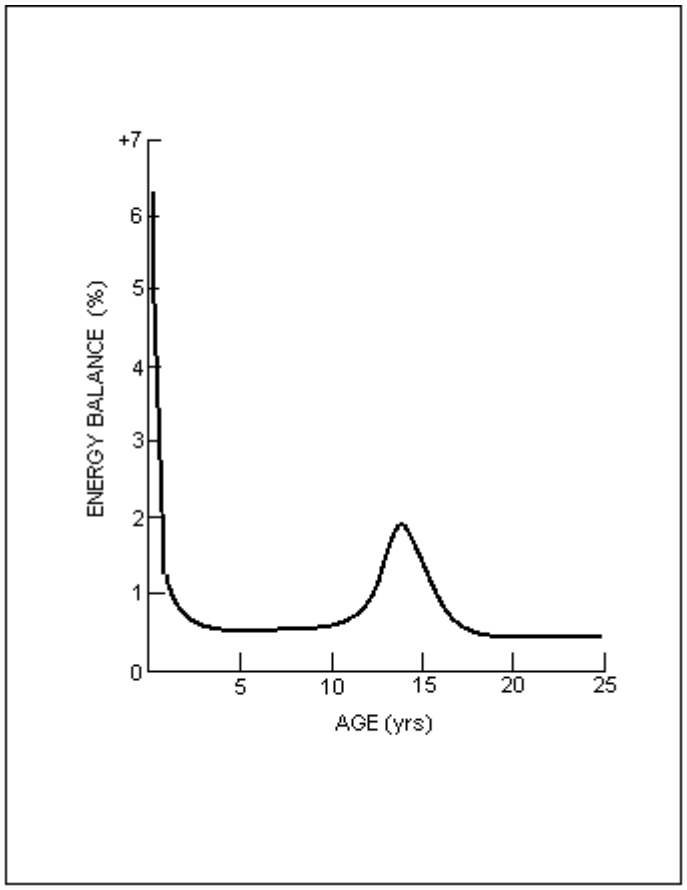
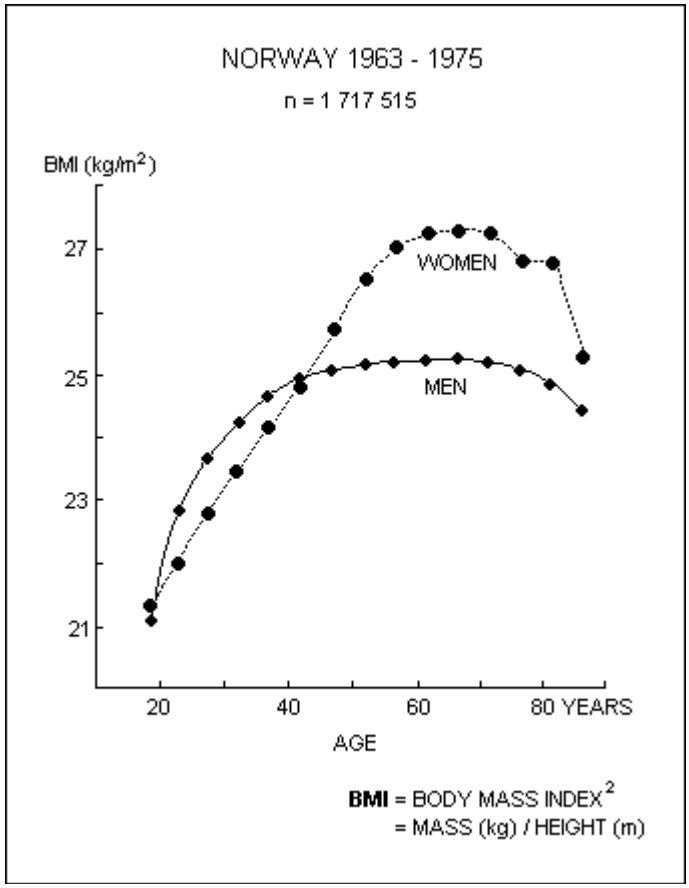
GROWTH EFFICIENCY IN HUMANS

Animals that are reared for meat production (chickens, cattle and pigs) convert food into flesh (and bones) at an efficiency of about 15% during "childhood". Thus for every 100 kg of food fed to these domestic animals, the farmer expects a return of about 15 kg of carcass mass. In comparison with these meat factories, human children are very inefficient growers. They convert food into flesh with an efficiency of less than 1% during most of childhood.



Immediately after birth the growth efficiency is about 8%, but rapidly falls to less than 1% in the first year. At puberty growth efficiency increases temporarily to nearly 2%, after which it falls back to about 0.8% in adulthood. Although human adults do not grow in height after puberty, they continue to gain weight slowly throughout adulthood. This results in the average 40-50 year-old weighing about 20% more than the average 20 year-old.



BMI is "Body Mass Index", which is mass in kg divided by height in metres squared. (BMI cancels the effect differences in height have on body mass). The average 20 year-old (young woman or man) has a BMI of about 21-22 kg/m^2, whereas the average 45-50 year-old has a BMI of 25-27 kg/m^2.

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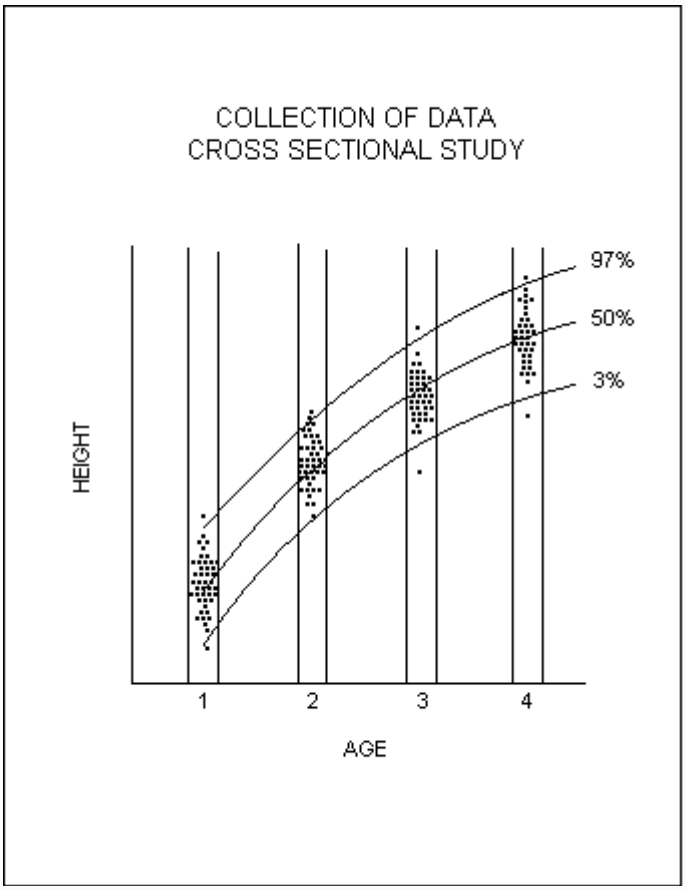
COLLECTION OF GROWTH DATA

There are 2 main types of investigation:

Cross-sectional studies

Here you simply find groups of children of different ages in a particular community, and you measure their heights, masses and anything else that meets your fancy. The data is then plotted on graphs of height against age, or mass against age etc.

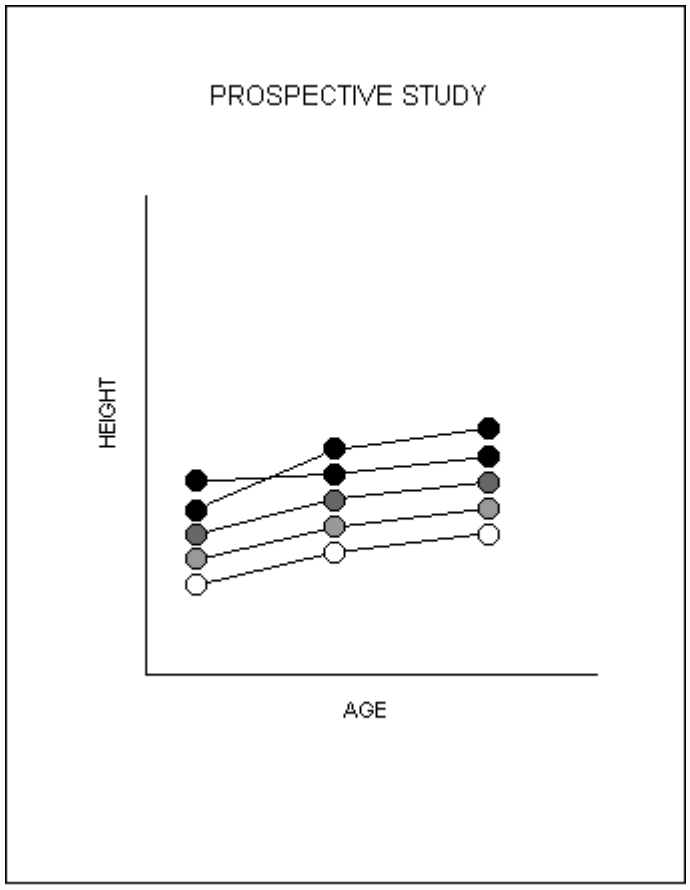


In this sort of study each child is measured only once and the results are almost immediately available.

In a longitudinal study

Here you take a group of infants or preferably neonates, and do your measurements on them. After an interval of months or a year you repeat the same measurement on the same group of children, and continue to do this till the children grow up, you retire, or you get tired of the process etc. It is

obviously a laborious way of doing things.



Both cross-sectional and longitudinal studies have their advantages and disadvantages. They do not give the identical information.

Cross-sectional studies are obviously cheaper and more quickly done and can include larger numbers than a longitudinal study. They are particularly good at providing information about the normal heights and weights (etc) for a population at different ages. In other words these studies inform us about the *results of growth,* and less about the process of growth.

If you want to know how humans grow you have to do longitudinal studies. Although cross-sectional studies show that the average height of children increases from birth to puberty, they do not tell us whether this is achieved by individuals growing a bit and then resting (or "consolidating themselves") at irregular intervals, or by a smooth growth curve.

Cross-sectional studies also tend to average out what different individuals are doing at any given chronological age. This is particularly noticeable at puberty, where the pubertal growth spurt occurs over a range of ages. Some individuals will therefore have finished growing when others are only beginning with the spurt. In other words, the pubertal growth spurt is less obvious in cross sectional data than it is in longitudinal data. In fact, before the availability of longitudinal data, the existence of the pubertal growth spurt in humans was frequently questioned!

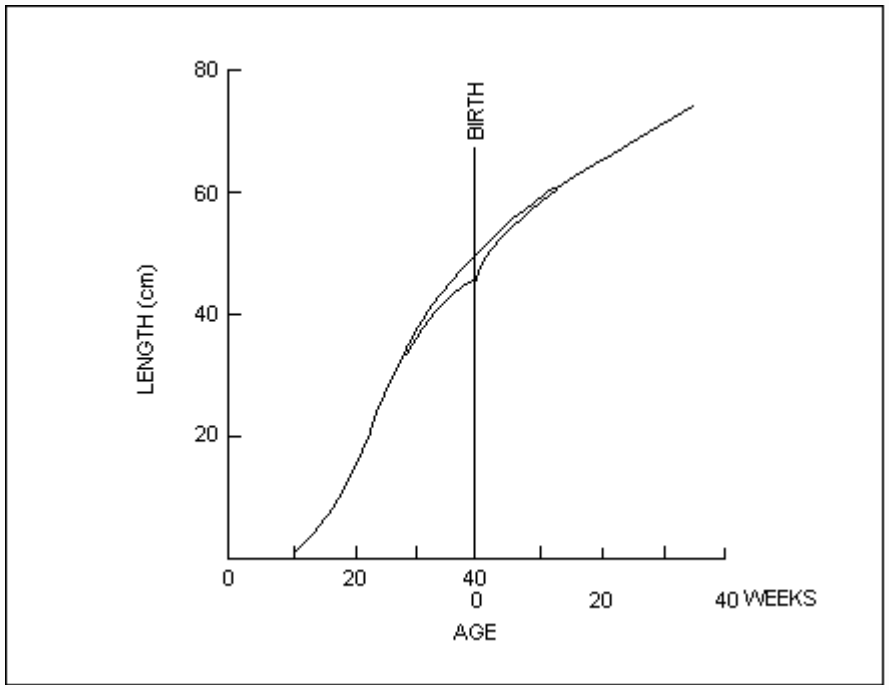
It is therefore essential to do longitudinal studies if you want to know how individual rates of growth can vary in normal population. As it turns out, it is the rate of growth, rather than the achieved height or mass etc., which gives the physician the best indication of whether all is well with a child at a given moment, or not.

Growth in height is probably the single most obvious change that occurs during post-natal growth in humans, and, being a measure of the maturation of a single tissue (the skeleton) it is therefore a fairly good yardstick against which other forms of growth can be measured.

Growth in mass, or in head circumference, or thigh diameter are influenced by too many different tissues, all undergoing specialised forms of development, to be useful as parameters of a child's state of maturity.

Growth in Height

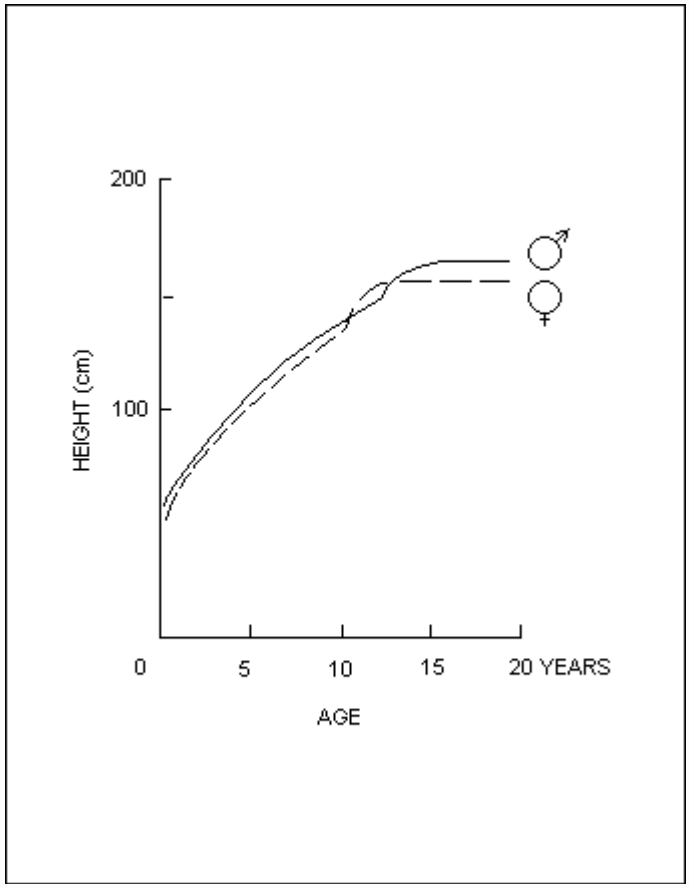
The velocity curve for height reaches its maximum during foetal life, at about 15 - 20 weeks post-menstrual age - i.e. before the maximum is reached in the rate of gain in mass.

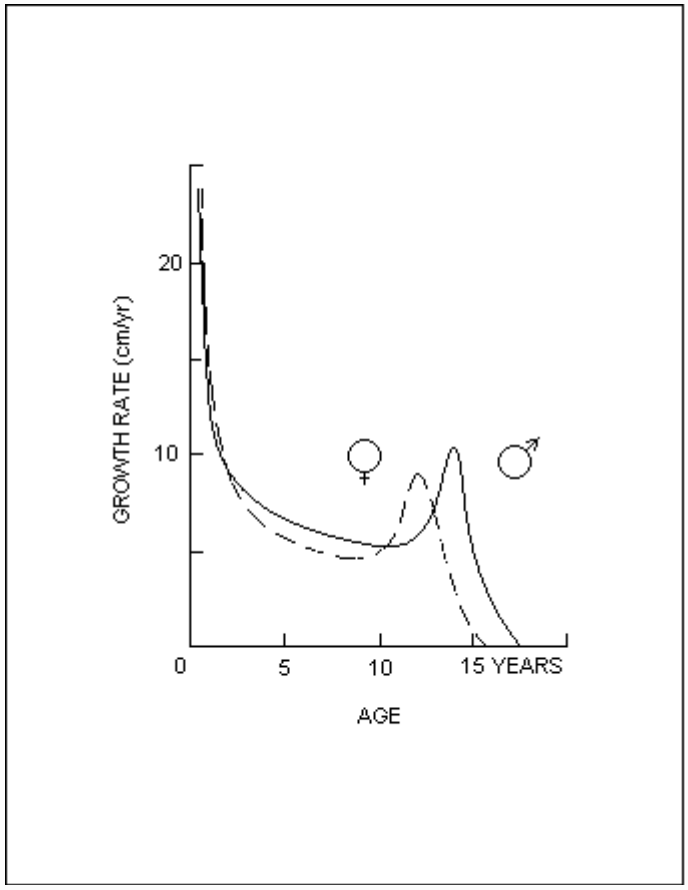


The diagrams are somewhat suppositional since it is difficult to measure foetal length between the 18th and 28th weeks in the uterus. The solid lines represent the actual length and the length velocity curves; the interrupted lines are the curves which one supposes might take place if there was no uterine restriction during the last weeks of pregnancy. After birth there is a short period of rapid growth (most marked in small babies born to small mothers), followed by a gradual decrease in length velocity.

Just after birth the average baby is growing at a rate of 3 cm per 4 weeks, or about 40 cm per year. At the end of the first year this has dropped to about 25 cm/yr, and between the age of 5 - 10 years it is down to 6 cm/yr. Longitudinal studies have shown that this decrease in height velocity is a gradual, smooth process, and that the child therefore does not grow in stops and starts (if all is well).

Growth in height does not alternate with growth in body circumference; everything proceeds along smooth curves, especially if care is taken to take the measurements always at the same time of day, and after emptying of the bladder and bowel, and ensuring that the child is always measured in the same posture (tilt of the head is particularly important in measurement of height).





The graphs show the height attained and the height velocity curves of a typical boy and girl (in

Britain in the 1960's).

The typical girl is slightly shorter than the typical boy at all ages between birth and adolescence. She becomes taller shortly after 10 yrs, because her adolescent growth spurt starts about 2 years earlier than in the boy. At 12 years the boy starts his adolescent growth spurt and in a year or two overtakes the girl, whose growth spurt is now nearly over. The girl attains her adult height at about 16 yrs, the boy at 18 yrs.

Growth in mass follows a similar pattern, with boys being slightly heavier than girls at all ages during childhood. The girls then become heavier than the boys at about 9 or 10 years, and remain so till the age of about 14 or 15 yrs.

The velocity curves show the process more clearly. At birth the typical boy is growing slightly faster than the girl, but velocities become equal at about 6 months, after which the girl grows slightly faster, and then again a bit slower than the boy.

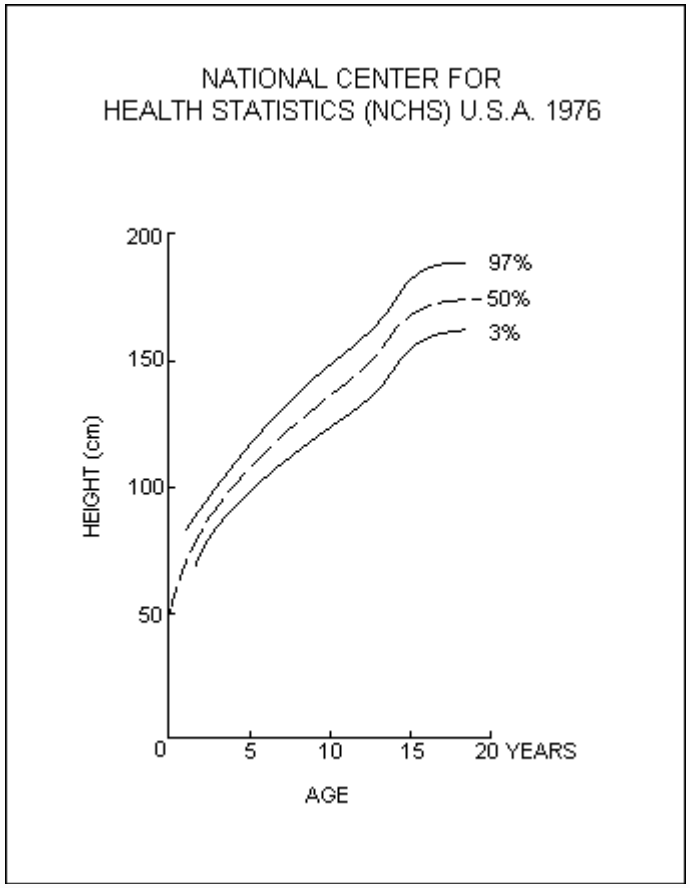
The girl begins her adolescent growth spurt at an average of about 10 years and is growing at peak velocity at about 12 years. These ages vary from country to country, being lowest in the most developed countries - Western Europe and the USA - and are highest in the poorest countries.

The boy starts about 2 years later (and therefore starts his growth spurt from a greater pre-spurt height), and has a higher peak velocity than the girl: 10.3 cm/year compared with 9 cm/yr. The later starting age of the adolescent growth spurt and its higher peak are together responsible for the greater adult height of men than women - a minor feature of sexual dimorphism, which helps regulate behaviour between members of the species.

Centile charts for height

If 1000 healthy 5 year-old children are arranged in order of height from the shortest to the tallest, and that line of children is then divided into 100 equal parts of 10 children each, then the divisions between the groups are termed "centiles". The first centile separates the 10 shortest children from the rest. The tenth centile separates the shortest 100 children from the rest. The 50th centile separates the 500 tallest children from the 500 shortest group of children. And so on.

If the same is done for children at ages 2, 3, 4, 5, 6, 7, 8 and 9 years of age, it is possible to join the 3rd centiles of the different age groups to produce the "3rd centile line" for height. The same can be done with the 50th centiles, and the 97th centiles (or any other centiles), to produce a "centile chart" for height of children. ("Centiles" are also called "percentiles". The former terminology is more correct, but the latter is in more common use.)



What is normal?

By definition, of course, 94% of the children have heights, at any given age, between the 3rd and 97th centiles. Three percent of the children have heights greater than the 97th centile line, and 3% have heights below the 3rd centile. The 50th centile is the 'median' height for a given age, with exactly half of the children having a height greater than that and half having a height less than that. The range of heights between the 3rd and 97th centiles are termed, for convenience sake, as "normal", although perfectly normal children occur above and below this range. The "range of normal" (between the 3rd and 97th centiles) is merely a convenient way of denoting the sort of variation in height that occurs in a normal population - it is uncomplicated by freak or record short or long statures. (Since records are there to be broken, if one waits long enough, the zero and 100th centiles, which indicate the current records, disconcertedly creep apart, into freakier and freakier territory. They are, therefore, never displayed on centile charts.)

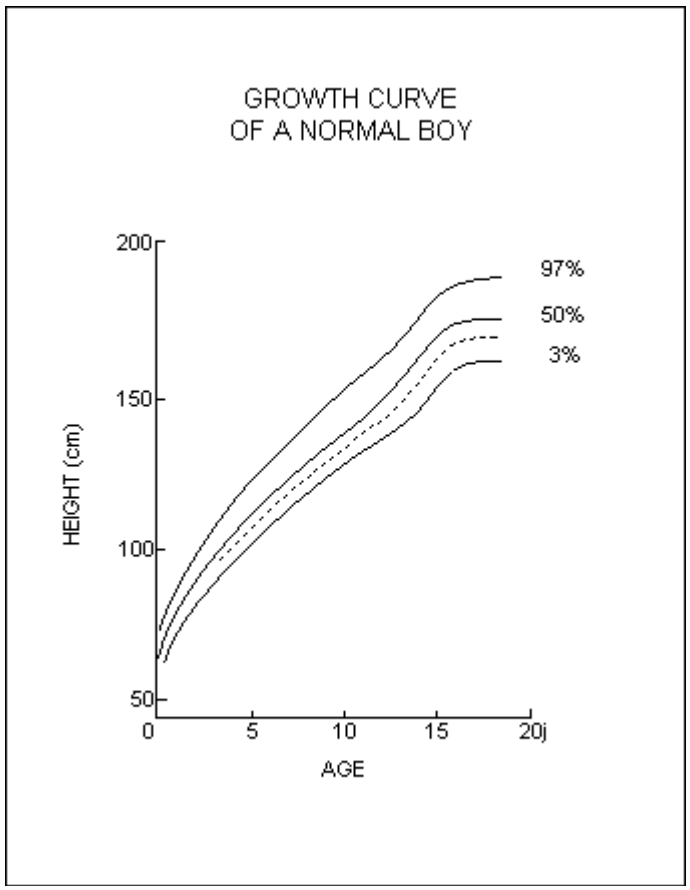
Children outside the 3rd to 97th centile range constitute a minority who are simply "unusually short" or "unusually tall". Of course when disease affects height then that generally only becomes obvious to the casual observer when the child's height is "unusually" short or tall (i.e. under the 3rd centile or above the 97th centile for height). Hence the association of these "unusual" values with "abnormal" values.

There are similar centile graphs indicating the normal variation in height velocity. They indicate that the fastest growers in a normal population of children at age 2, are increasing their height at about twice the rate of the slowest growers. Just before puberty the difference is not so great - the fastest growers growing at a little more than 50% faster than the slowest growers.

Such graphs also show the variation in the timing and magnitude of the adolescent growth spurt. The adolescent growth spurt tends to the greater if it occurs early, and considerably smaller if it

occurs later than the average time.

In health, children remain remarkably consistent in the way they grow: a small infant grows into a small child, and, usually, into a small adult.



In other words children tend to grow along the centile lines on the graphs we have just considered. They do not belong to the fast growers at some stages of their development, and to the slow ones at another times, except just after birth, and round about the time of puberty.

Babies who are going to be large adults, but who were born to small mothers move up through the centiles during the first 6 months of life, after which they then remain on that centile. Genetically small babies born to large mothers do the opposite. Their rate of growth remains small for about 18 months till they reach their genetically determined centile which they will then follow to adulthood. There is therefore very little correspondence between birth weight and the final adult size ($r = 0.3$). But there is quite a good correspondence between the length of the child at 1 year and her adult height ($r = 0.7$). Just before puberty the coefficient of correlation between attained height and the final adult height is $r = 0.8$.

Significance of "crossing centile lines"

A child who is growing along, say, the 2nd centile line for height, and has been there since 1 year of age, is simply an unusually short child. She is perfectly healthy, and there is no need to investigate "the cause" of her short stature. Nor is any treatment indicated. In fact "treatment" will do more harm than good.

The same applies to any other child who has been growing along its centile line.

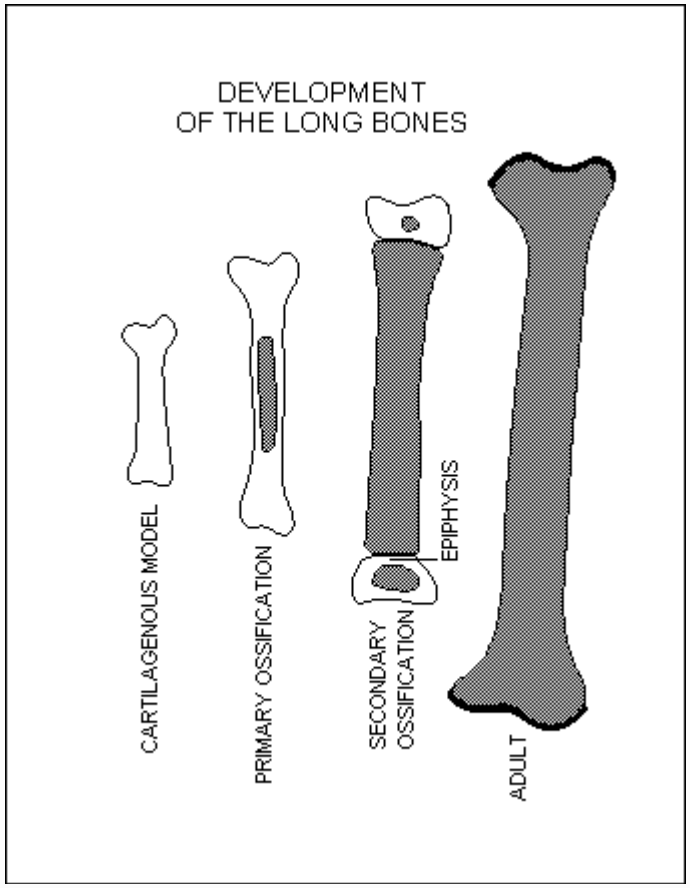
When children become seriously ill, however, they almost invariably move to another centile line, usually downwards. In other words, they start crossing centile lines. This "crossing of centile lines" is, in fact, one of the most sensitive indicators of a health problem in a child. Since most children's diseases are treatable, it is imperative that the Paediatrician checks for this phenomenon as a matter of routine. It, of course, requires the availability of the child's growth data up to the point where the Paediatrician is consulted. Most parents do, in fact, keep records of their children's growth, or are able to reconstruct parts of the graph from scattered data.

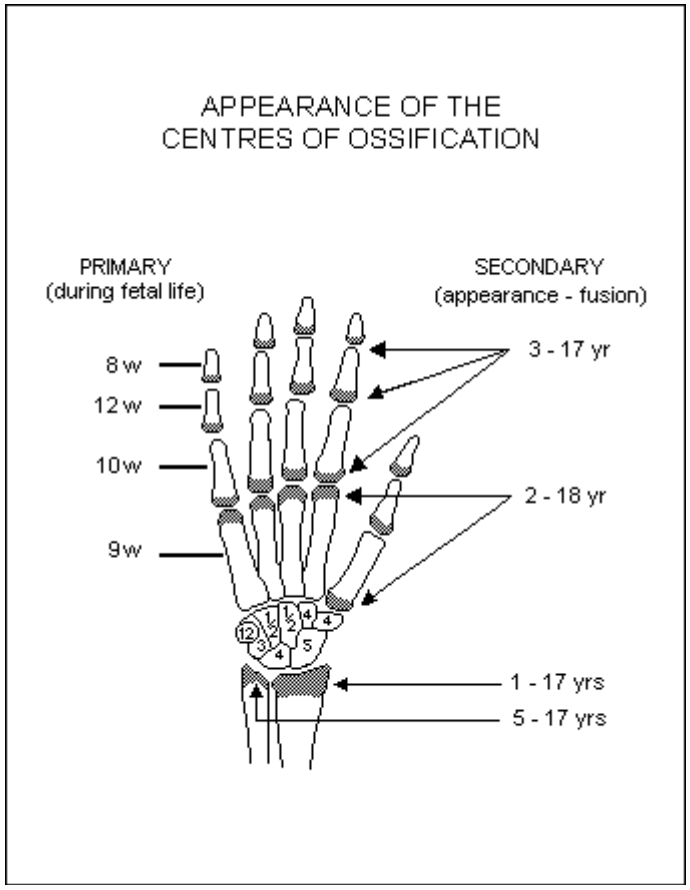
Thus a child who had been growing along the 90th centile line, and is suddenly found to be on the 75th centile for her age needs urgent investigation, despite the fact that her height is still above the median (the 50th centile), and well within the "normal range".

Girls aged 4 or 5 years often develop breast buds, usually only on one side. This can cause the parents considerable anxiety, as it could be a sign that the child is entering a precocious puberty. If it is precocious puberty, then the girl will be growing faster than her peers (i.e. the pubertal growth spurt will have commenced too), which shows up as a crossing of centile lines upwards. If the girl, however, remains growing along the centile line she has been on since 1 year of age, then the parents can be reassured that this is a perfectly normal phenomenon; the breast bud will disappear and there is nothing the matter with "her hormones" at this stage.

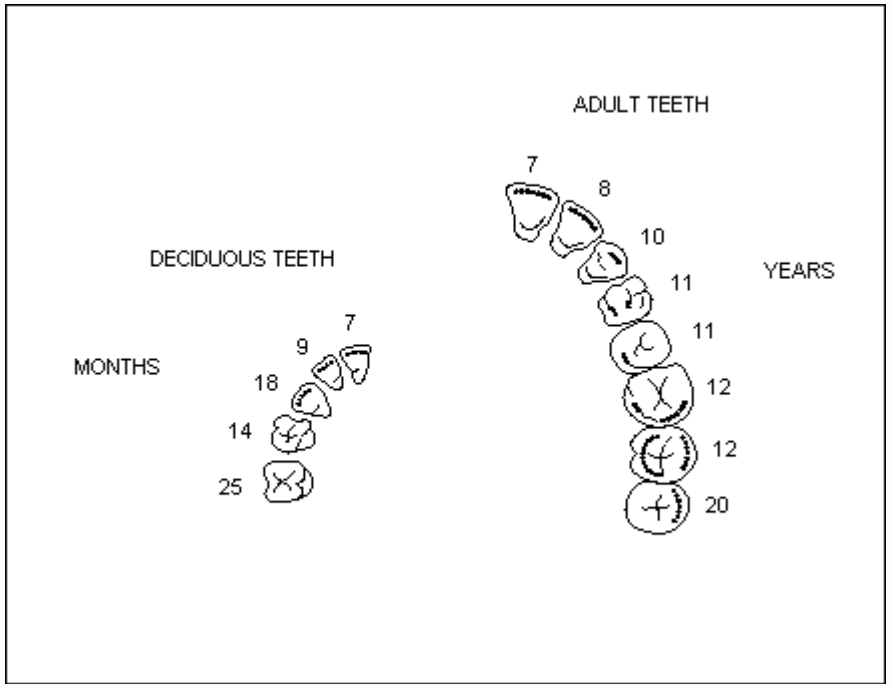
Developmental age

The concept of 'developmental age', as opposed to chronological age, is an important one. To obtain a measure of developmental age one usually looks at the appearance of the wrist (or other parts of the skeleton) on Xray. Note is taken of the appearance of centres of ossification (especially in small bones), and the closure of epiphyses (especially in long bones).



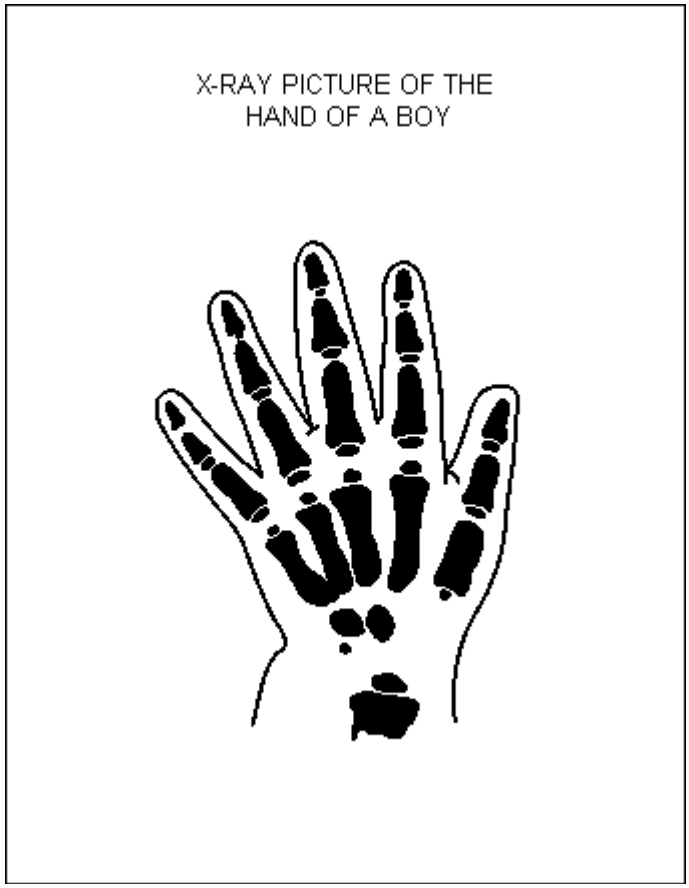


An inspection of the child's dentition yields similar information.

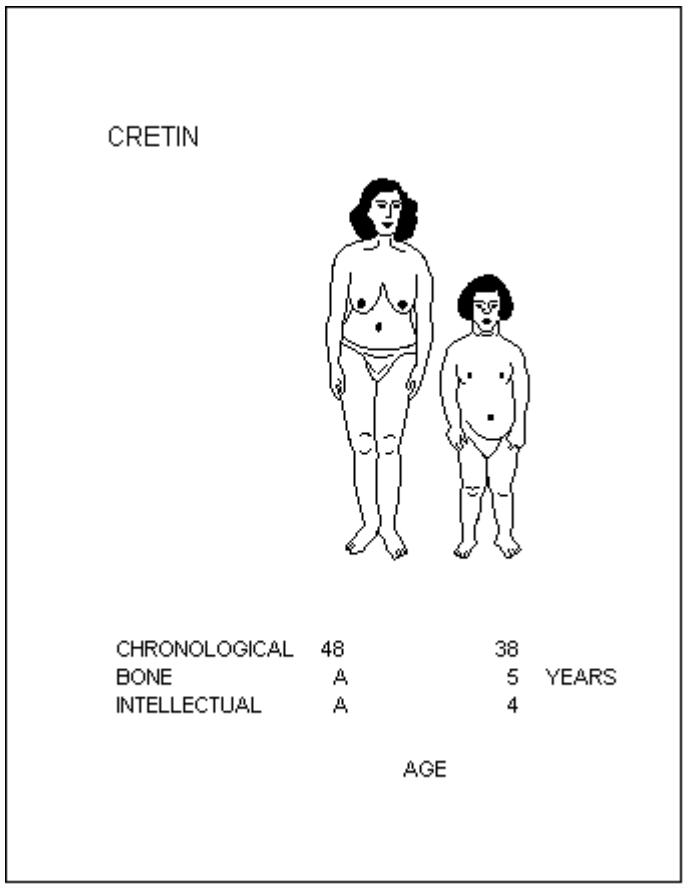


But since there are longer gaps between the dental events (the appearances of the first teeth, or their replacement by the adult teeth) it gives a coarser indication of "developmental age" than does an Xray of the hand and wrist where there are many more bones than there are teeth in the mouth. Each of the small bones of the hand and wrist develops its centre of ossification at its own characteristic rate.

The child's "developmental age" is a description of the *appearance*of her dentition, or of the bones of her hand and wrist.



If a radiologist were to be presented with an Xray of a given child's wrist, he would be able to say that children, on average, develop that appearance at the age of, say, 3 years. That child's "developmental age" is then recorded as "3 years". Most normal children will have a "developmental age" that is close to their "chronological age", but there are diseases where the two can diverge markedly. In untreated hypothyroidism (or "cretinism") a person can have a chronological age of 40 years, but have a "developmental age" of 4 years!

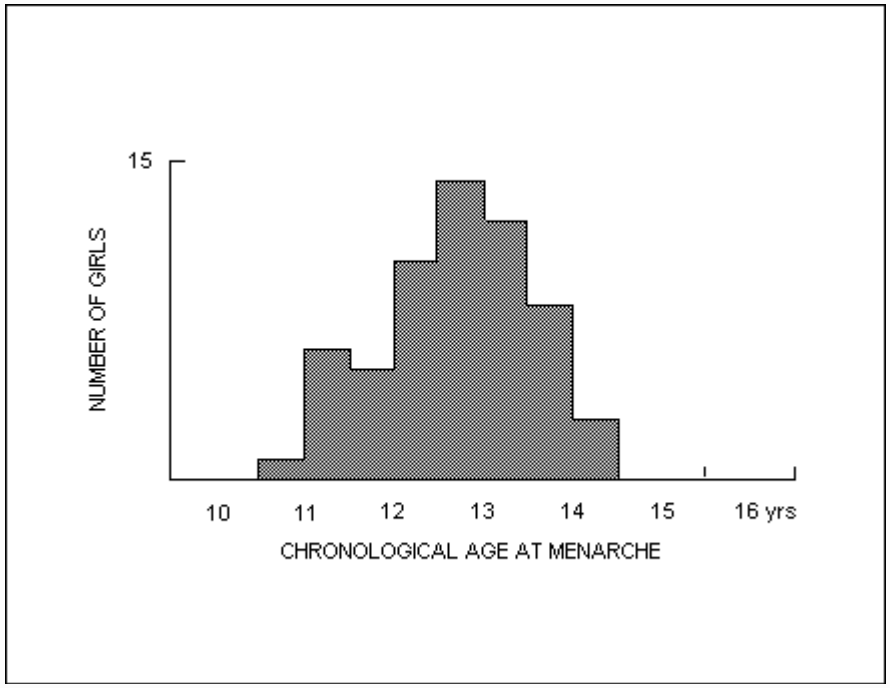


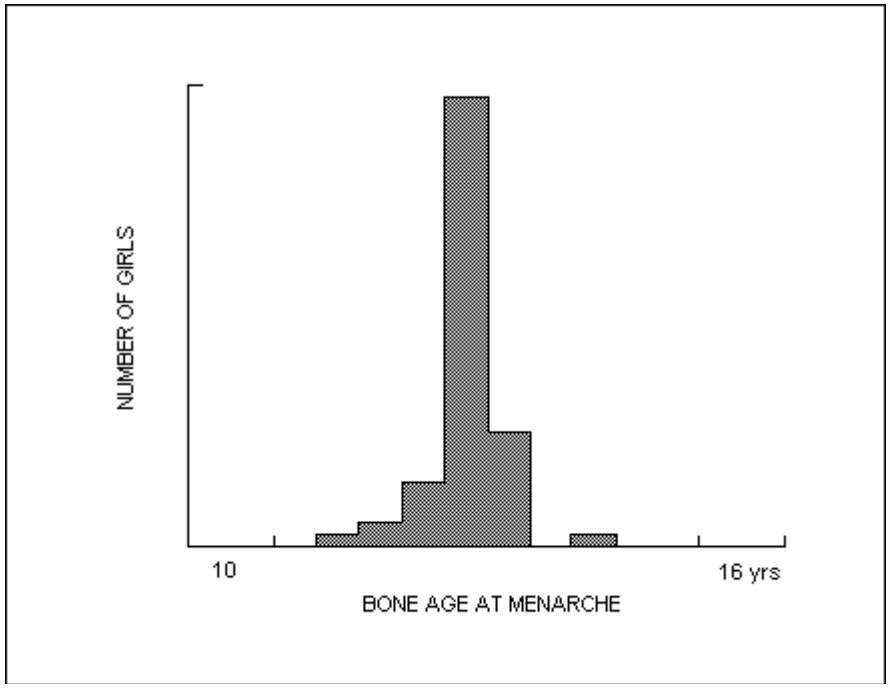
The "4 years" is not a measure of time in this case; it simply means that a radiologist looking at that person's X-rays would say that they were from a child aged 4 years. A dentist looking into that same person's mouth would also say that she possessed the teeth of a typical 4 year old. In fact, everything about the person (with the exception of a strange "puffy" appearance) suggests that she is only 4 years old!

Because "developmental age" is usually gauged from X-rays, it is often also known as "bone age" or "skeletal age". These terms are synonymous.

Girls have a slightly more advanced bone age than boys at any particular chronological age.

Skeletal age is closely related to the age at which puberty occurs. Thus the chronological ages within which menarche normally falls is from 10 years to 16œ years, but the corresponding bone ages are only 12 - 14 yrs.





Evidently the physiological processes involved in a child's development are therefore not governed by a host of independent variables, but rather by a well orchestrated programme in which maturity in one sphere is related to maturity in other spheres.

Illustrations and website design by Ann Koeslag

From Womb to the Tomb

The Human Lifecycle
Part 6

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CATCH-UP GROWTH IN HUMANS

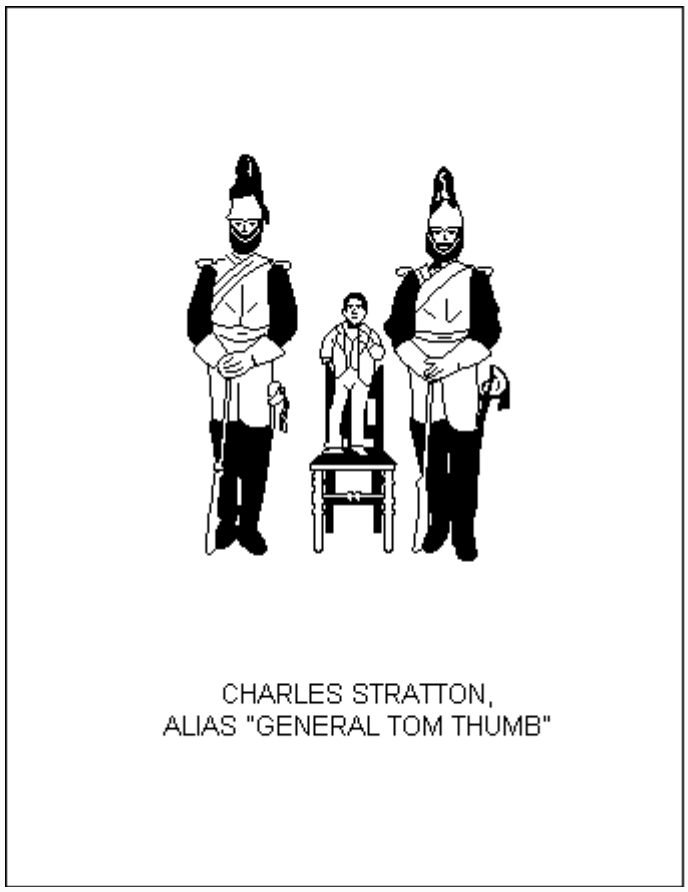
Failure to grow (along species-specific centile lines) may be due to many causes: malnutrition, infections, digestive problems, hormonal problems, chronic heart, kidney, or lung disease etc. The reasons for the slowing down in growth in all these conditions probably differ from one disorder to the next. But, though the causes of growth failure are many, the response, when the failure is repaired, is one. When a malnourished child is given an adequate diet, or a hormonal upset is relieved, the child resumes growing, but at a rate that is usually well above that expected for her age. This is called 'catch-up growth'.

Since disease and episodic undernutrition were common in the past, children were noted to grow literally in stops and starts, as the disease slowed them down, and they then grew to catch-up again when the infection had gone away. In fact, a great many old wives tales grew up around the phenomenon: Such as:

> That children would grow properly only if they had been seriously ill.
>
> Or, that growth cured disease.
>
> Or, that children grew and then consolidated their growth, grew again and consolidated their growth. Growth, it was felt, drained a child of her energy, and she often became sick as a result of too long a period of growth.
>
> Or, that the pubertal growth spurt did not exist in humans, except in cases where the person had been properly ill just beforehand.

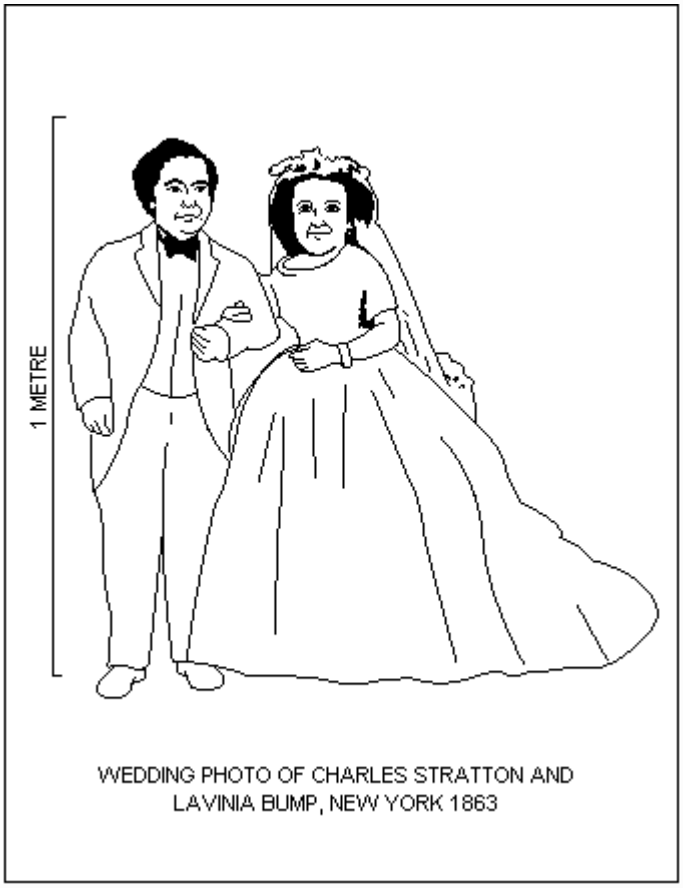
Catch-up growth has been studied most extensively in hormone deficient children, as it is in these cases, firstly, that one knows exactly what is wrong, and, secondly, you can also be sure that you can cure the condition completely with your treatment. In the case of infections and organ malfunction, you are never sure whether the child is completely normal after treatment, or whether she still has some residual malfunction or lingering infection.

There are 2 hormones which are particularly important for normal growth in childhood. Growth hormone (hGH), which stimulates the skeleton to grow, and thyroid hormone which seems to be responsible for tissue maturation. If hGH is absent in childhood the child develops normally, but remains abnormally short.



CHARLES STRATTON,
ALIAS "GENERAL TOM THUMB"

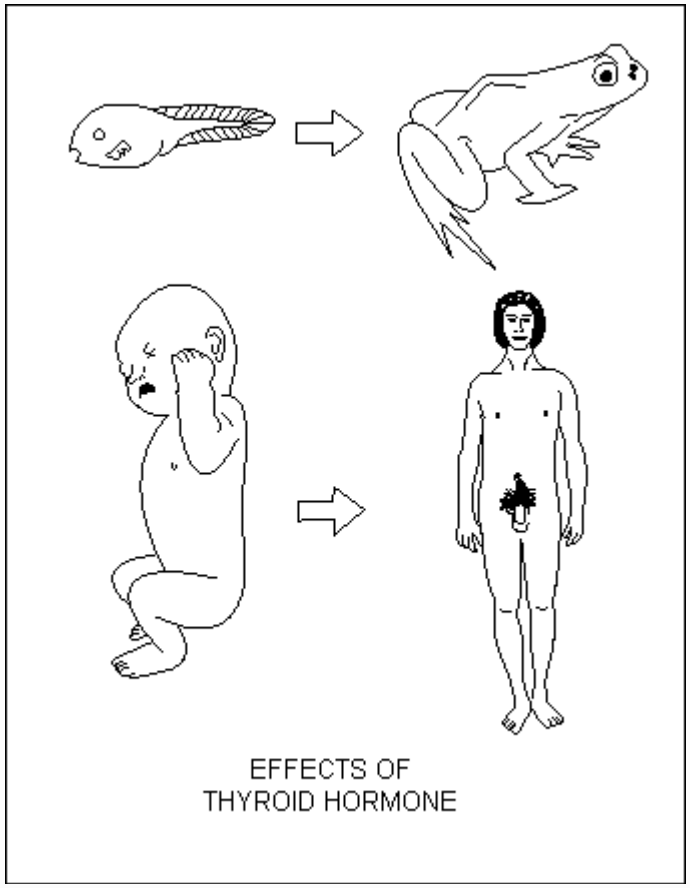
They reach sexual maturity at the normal time, and can then have babies.



WEDDING PHOTO OF CHARLES STRATTON AND
LAVINIA BUMP, NEW YORK 1863

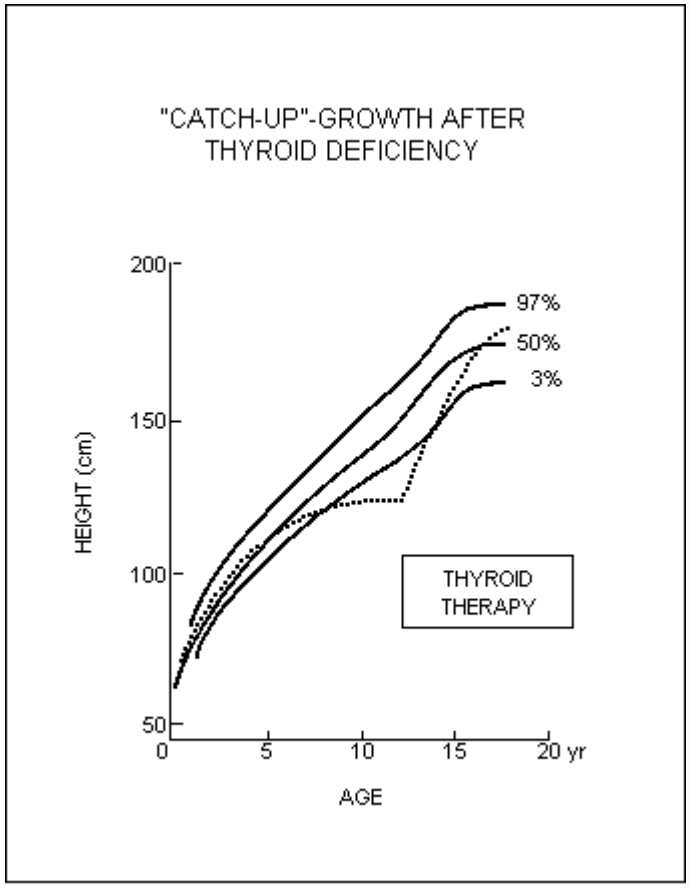
They have a normal intelligence.

The thyroid deficient child (or "cretin", see above) does not grow basically because her tissues retain their infantile physiology, or character. Thyroid hormone is the hormone that converts tadpoles into frogs, and promotes the equivalent metamorphosis in humans.



Mentally they are babies, and are unable to dress themselves, or go to school, or learn to ride a bike, or do up their own shoe-laces etc. They are of short stature, like infants, and retain the infantile body proportions. They never develop the secondary or adult dentition, keeping their baby teeth, etc. They do not become sexually mature. In fact they never 'grow up'; they are literally perpetual children (i.e. the Peter Pan's of this world!).

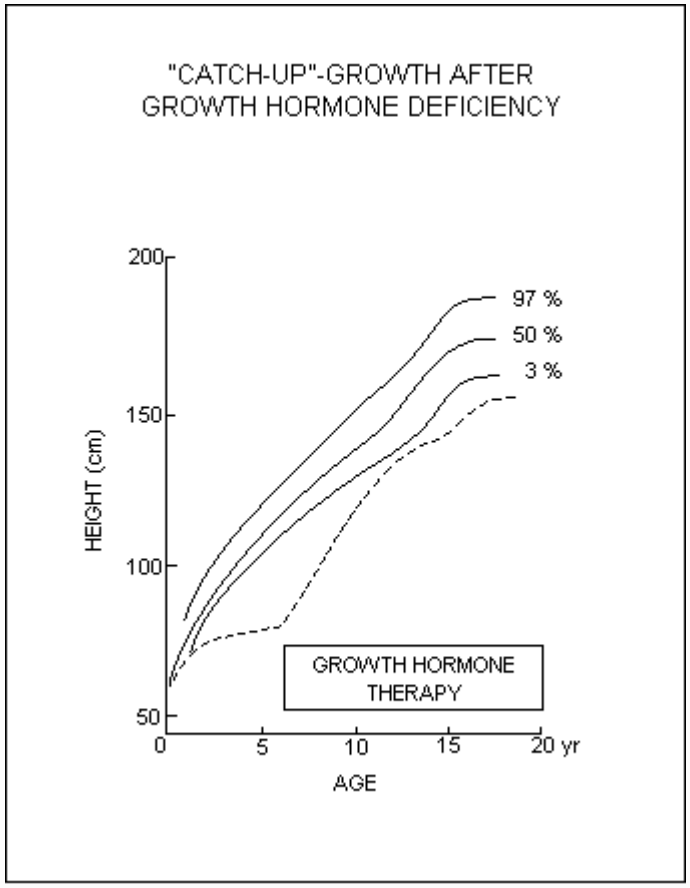
The graph shows what happened to a boy who gradually became hypothyroid after the age of 3 years.



He started to cross centile lines and was 12 years old when the diagnosis was made. He was well below the 3rd centile line at that stage, having started out at the 97th at the age one year of age!

Thyroid hormone was then given to him, and you can see that he immediately started to grow, at such a rate that at 19 years he was above the 90th centile for height, where he would have been at that stage, if nothing had happened. During the catch-up period children can grow up to twice as fast as is normal for that age. In the example given, the child with the thyroid deficiency eventually caught up completely with what his height 'ought' to have been.

In growth hormone deficiency, there is catch-up growth if the missing hormone is administered during childhood, but here the child rarely catches up completely.



She usually ends up as slightly shorter than the average adult of her gender. The longer the delay between the time of the development of the deficiency and the institution of treatment the greater the residual loss of adult stature. If treatment is instituted after the epiphyses of the long bones have closed at the end of puberty, then no amount of growth hormone will cause "catch up growth", or any other type growth in height whatsoever. The tissues have matured to the point when they no longer respond in the child-like way to growth hormone. (In thyroid deficiency this, of course, does not happen; the tissues do not mature at all, and will respond to all the hormones of development, which include hGH and the sex hormones, in the normal child-like manner when the thyroid deficiency is relieved. The only tissue that does not develop normally when thyroid hormone is given to a long-standing hypothyroid child, is the brain. This means that should a 40 year-old cretin with a developmental age of 4 years be treated with thyroid hormone, she will start developing physically at a very fast rate, going through puberty and attain physical adulthood in a few years. However, there is no mental development. That person who has now developed an adult body, will, unfortunately, always have a 4 year-old mind!)

When chronic malnutrition is relieved with a normal diet, there is very rapid catch-up growth, but some growth deficit remains. This would indicate that malnutrition causes greater hGH-type growth retardation than a thyroid hormone-like retardation of maturation.

The residual deficit which occurs after catch-up growth in cases other than hypopituitarism, depends on how badly and how often (or for how long) the abnormality existed before treatment was instituted. A short bout of malnutrition is made up completely. Prolonged, or frequent bouts of malnutrition result in a certain amount of stunting, which is not made up during catch-up growth.

Catch-up growth tends to be more complete in infancy and early childhood, than in late childhood and puberty.

No one knows why catch-up growth should occur. Why does the growth retarded child not simply grow at the rate that his state of 'maturity' would predict? Why does she in fact grow much faster to make up lost calendar-time? No one knows. All we can say is that somewhere, somehow, the body must keep some record of calendar-time, or the phenomenon would not be possible.

A final comment:

The growth spurt just after birth is probably a form of catch-up growth to compensate for the growth retardation which occurred *in utero* during the last few weeks of pregnancy!

Illustrations and website design by Ann Koeslag

From Womb to the Tomb

The Human Lifecycle
Part 7

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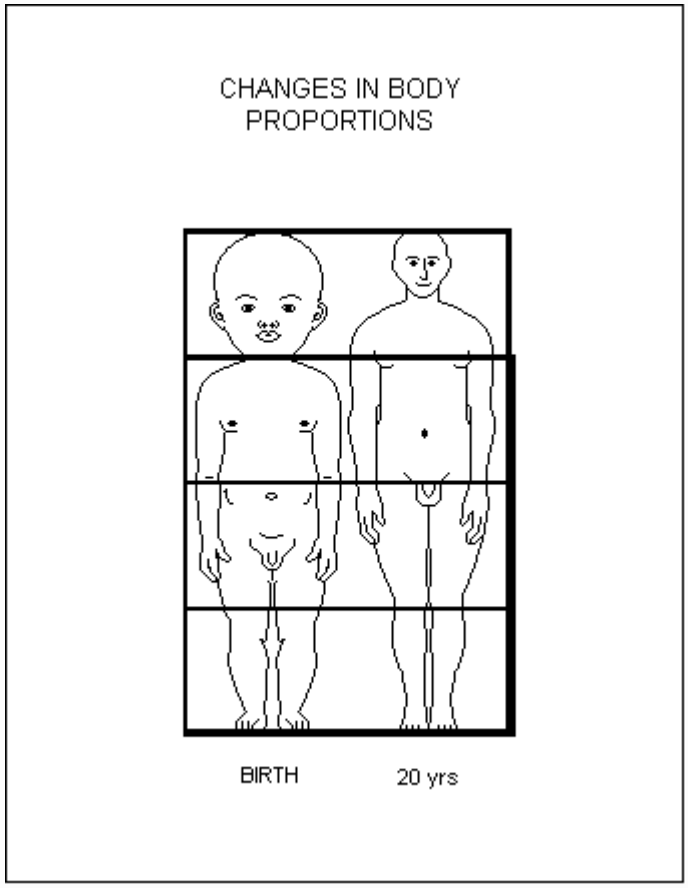
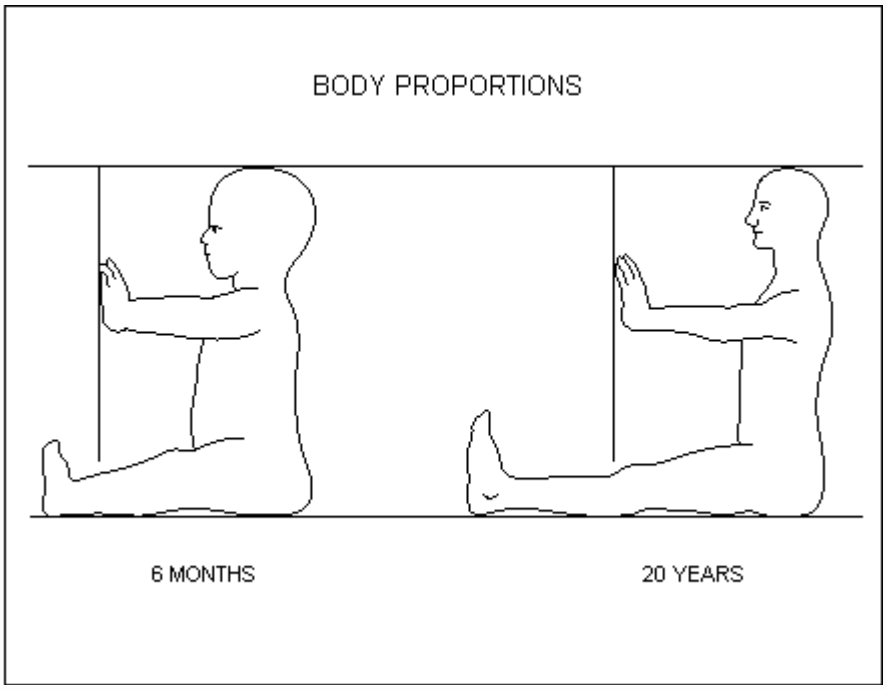
GROWTH CURVES OF DIFFERENT TISSUES AND DIFFERENT PARTS OF THE BODY

Growth during the embryonic stages of life are characterised by very drastic changes in body form. These changes are studied in the discipline called 'Embryology', and will not be touched on here, fascinating though they are.

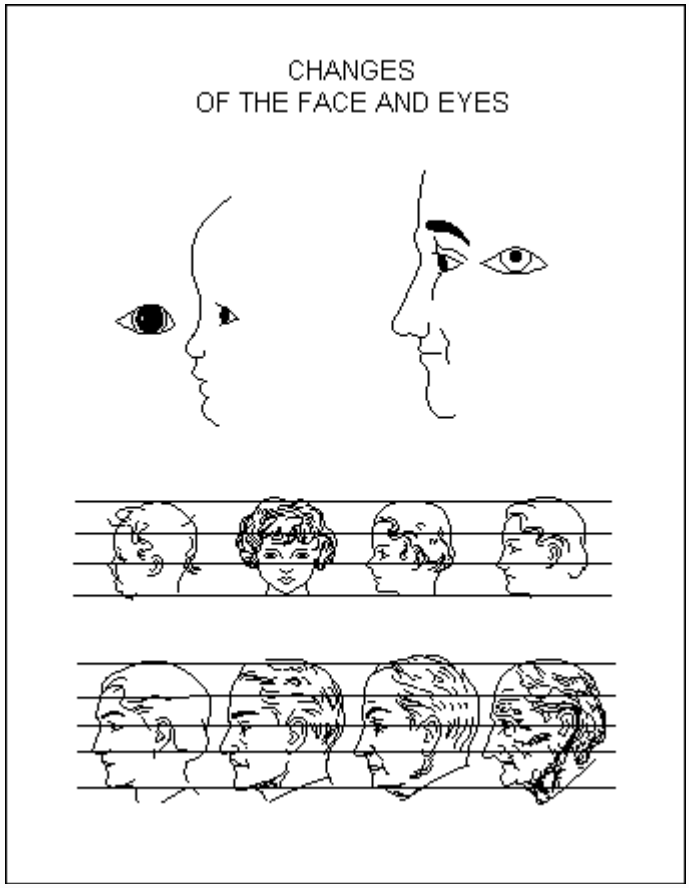
By the stage that a baby is born she has the overall human form, and contains all the organs that she will have as an adult, but the proportions of these organs are different from the adult.



The baby is born with a very large head, and relatively short limbs. The umbilicus marks the mid-point of body length. In the adult, the head is about 1/8 of the length of the body, and the legs are about œ as long as the standing height.



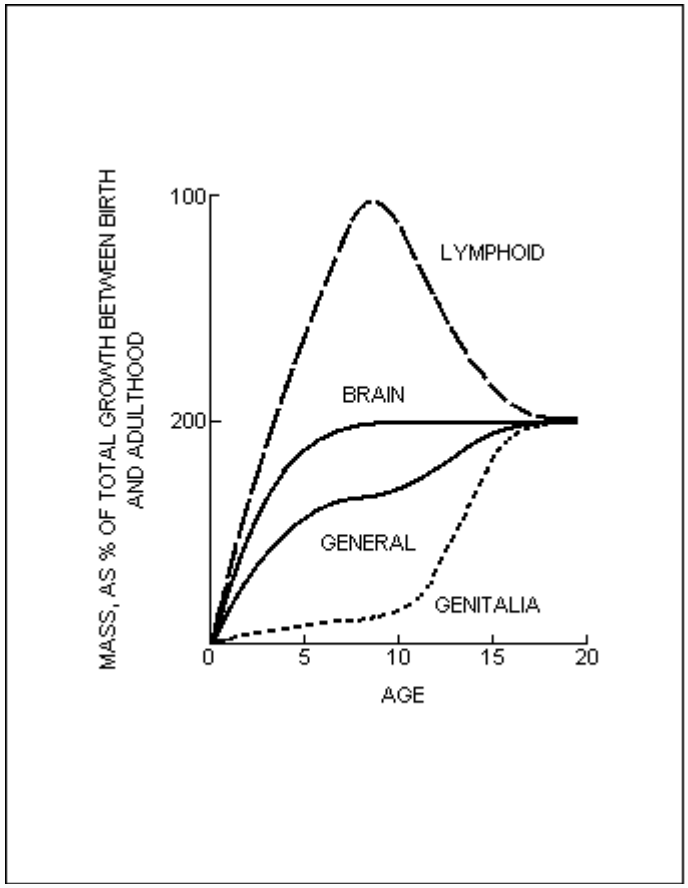
The arms of the baby reach as far as the hips, but in the adult they reach half way down the thighs. In addition there are important differences in the architecture of the face, the appearance of the limbs and the trunk etc.



All of which make the individuals recognisable as babies or as adults. There is, in fact, considerable redundancy in these signals. This means that even if the most prominent difference between children and adults is removed, namely the difference in height between the two, a short statured adult is still always recognised as being adult; although, of course, such individuals evoke our curiosity, and used, in the past, often find employment in circuses where they could be gawked at, in the same way that people gawk at a "lady with a beard".

Internally there are also different rates of growth, though the great majority of tissues grow in the manner described for height.

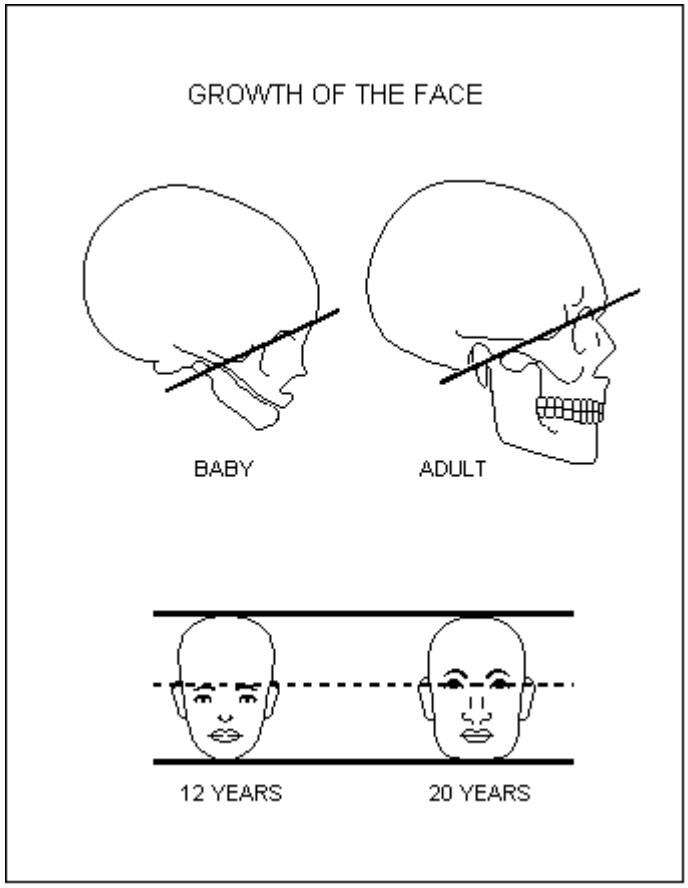
There are some exceptions, which are graphically illustrated in the following diagram:



The musculo-skeletal system grows according to the 'general' curve. The reproductive organs, internal and external, have a slow pre-pubertal growth, followed by a very large adolescent spurt.

The brain, cranium, eyes and ears characteristically develop earlier than any other part of the body, attaining 90% of their final size by the age of 5 years. If there is an adolescent growth spurt for the brain it is very small.

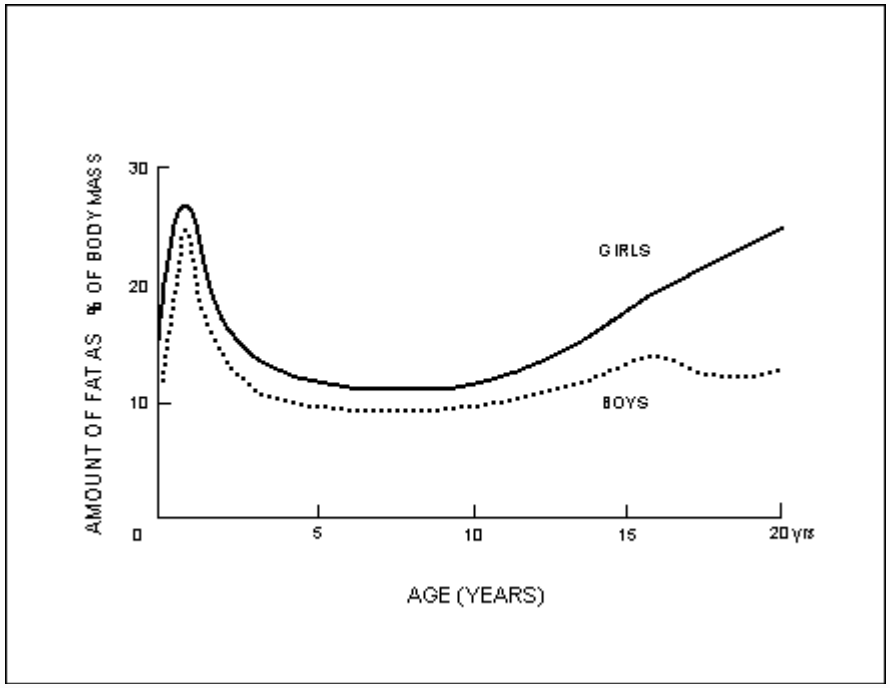
The face, as opposed to the rest of the skull, does undergo an adolescent growth spurt, changing the whole facial appearance of the person. The nose grows, and so do the jaws and cheeks (the latter due to the development of the sinuses), to give the person a typical adult appearance, with the cranium, housing the brain, constituting a smaller proportion of the skull than in the child.



Lymphoid tissue (tonsils, adenoids, thymus and lymph nodes) has quite a different growth curve from the rest of the body. It reaches its maximum size just before puberty, and then regresses to about half that size under the influence of the sex hormones which are secreted during puberty.

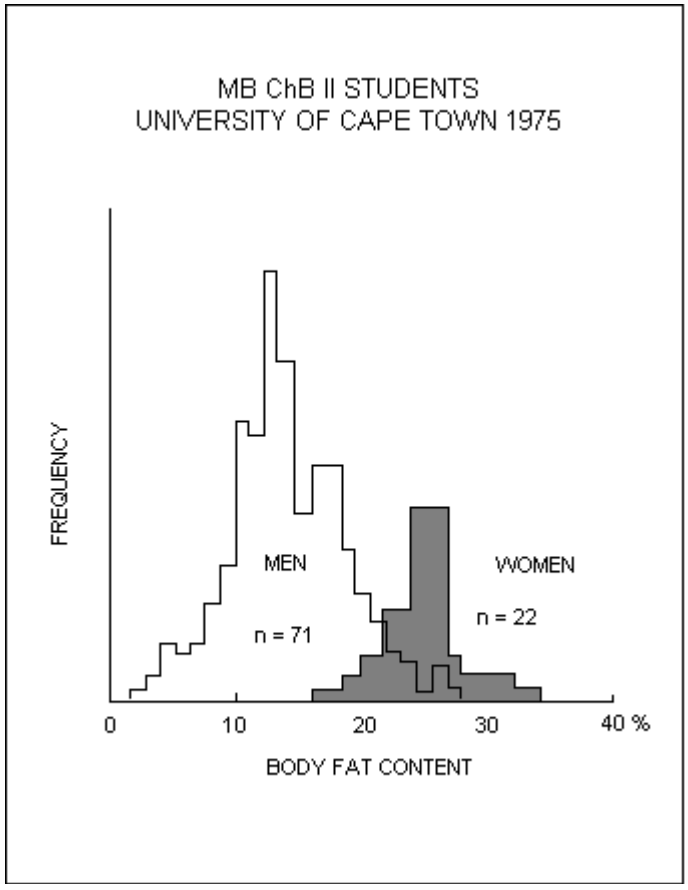
The fact that lymphoid tissues develops in this peculiar manner means that the tonsils, for instance, appear "abnormally large" in late childhood. Many tonsils were removed for this perfectly normal reason in the past! Towards the end of the 19th century when many children died, sometimes for no obvious reasons, autopsies revealed "enormously large" thymuses in the chest. Since they seemed, like the childhood tonsil, to be "abnormally" hypertrophied and intrusive these excessively large (but, by today's knowledge, normal) thymuses were noted as the cause of death, in a syndrome called "Status Lymphaticus". This "disease" is no longer recognised as an abnormality today.

Subcutaneous fat has a curve of its own too. It begins to be laid down in the human foetus at about the 34th week post-menstrual life, and increases in thickness till the child is about 9 months of age. It is of fairly uniform thickness around the body at this stage. After 12 months it decreases in absolute (and therefore relative) thickness, producing a marked change in body shape - so much so that a change in name from infant to child is warranted.



Girls have a little more subcutaneous fat than boys, even at birth, and the difference becomes more marked with age.

Just before puberty the subcutaneous fat layer increases in thickness in both genders, but in boys it decreases again, particularly on the limbs. By the time early adulthood is reached, the young woman's body mass comprises about 25% adipose tissue, and in the man about 12%, on average.



Not only that, but there is a marked difference in the distribution of the fat, which is responsible for most of the sexual dimorphism found in humans. The curvaceous shape of the young woman is almost entirely the result of the shape of her fat organ.

Subcutaneous fat does for humans what different coloured plumage does in birds, and different scents do in many mammals.

Illustrations and website design by Ann Koeslag

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Part 8

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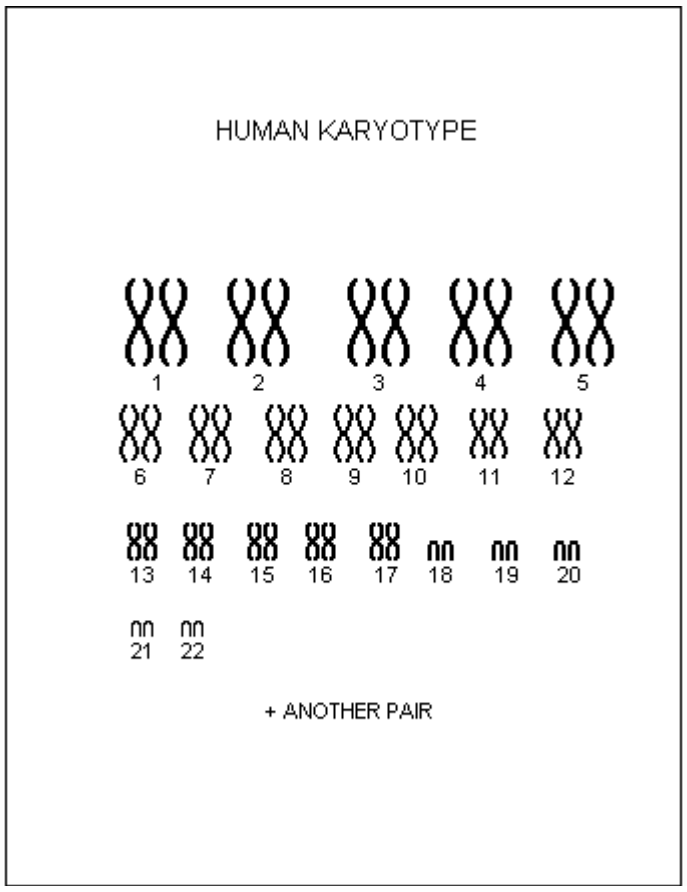
SEXUAL DIMORPHISM BEFORE PUBERTY

Karyotypic gender

It is possible to take human white blood cells, or connective tissue cells from a tiny piece of skin and grow them outside the body. If one then administers colchicine (a drug), cell division is stopped at the moment in mitosis when the chromosomes are especially visible (i.e. the cell cycle is stopped in the metaphase stage). The chromosomes which are in the nucleus of the cell, can then be stained and the cell photographed. The chromosomes are especially visible. The chromosomes are made of tightly rolled up DNA molecules. This DNA is in the form of strands which contain, along their length, "genes" - the genetic blueprint for the development, growth and function of the body. Everything about you: whether you turned into a human or into a mouse, whether you have blue eyes or brown, how tall you will be under ideal circumstances etc., etc. - are specified in code form in the DNA molecules which comprise the chromosomes.

The chromosomes also specify whether a cell belongs to a male or a female. The chromosomes come in pairs, one member of each pair having come from the mother, and the other from the father. In humans there are 23 such pairs, and each pair is distinguishable from the other pairs by size, shape and staining properties.

When the stained chromosomes are seen in a photograph of the cell nucleus they lie higgledy-piggledy, and are not paired up with their opposite numbers at all. For clarity the photograph of the chromosomes is therefore cut up and the chromosomes are then arranged in pairs and pasted on to a card.



Such a display is called a karyotype.

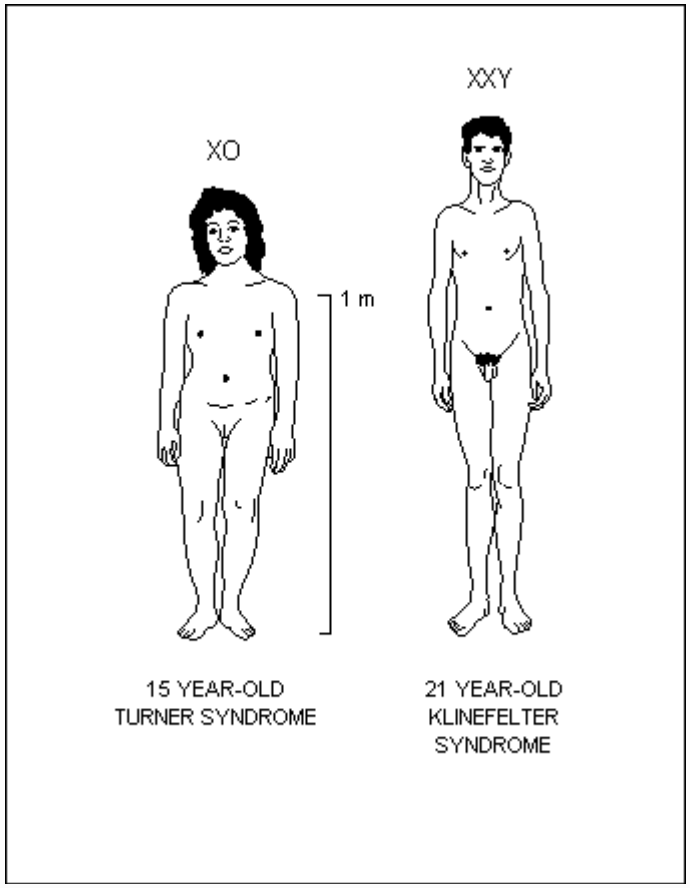
The members of each pair appear identical, and indeed carry exactly matching sets of genes along their lengths. There is one major exception however. The members of one pair are sometimes grossly dissimilar. One of the pair is called the X chromosome, which is sometimes matched with another X chromosome, but in half the population it is "mismatched" with a tiny Y chromosome. These are the chromosomes which determine the person's karyotypic gender (sometimes incorrectly called their "genetic sex"). In mammals karyotypic females have an XX combination and karyotypic males an XY combination. (In birds it is the other way around!)

This difference is established at conception. The ovum always contains an X chromosome, but the sperm which fertilises it may carry either an X or a Y chromosome. When they combine to form the zygote there is an approximately 50:50 chance that an XX or an XY combination occurs. If an XX combination occurs then that individual's "karyotypic gender" is female; if an XY combination occurs the "karyotypic gender" is male. (In most cases karyotypic females will turn into girls and women, and karyotypic males into boys and men.)

As the zygote divides each daughter cell receives a set of 23 pairs of chromosomes, identical to that of the fertilised ovum. This happens at each cell division, and accounts for the fact that you can find these chromosomes in all the nucleated cells of the body, even in the adult.

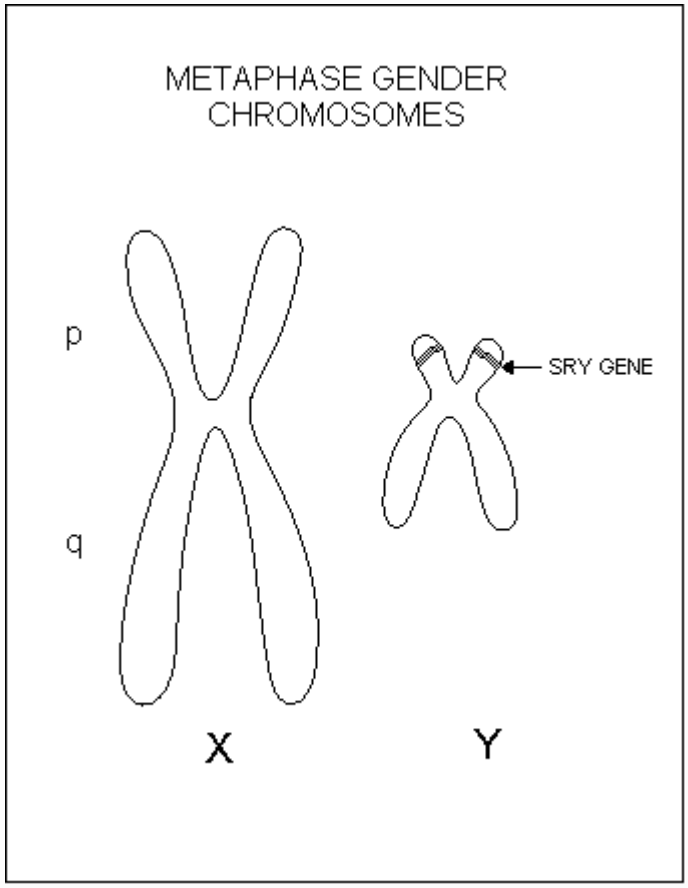
Occasionally things go wrong, and a zygote is formed with an extra chromosome, or a missing one. This can affect any of the pairs. Thus you may get 3 chromosomes No. 21, which in technical jargon is referred to as "trisomy 21". Most of these chromosomal abnormalities are not compatible with normal development, and are aborted within the first few weeks of intra-uterine life. Some are compatible with reasonably normal development, and trisomy 21 is one such case, giving rise to Down's syndrome.

This type of abnormality can obviously also affect the sex chromosomes and most of them are perfectly compatible with life, and reasonably normal growth and development. XO, XXY, XXX, XXXY and XYY are known. Apart from the first 2 (XO and XXY), the carriers of these chromosomal abnormalities look and develop reasonably normally, and would not normally be detected unless they are karyotyped for one or other reason.

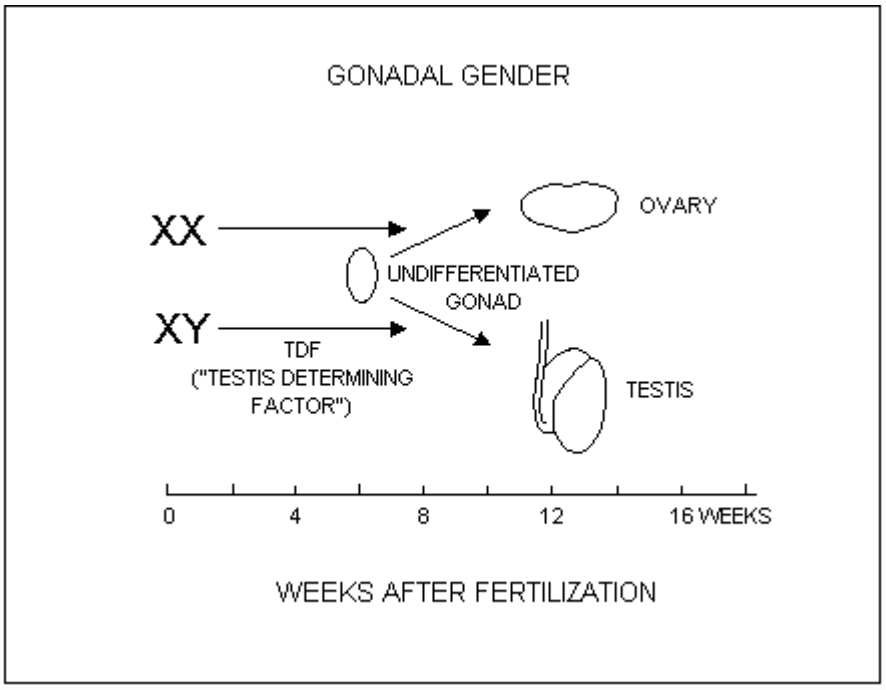


Gonadal gender

During the earliest development only examination of the chromosomes will tell us the (karyotypic) gender of the embryo. When the gonads appear at about the 6th post-conception week, they are neither testes or ovaries (i.e. they are "undifferentiated gonads"). But soon differences appear, triggered by the presence or absence of "testis determining factor" (TDF) which is protein coded for by the sry gene on the Y chromosome.



(There is no sry gene on the normal X chromosome, so karyotypic females do not usually make TDF.) If TDF is secreted during the 7-8th week of embryonic development, the undifferentiated gonads develop into testes; if not, they develop into ovaries.



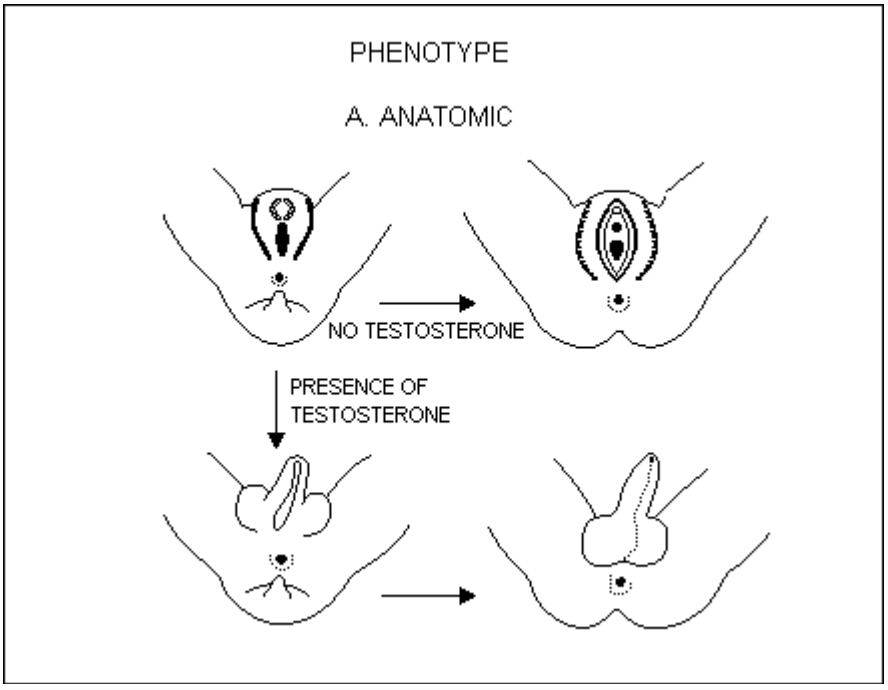
Note that it is the presence or absence of TDF which causes the testes to develop or not, and not the karyotype (except indirectly). Thus, if the embryo is a karyotypic male, but has a dysfunctional sry gene, then that embryo will develop ovaries and not testes. This embryo thus becomes a "gonadal

female", despite being a "karyotypic male". Similarly, if the sry gene has been translocated on to an X chromosome, then a karyotypic female embryo will develop testes, and become a "gonadal male".

Phenotypic gender

At about 9 weeks after fertilisation hormone-secreting cells appear in the gonad if it is a testis (and only if it is a testis). These cells start secreting testosterone. The developing ovary produces no hormones at this stage.

The secretion (or not) of testosterone is vitally important if the individual's anatomical gender is to correspond with his or her gonadal (and karyotypic) gender. If there is no secretion of testosterone then, irrespective of the person's karyotype or gonads, a set of female genitalia will develop. Conversely if testosterone is present at the 9th week of the post-conception life, then a set of male genitalia will develop, whatever the person's karyotype happens to be: XO, XX, XY, XXX, XXY, or XYY etc.

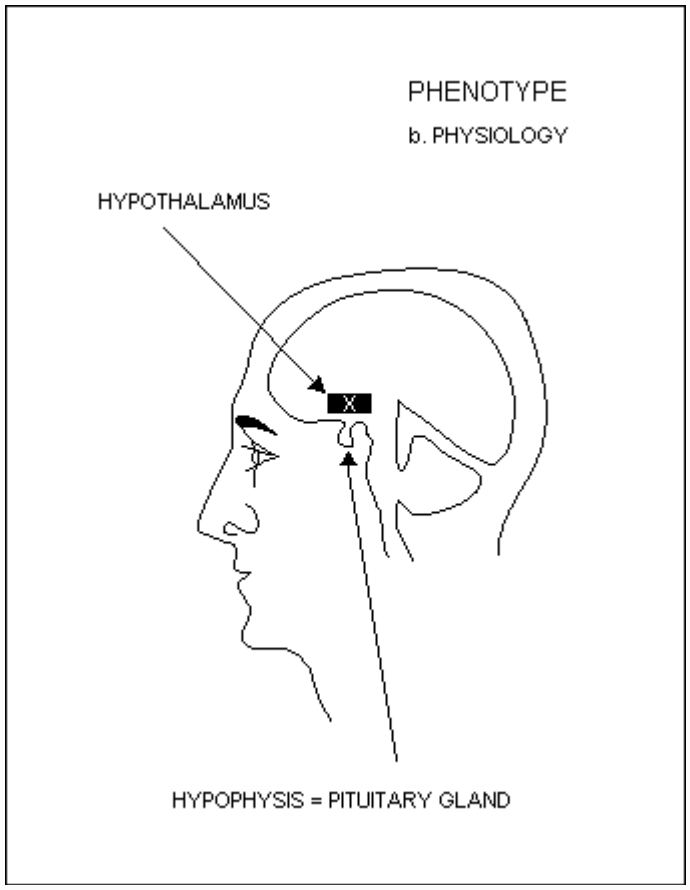


Most of the time, of course, a person possessing an Y chromosome (XY, XXY, XYY) will secrete testosterone at this stage, and will be born looking like a boy.

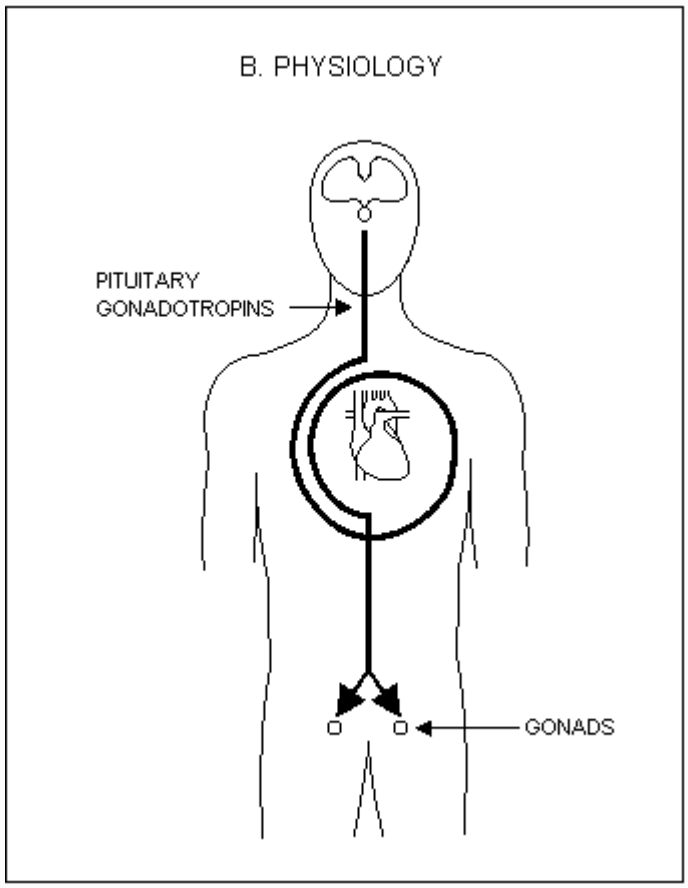
In the "testicular feminisation syndrome" the person is a karyotypic and gonadal male, but lacks the ability to respond to testosterone. They are therefore born looking like girls, and are brought up accordingly, and, in many cases, experience a normal female puberty. They are therefore normal women, but are sterile. The gonads generally are abdominal like ovaries, but when biopsied they are found to consist of testicular tissue. Except where there are other abnormalities, or the syndrome is incomplete (i.e. the tissues are partially sensitive to testosterone, and the person develops unacceptable male features during puberty), the condition can remain completely unrecognised unless the person is karyotyped. Such karyotyping might be done during an infertility examination, or because the person needs to provide proof of their gender in order to take part in the women's Olympic Games. Needless to say, such a discovery can be highly traumatic for the person and their

family.

This secretion of testosterone has one other important effect, which will become noticeable only at puberty. It affects the hypothalamus and pituitary gland, which is situated in the skull just under the brain.

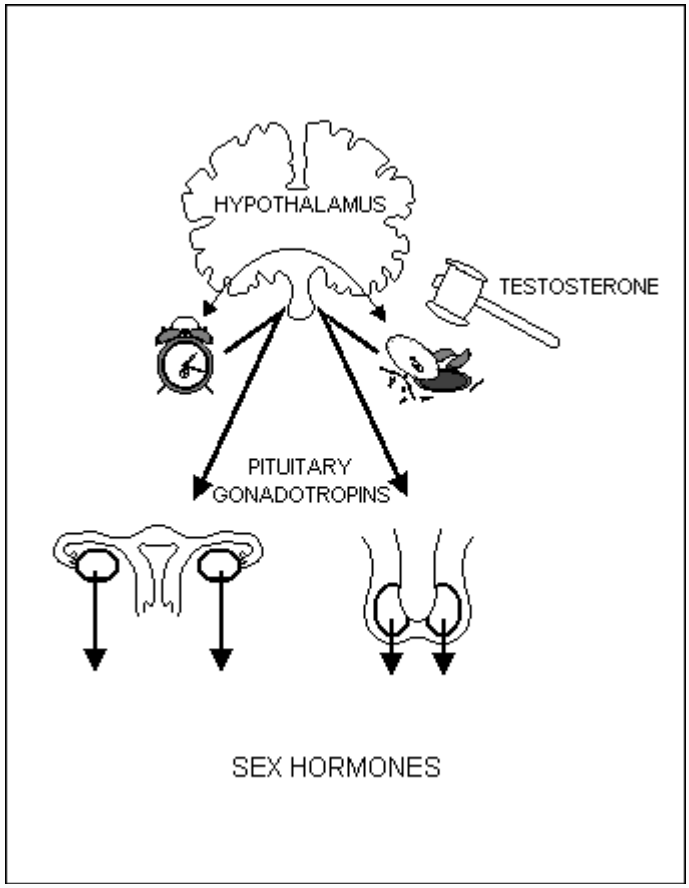


The pituitary gland secretes, amongst others, two hormones which together are known as the "gonadotropins". These are secreted into the blood where they circulate to all parts of the body, but affect the function of only the gonads:



The gonadotropins stimulate the gonads (ovaries in the woman, and testes in the men) to produce the sex hormones (oestrogen or testosterone) and gametes (ova or sperms).

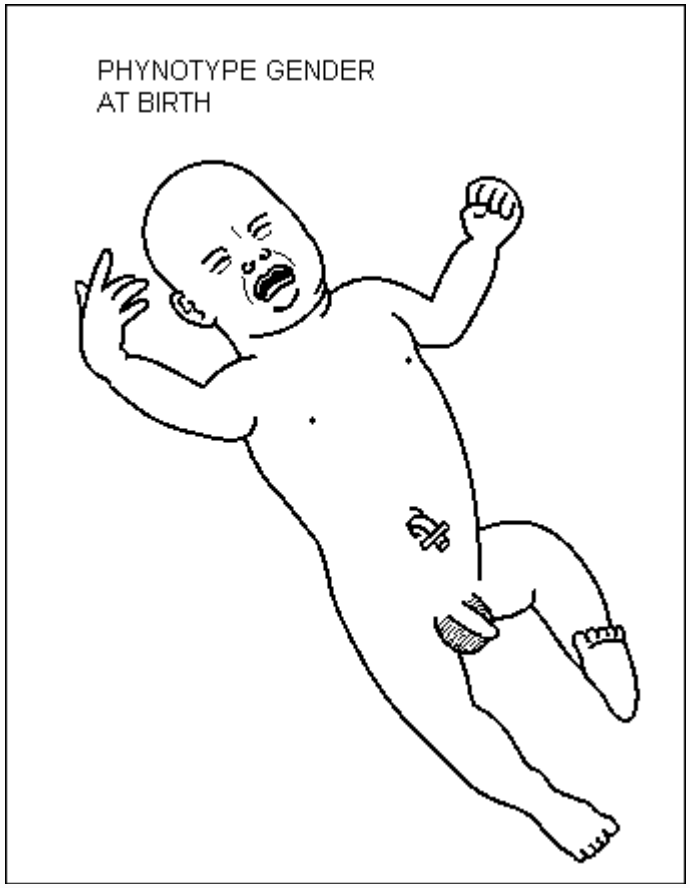
In the absence of testosterone during the 9 - 12th week of post-conception life, the pituitary will secrete these gonadotropins in a cyclical manner during adult life, as occurs in normal women. Whatever it is that causes the pituitary to secrete its gonadotrophic hormones in this cyclical manner is blotted out for good by the presence of testosterone during embryonic life.



Normal adult men therefore do not secrete the gonadotropins in the cyclical manner of women, and do not experience the equivalent of a menstrual cycle. (Note that men and women secrete exactly the same gonadotropins. It is only the pattern of secretion that differs between the genders.)

Development of gender role

At birth the human child's gender is surprisingly obvious and conspicuous, compared to that of other mammals.



In dogs, cats and rats it is very difficult if not impossible to sex the offspring at birth. In some species, in fact, the gonads are still in the undifferentiated stage of development at birth. But in humans the appearance of the external genitalia of the two genders are very distinctly different.

It would appear that this peculiarity of humans is not trivial. The first thing adults remark on when a baby is born is its gender. This happens before its fingers have been counted, or other parts of the neonate have been checked. It is the first thing the mother enquiries about: is it a boy or a girl?

The importance of this is illustrated by the problems posed by babies whose genitalia are ambiguous (so-called "Inter-sex"). Clinical experience has taught that a final irreversible decision has to be taken concerning the child's gender before the age of 6 months. The parents must then adhere to this decision whatever happens afterwards. The baby's name obviously depends on the chosen gender, as will be the way it is clothed and brought up, and how it is treated by family, friends, teachers, school mates and strangers. It appears that how the child (and later the adult) feels about herself depends heavily on this "upbringing", although how this happens is not certain.

Should a "mistake" have been made about the choice of gender of such a case (e.g. the child was brought up as a girl, but starts developing predominantly male features at puberty), then steps have to be taken to match the pubertal changes with those of the chosen gender. Since it is always easier to change male external genitalia into what will pass for female genitalia than the other way round, the tendency is to opt for a girl up-bringing when there is doubt. The other features of femininity are then induced by the administration of the female sex hormone, oestrogen. This then looks after the development of the female figure (i.e. the shape of her fat organ), with breasts and a female facial complexion.

Phenotypic gender during childhood

Apart from the appearance of the genitalia, the genders are very similar at birth. The differences that exist between the genders at this stage are small:

Boys weigh, on average, about 100 g more that girls.

Boys have slightly less subcutaneous fat than girls.

The length of the forearm is longer in proportion to the upper arm in boys than in girls.

The fourth finger of the hand is generally longer than the index finger in boys. It is the other way round in girls. Skeletal maturity, based on the X-ray appearance of the growing bones is less advanced in boys than it is in girls.

These differences already exist at birth, though, as has already been mentioned, they are hardly noticeable in the individual case, because of the wide variation that exists in all of these parameters, giving rise to tremendous overlap of these features between the genders.

During childhood development, however, the differences become more and more noticeable. Girls grow up faster (physically and mentally) than boys, with the difference in skeletal maturation persisting and becoming more pronounced with age. Girls are physiologically and mentally more mature than boys of the same age, but the order in which the developmental milestones are reached is the same in the 2 genders.

For all of this, the physical differences between the genders remains relatively small during childhood, and the main expressions of sexual dimorphism are in fact cultural: the name the child is given, how it is dressed, and how long its hair is cut etc.

Illustrations and website design by Ann Koeslag

From Womb to the Tomb

The Human Lifecycle
Part 9

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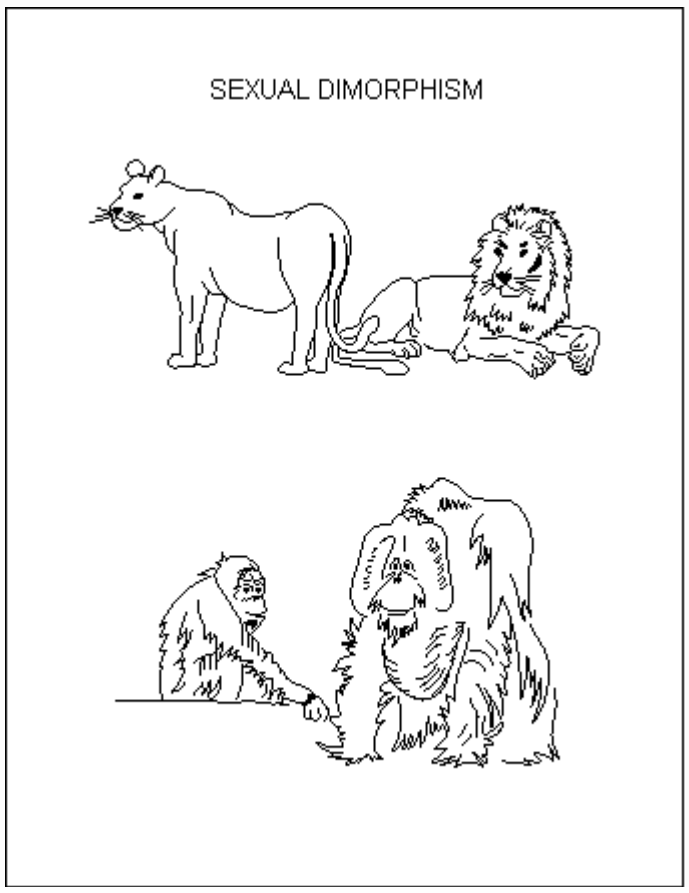
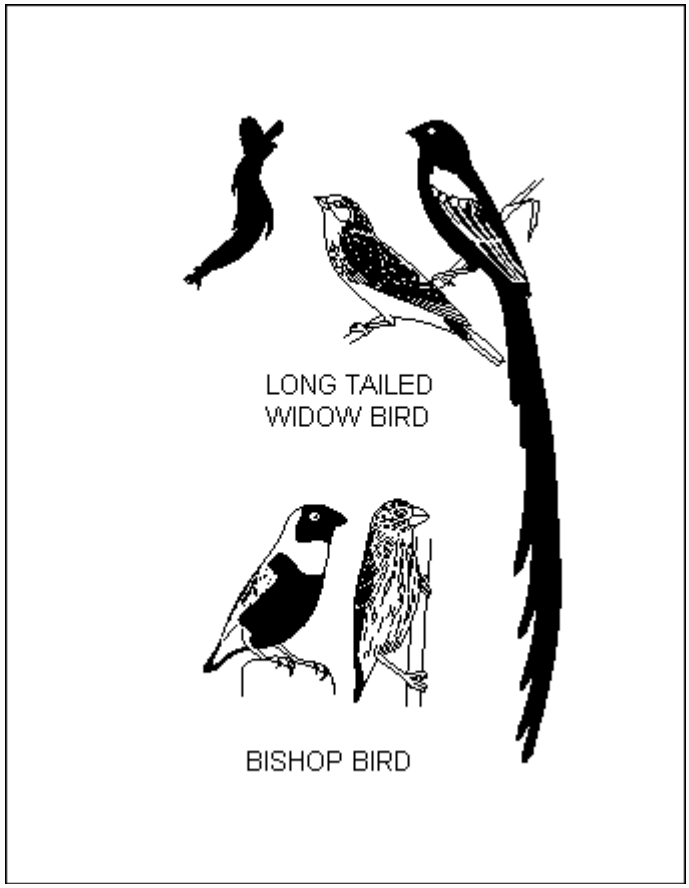
PUBERTY

Puberty is the time of the greatest gender differentiation since the 9th - 12th week of intra-uterine life. We will use the words adolescence and puberty interchangeably, though some people would like the one term (puberty) to be used exclusively to describe the period of physical change, and the other (adolescence) to denote the psychological and behavioural development. But since few people follow this convention, it is not worth being pedantic about it. What words mean is what people understand them to mean, and for most people adolescence means the same as puberty.

Puberty is here defined as the period in which reproductive capacity is reached. It therefore means that the individual needs to develop new signals to indicate this new capacity to other members of the species:





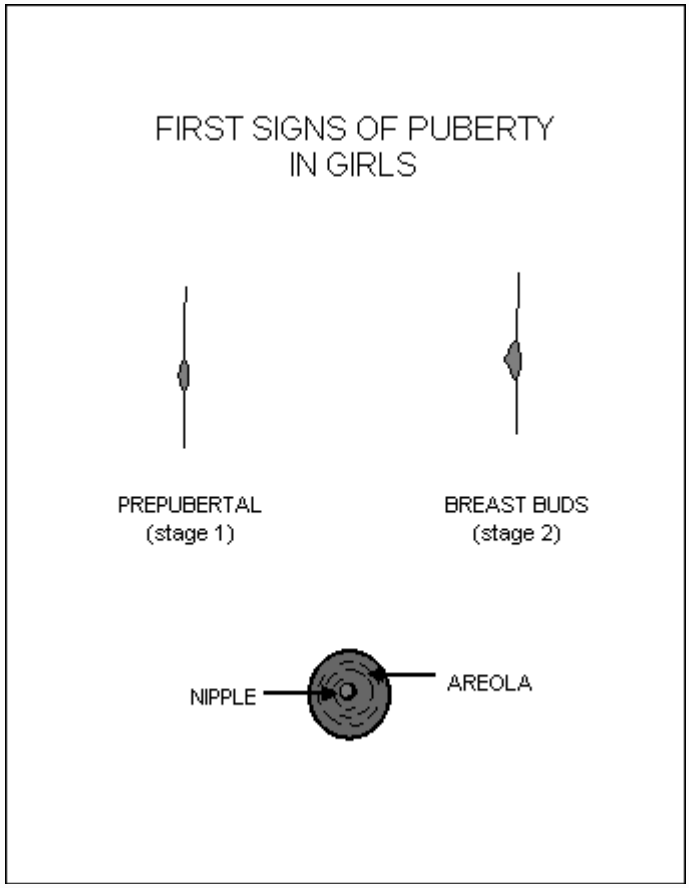
The physical manifestations of puberty, specifically the appearance of the secondary sexual characteristics (or signals of sexual maturity) , begin to appear on average by the 11th birthday in girls, and 11œ in boys. The first manifestation of female puberty, enlargement of the breasts, is much more visible than the first manifestation of male puberty, enlargement of the testes. Enlargement of the ovaries in girls presumably predates the appearance of breast buds by about 1œ years, but cannot be seen or felt under normal circumstances. So the "first signs" of puberty in the two genders are not equivalent. The appearance of equivalent features such as pubic hair and the start of the growth spurt are delayed by about two years in boys compared with girls.

The timing of puberty, and its duration are subject to very wide variation, with some individuals taking 5 - 6 years to go through all the stages, while others take only 18 months. The timing of the onset of puberty does not seem in any way to presage the duration of the pubertal change.

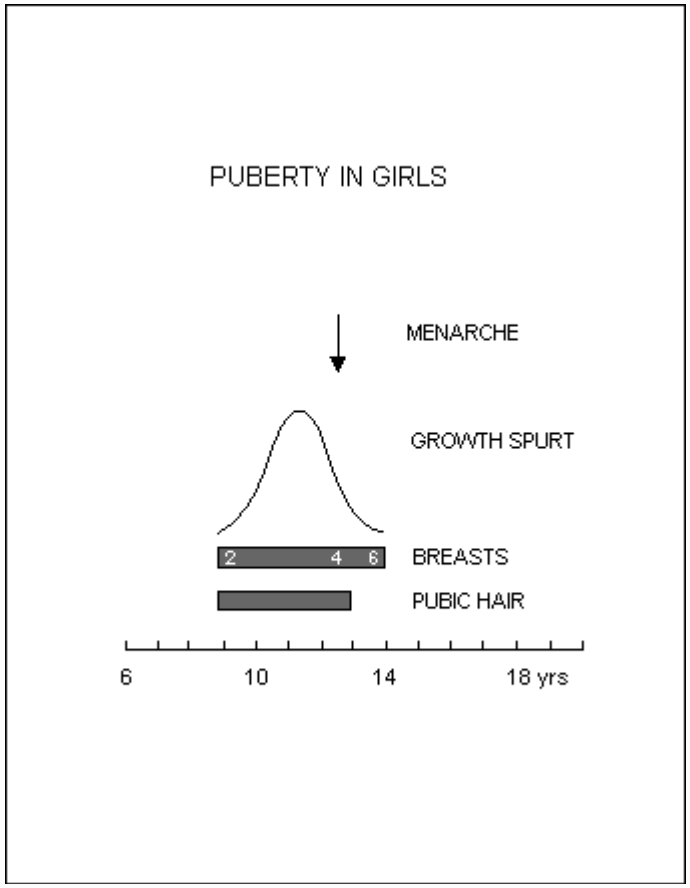
By comparison, the sequence of events is less variable, and it is to this sequence of events that we now turn.

Puberty in girls

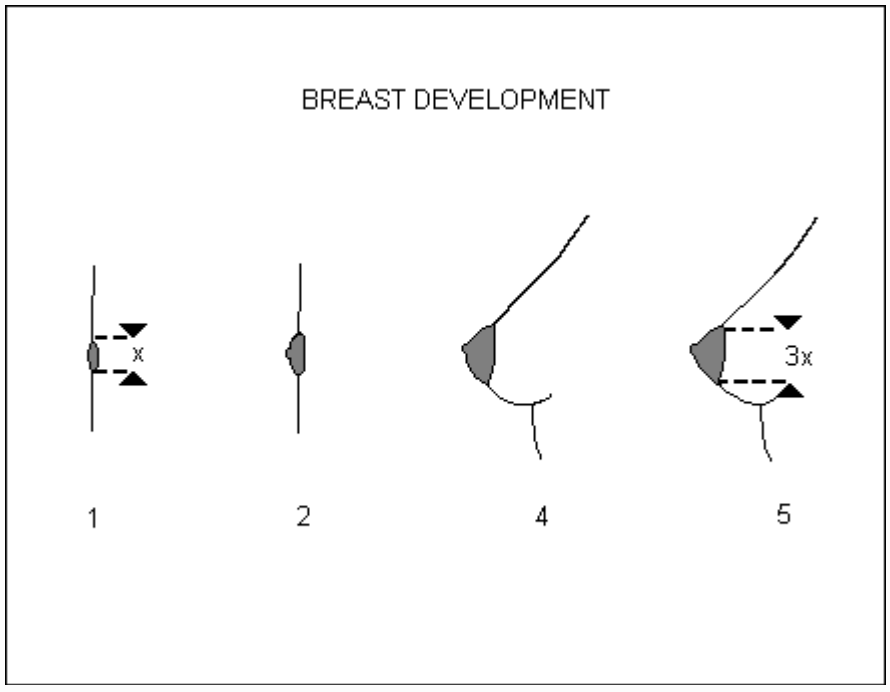
Usually the first event to be noticed is the advent of "breast buds". These consists of an elevation of the areola and papilla as a small mound, with slight enlargement of the areolar area.



Occurring more or less at the same time, sometimes before, sometimes a little after, are the beginning of the growth spurt, and the appearance of pubic hair.



Menarche (the first menstrual period) occurs relatively late in puberty, usually after the growth spurt has started to subside. On average girls grow only another 5 - 6 cm after menarche. At menarche the breasts consists of well-formed local accumulations of fat, approximately the adult size, but the areola projects beyond the contour of the breast.



It may take another 2 years or so for stage 5 in breast development to be reached, though in some

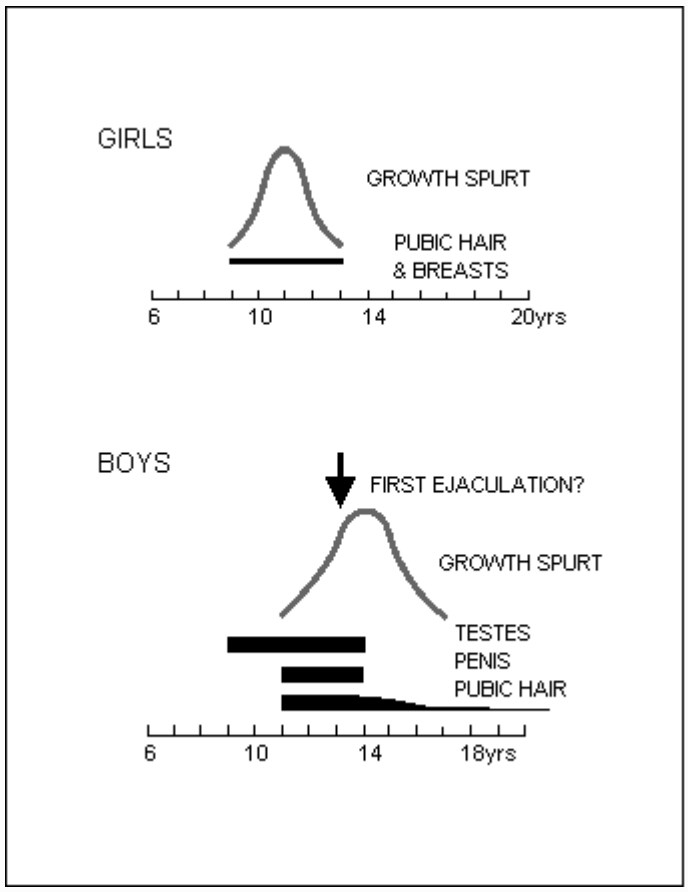
women it may persist as stage 4 for much longer. In some women stage 4 is missed out altogether.

Pubic hair is usually fully developed at menarche. Axillary hair still has to develop to its fullest extent.

In the mean time, the girl has accumulated substantially more subcutaneous fat than she had before, and as a consequence now has a typical female figure and complexion.

Puberty in boys

After the testes start to increase in size, it takes about a year before other manifestation of puberty occur. The growth spurt, increase in the size of the penis and the first appearance of pubic hair all start more or less concurrently.



Breaking of the voice in boys is a fairly late event in puberty, as is the acquisition of facial hair (which in many human groups, e.g. the Chinese, may not develop till the age of 40 years, or later). Body hair starts to grow during late puberty and continues to develop into the full male pattern often up to 30 years of age, although that too is race-dependent. Being able to grow a full beard, and having the full complement of body hair already at the end of puberty is characteristic mainly of the descendants of the Barbarians who invaded Europe and replaced the earlier European populations (e.g. the Romans, Gauls, Iberians and Ancient Britons) during the 3rd - 5th centuries of the Christian Era. (The Romans did not call them "Barbarians" - the bearded ones - for nothing!)

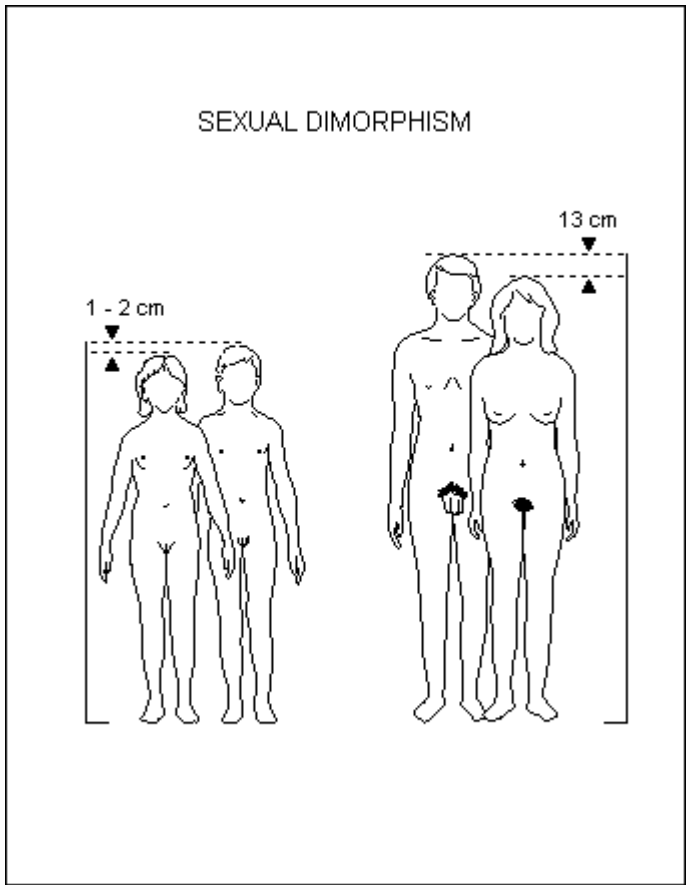
Boys also often develop breast buds during puberty, and the areola increases in diameter, but not as much as in girls. This usually occurs midway through puberty and the swelling regresses after about a year, but the areola remains larger than it was in childhood (about 2 x the diameter in the child. In

women it is about 3 x the diameter in the child).

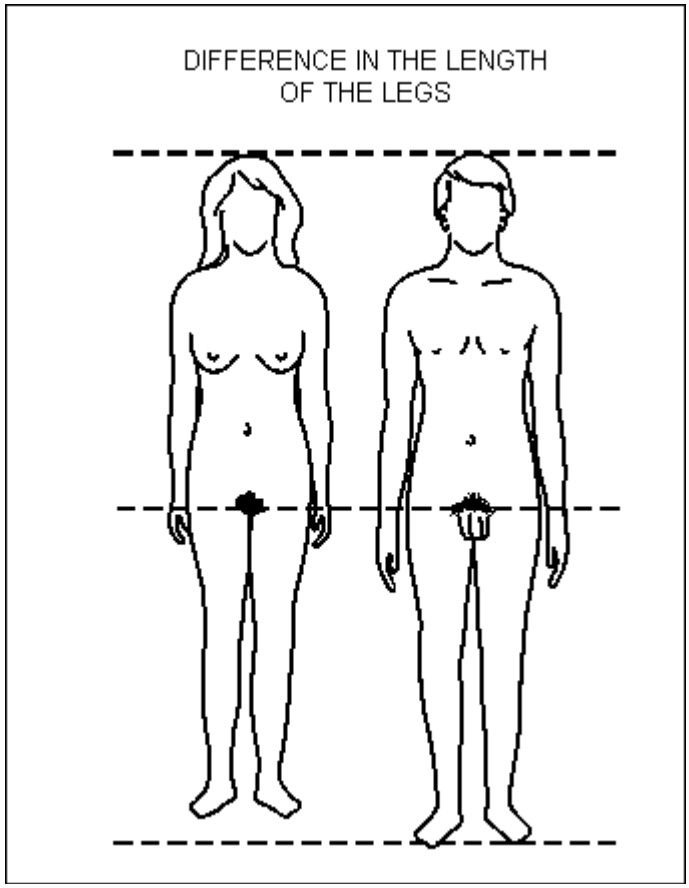
It is uncertain at what stage of puberty the boy's first ejaculation occurs. The first ejaculation, unlike the first menstrual period in girls, generally happens in secret, and in many cases the boy is not prepared for it in the way that girls are informed about menstruation. Many men can therefore not recall exactly when their first ejaculation occurred. It is believed that the first ejaculation occurs fairly early on in puberty before the peak of the growth spurt is reached, but information on this matter remains largely conjectural. It is not known what the first ejaculate consists of. Does it contain any sperms? If not, when are sperm first ejaculated? These are unanswered questions.

Puberty and sexual dimorphism in humans

Before puberty boys are only slightly taller than girls, whereas after puberty the difference is quite marked (on average 13 cm).

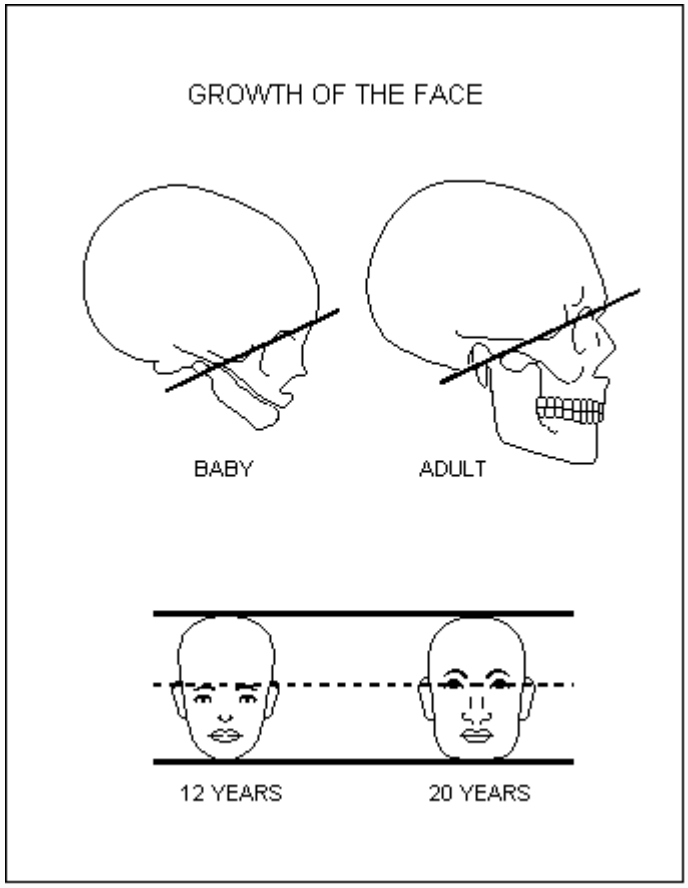


The difference in height between the genders is chiefly the result of the extra length of the legs in men - the sitting heights of men and women are approximately the same.

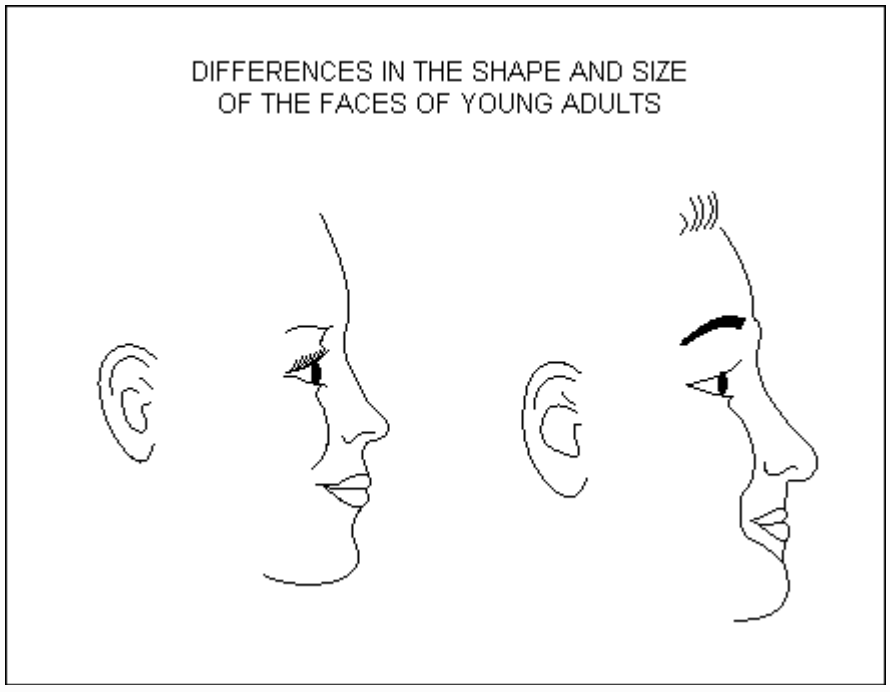


At puberty the shoulders and muscles grow more in boys than they do in girls, and a marked difference in muscular strength develops. The most prominent differences however concern the distribution of subcutaneous fat, particularly in the form of breasts that enable persons to distinguish the genders in adulthood.

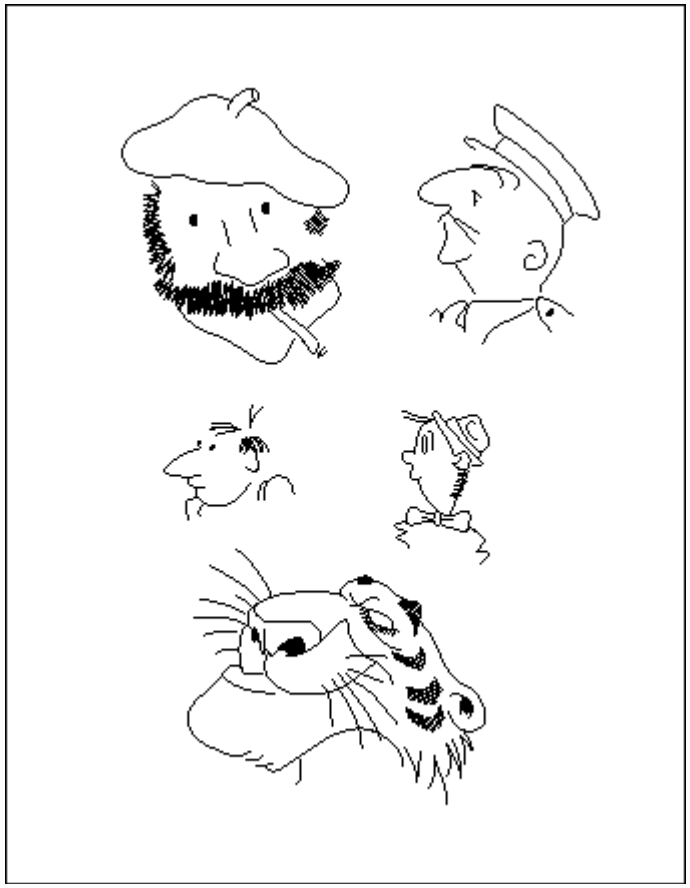
The part of the body that also prominently displays the young post-pubertal person's gender is the face. During puberty the face undergoes a growth spurt in both genders. It affects the face, but not the cranium (housing the brain), which is already at almost at its adult size at the age of 5 years.

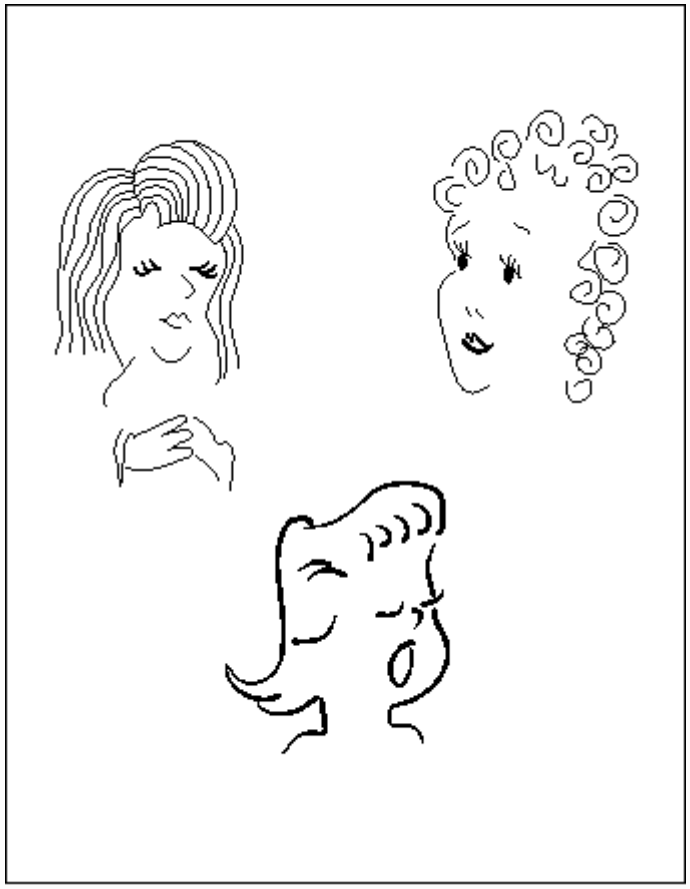


The pubertal growth spurt of the face is more marked in boys than it is in girls. Boys therefore have noticeably larger noses than their female counterparts; their sinuses are bigger, giving them bigger brows and more prominent boney cheeks than the young woman. Their mandibles are generally larger than those of the young woman.



These differences in facial structure of the young man and woman are used by cartoonists to economically caricaturise the gender differences between young adults.



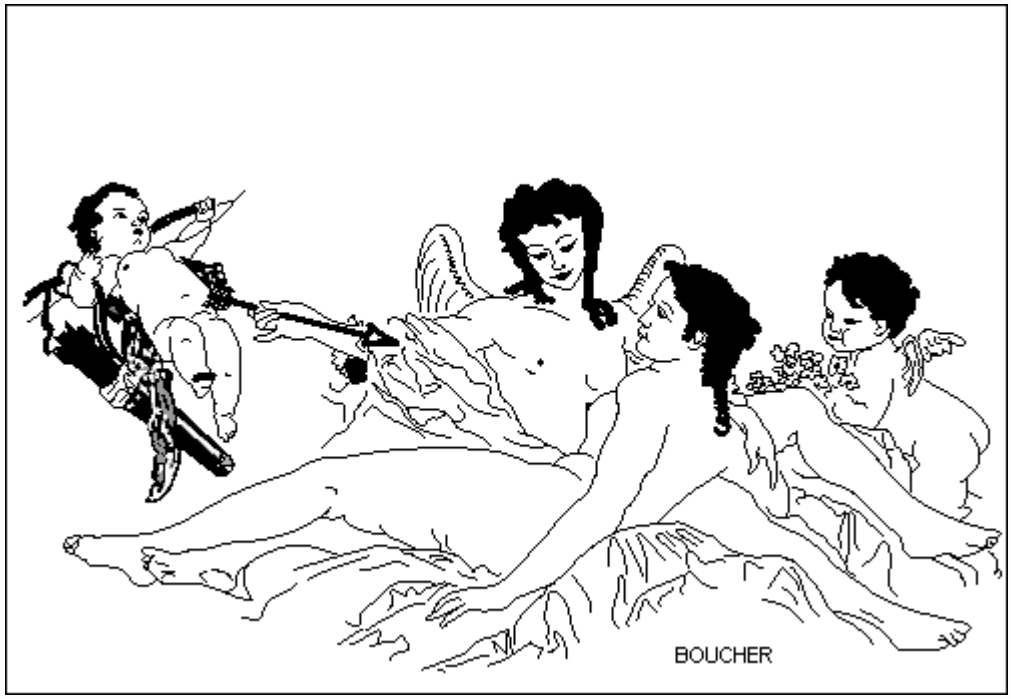


Note that the young woman is always drawn with a very small or even absent nose (compared with

the very large ones used to denote manhood); they always have prominent foreheads, which are absent in the cartoon men (men's faces are so large that they totally overshadow their craniums!). The relative small size of the brow in the young woman makes her eyelashes more prominent than they are in men. The cartoonist therefore always endows his young women with prominent eyelashes.

As a self-study exercise the reader is encouraged to use the information gleaned above to attempt to analyse the genders of the two characters depicted in the cartoon below. The correct answers will be e-mailed to you on request.

Note that, once again, there is enormous redundancy in the signals which indicate the person's gender. Thus, a man with a high pitched voice causes confusion only over the telephone, when none of the other signals about his gender are available to the other person. However, the various signals do have a hierarchy of importance. Thus a person with well developed breasts and a beard is known as a "woman with a beard" and not as a "man with breasts". Breasts therefore take priority over beards as a signal of gender.



What is the angel's gender in the above picture? The face is decidedly feminine, but the lack of breasts casts severe doubt on this diagnosis. The conflicting signals are very disturbing, but in most person's minds the absence of breasts would be the deciding factor.

Illustrations and website design by Ann Koeslag

From Womb to the Tomb

The Human Lifecycle
Part 10

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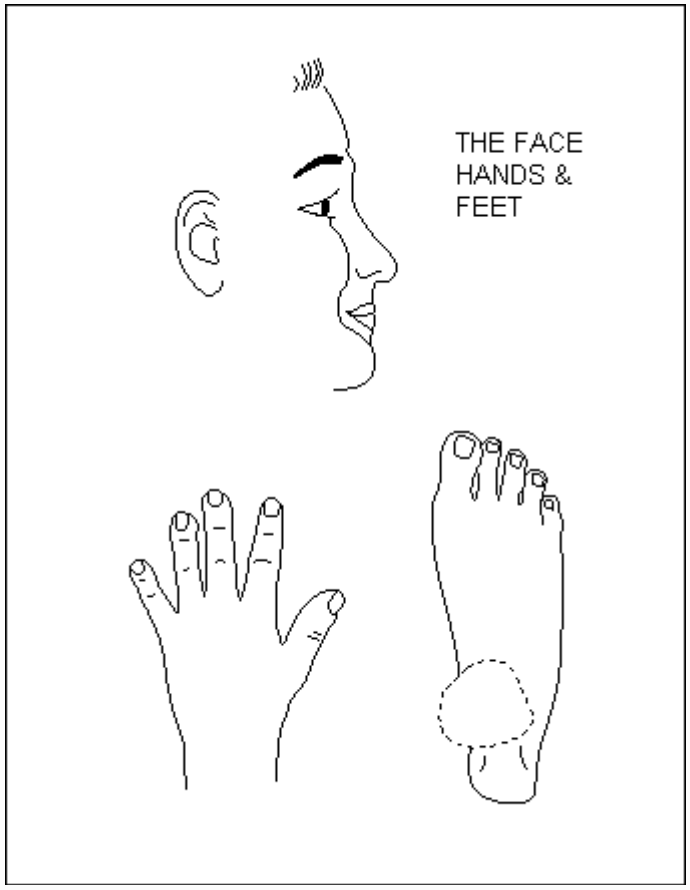
POST-ADOLESCENT GROWTH AND DEVELOPMENT

Growth, even of the skeleton, does not entirely cease at the end of the adolescent period. The limb bones stop growing in length, but the vertebral column continues to grow and be remodelled, increasing stature by, on average, just less than half a centimetre between the ages of 20 and 30

years (not generally noticeable in individual cases, but becomes evident when the average height of large numbers of young adults is measured). From 30 - 45 years there is little change in height, but after that it declines slightly (see: Fig. 112, Life Cycle, Part 11).

Bi-iliac diameter, chest depth, nose length, ear length, ear breadth, all increase throughout life, as do the face, hand and foot measurements.

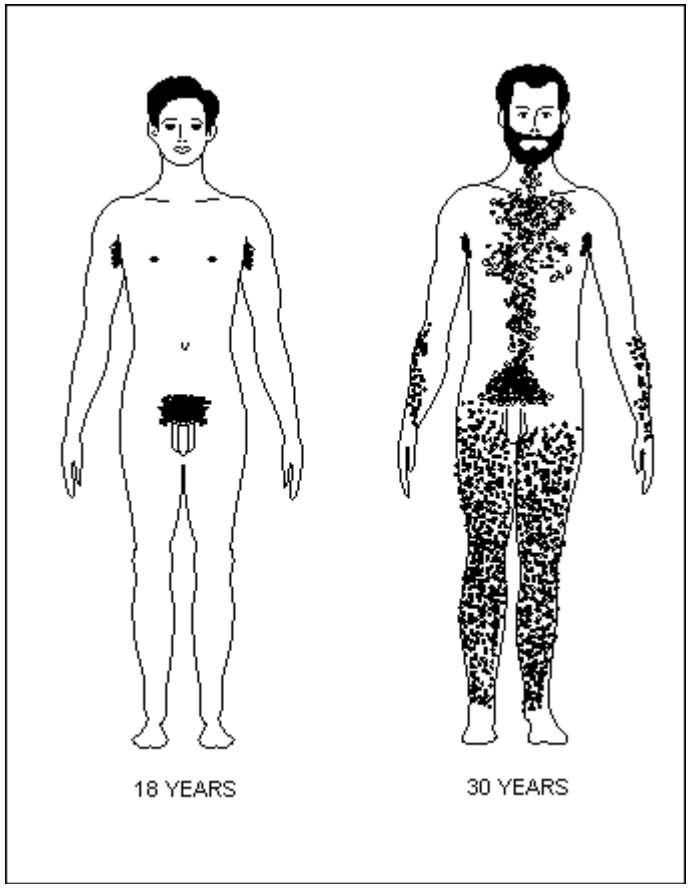
After puberty the face continues to grow slowly throughout life, and the nose and jaws become gradually more prominent. There is also widening of the bones of the hands and feet.



This is all an exaggeration of what had already occurred in boys during puberty, and has the effect of making the face and hands of men look more masculine and rugged. But it also occurs in women, obliterating the girlish facial complexion, and replacing it with more 'masculine' features. The result is that young boys can masquerade as young women (and vice versa) in plays and pantomimes, whereas adult men can usually only masquerade as older women (or vice versa, if they can hide the swelling of the breasts!).

But as some features of sexual dimorphism become less distinct, others take their place. Such is the case with body hair distribution. The woman retains the immediate post-pubertal hair distribution, adding only a little extra coarse hair growth to the outer aspects of the arms and on the legs, and especially on the inner aspects of the thighs.

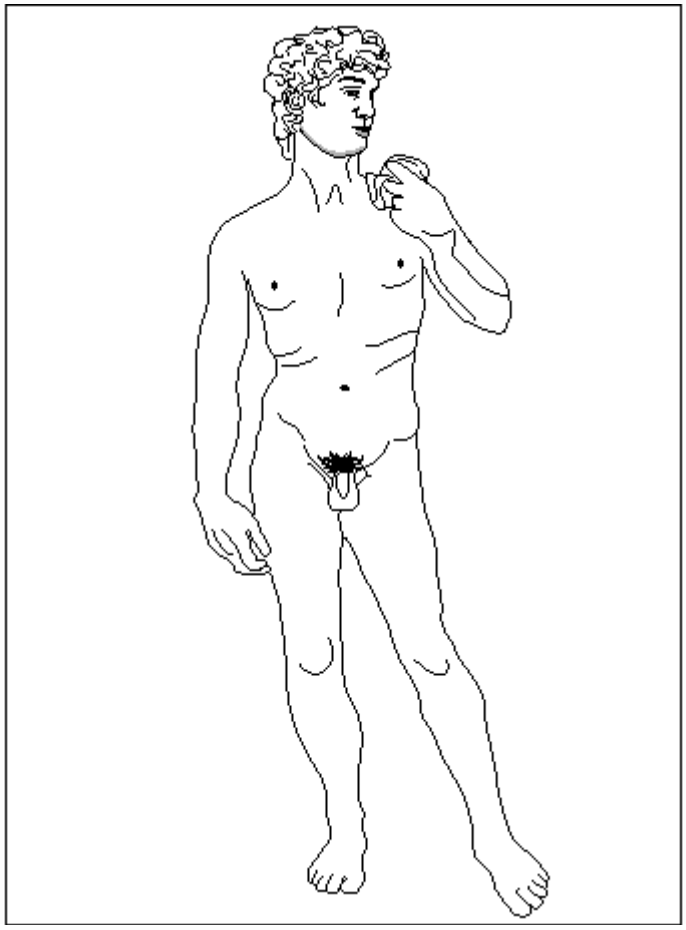
In men hair appears on the face late in the second half of puberty. It starts at the corners of the upper lips, and spreads over the moustache area. Then it appears in the side-burn areas and spreads to the chin, but may cover the entire beard area only well into the 20's. Body hair, on the chest the abdomen, starts to grow, on average, only during the 20's and may not be complete till the age of 30.



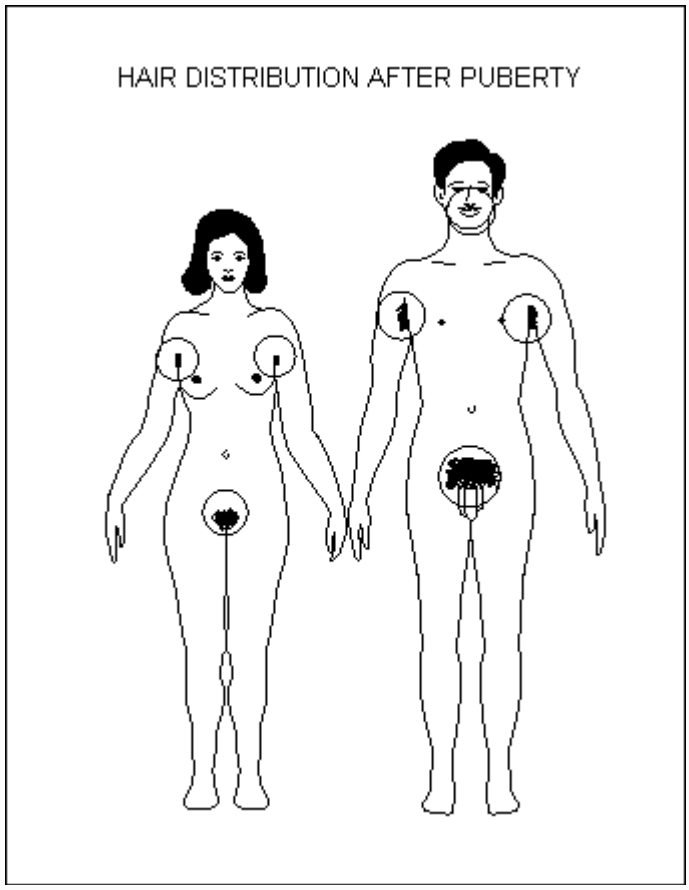
The facial features change. The young man already has already developed a large nose and prominent nasal sinuses during puberty, which enlarge further during adult life. The young woman, however, retains, for a long time, the relatively small face, nose, brow and other features of the child's face. But as she gets older these grow as they do in men, partially obliterating the differences in facial appearance of the young man and woman.

The voice changes rather abruptly in boys during puberty, giving him a characteristically deeper voice than that of a child or of a woman. The female voice also changes, but less dramatically and over a longer period of time.

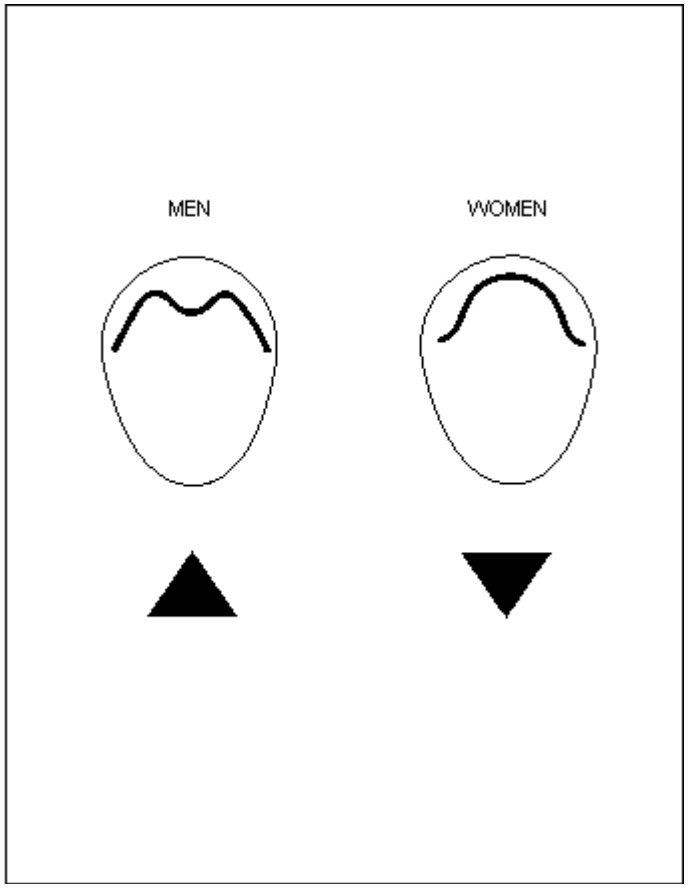
The most obvious, and most consistent difference between the sexes is however in the amount and distribution of subcutaneous fat (i.e. the shape of the fat organ). It is this feature, in particular, that serves to bring the genders together, and serves as a stimulus for sexual activity.



When fully developed, there are marked differences in the distribution of hair between the sexes, but at the end of puberty these differences are minimal if they exist at all.

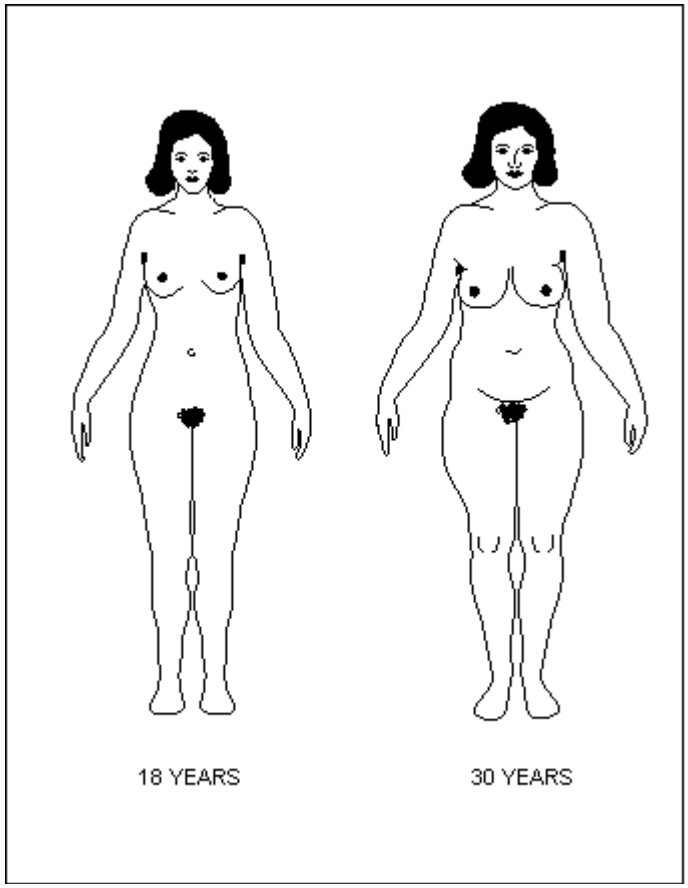


Temporal balding occurs as part of the male sexual dimorphism during the 20's, and may progress to complete balding on the top of the head later in life. At the same time abdominal hair growth converts the horizontal bar of pubic hair in the post-pubertal boy into the upright triangle of the adult man; while that of the adult woman is an inverted triangle (apex downwards).



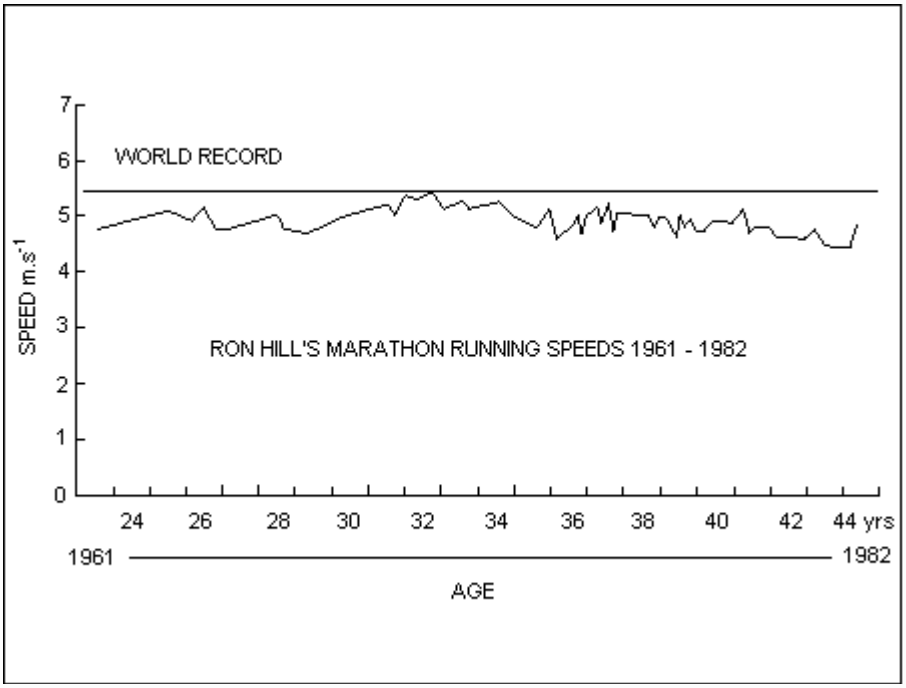
Fat on arms is fairly stable, but deposition of fat internally (in the abdomen) increases with age. Therefore with age their is an increase in abdominal girth.

In women it is the distribution of body fat that continues to change after puberty. It gradually increases in amount without interruption from before puberty till after 60 years. Thereafter it usually decreases again. The change in distribution alters the external body shape, and is responsible for the 'matronly figure', which in some cultures is highly valued, but which our culture - worshipping youthfulness as it does - despises!

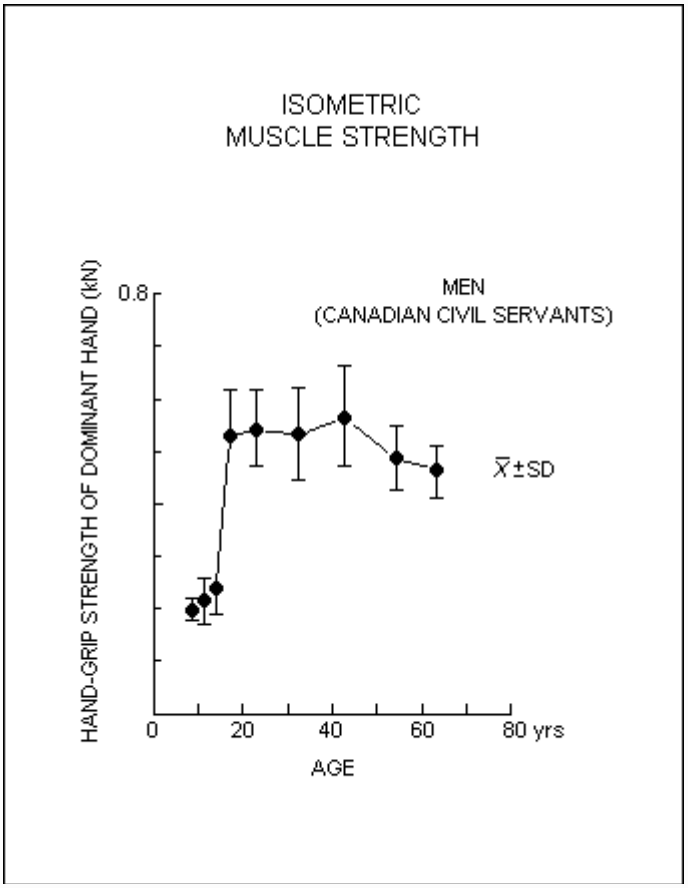


At puberty boys develop on average more muscle than girls, and there is a marked difference in the strength of men and women: but this does not remain static after puberty. Maximum speed of muscular contraction is attained almost as soon as the growth spurt is completed, or a little after.

Maximum muscular endurance is generally achieved at about 30 years of age.



Maximum muscle strength may not develop before the age of 50 years.



Weight lifting champions in the era before the use of anabolic steroids were generally at the peak of their careers at the age of 50 years or so.

Illustrations and website design by Ann Koeslag

The Human Lifecycle
Part 11

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AGEING

At each stage in life one reaches the "peak" for what has to be performed at that age:

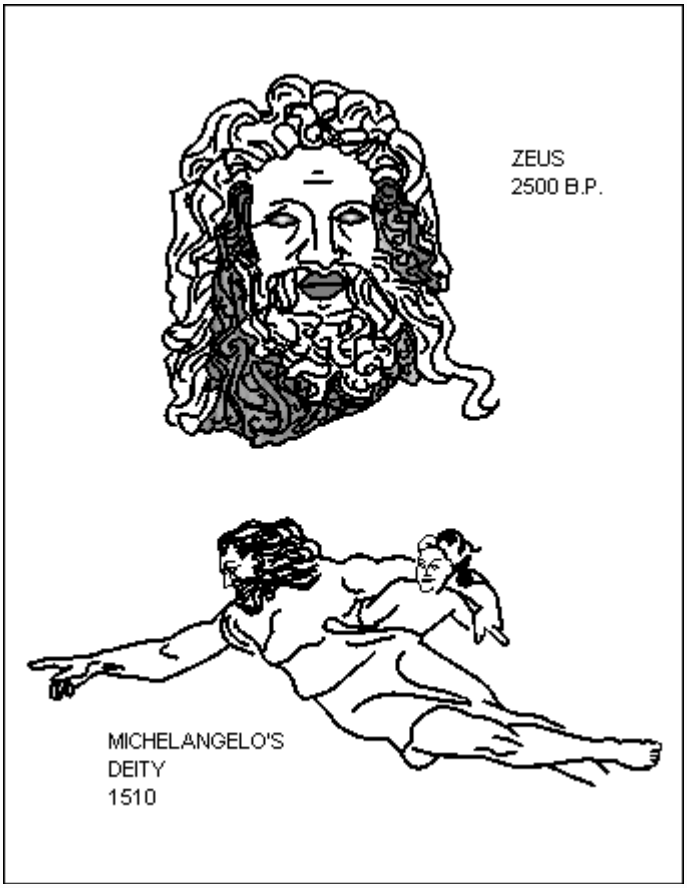
Between 2 - 5 years one reaches the peak of language acquisition ability.

Between 10 - 12 years peak assimilation of cultural traditions, prejudices etc, etc.

At 20 - 25 years peak sexual attractiveness. Also the peak for impulsiveness.

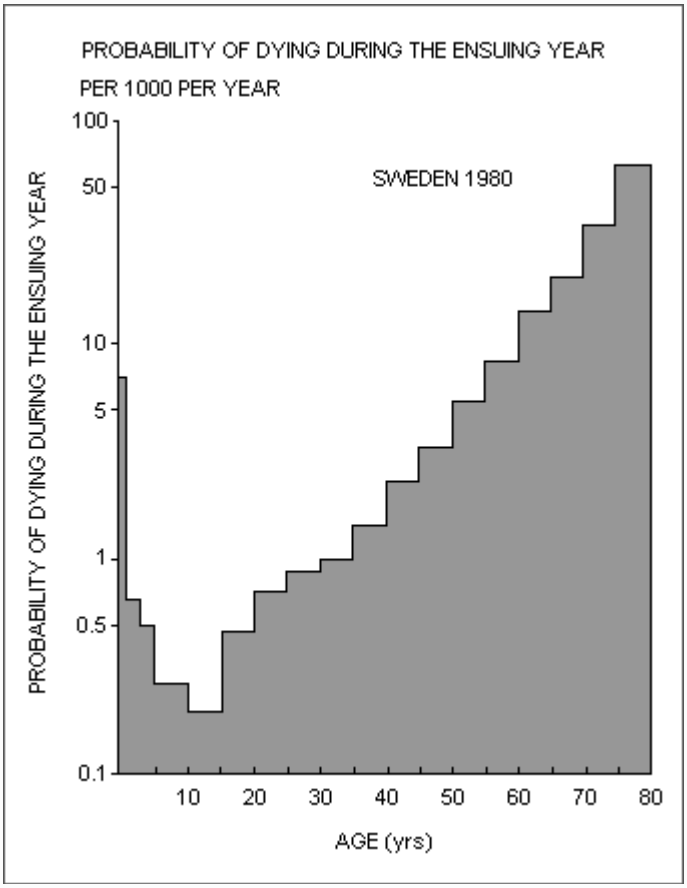
At 50 - 70 years peak leadership ability, ability to compromise. Things are not seen as black-and-white anymore.

Hence physical beauty in art is always depicted with the bodies of young men and women, but deities are always depicted as old men (with beards!).



At no stage in life does the human body remain static and unaltered. We have seen that there are very rapid and dramatic changes in body form during embryonic life. This is followed by growth and maturation during foetal and childhood life. There is another marked change in body size and form at puberty, at the end of which time growth in height ceases. But changes in body shape and outward appearance continue at a leisurely pace, and never cease till life ends at 'old age'.

There is no easy definition of old age. Most people would define it as the period of life when there is an ever increasing chance of dying in the next year. But by that criterion you commence life as an individual in old age because at no time is the chance of dying as great as during the embryonic period, when nearly Ÿ of the conceptions are lost. Compare this with the chance of dying at 85 years: 20 - 30% expected to die in the next year! In the past the chance of dying during the first year of post-natal life was about 20%, and therefore equal to the chance of dying at 85 years of age!



Notice that age-specific mortality is high immediately after birth and reaches its lowest point just before puberty. Thereafter it increases exponentially, doubling every 7 years. (On a semi-log plot as the one used above, an exponential increase becomes a straight line). This means that the average 21 year-old has twice the probability of dying before her next birthday than the average 14 year-old. At 28 years the probability of dying during the next year has increased 4-fold. At 35 years it is 8 times higher than at 14 years, and at 42 years it is 16 times higher. And so on.

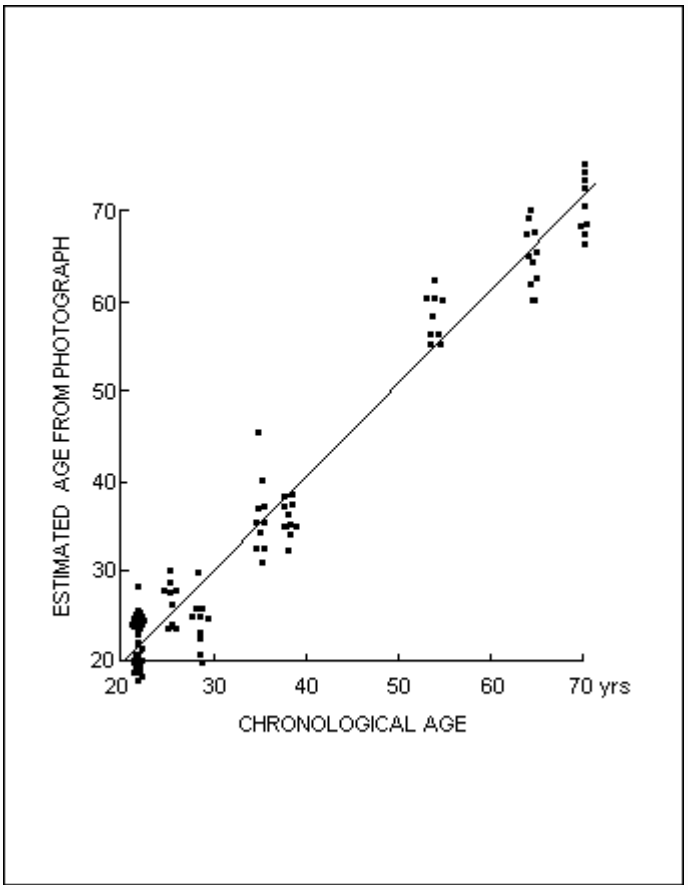
Perhaps the best definition of old age is simply that period of life when one develops the characteristic appearance of the most senior members of the species.

In species where both parents care for their young for much of their life, it is evident that pairing should occur predominantly between young adults. Age-related polymorphism would, in such cases, be expected to produce peak sexual attractiveness on reaching sexual maturity, after which it would be expected to decline fairly rapidly, despite, possibly, of increasing sexuality.

This is clearly the case in humans, where considerable changes in appearance continue to develop during adult life. Alterations in appearance are particularly prominent in the face. The increase in the size of the face, the nose, brow, and ears have already been mentioned. The large size of the nose is used extensively by cartoonists to depict older people.

The age related changes in appearance are obvious and standard enough that other people readily interpret the signals correctly. The following graph depicts the results of an experiment performed by some students who circulated photographs cut from magazines and newspaper articles among their class mates. The photographs were of people whose ages were mentioned in the legends to the magazine photographs. But these ages were omitted from the document circulated in the class. The class was asked to estimate the ages of the persons in the photographs. It can be seen that even from the static photographs of just the faces of the persons, the class was able to accurately

estimate the subjects' ages.

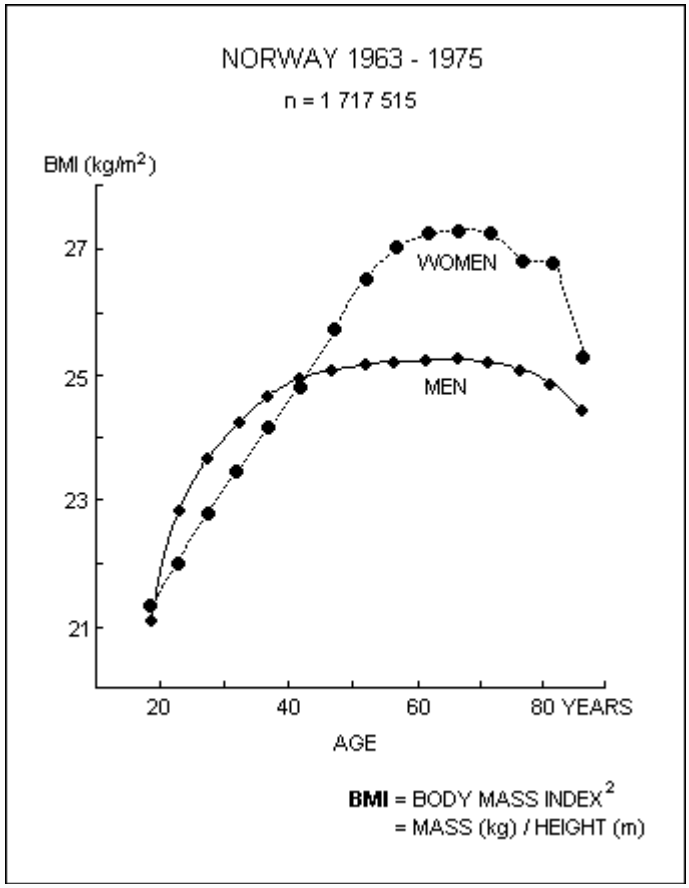


These signals are therefore not trivial, arbitrary or random. They are standard enough that other members of the species can accurately read the messages they are intended to convey.

The skin of the face grows faster than the skeletal structures, causing it to form loose folds and wrinkles. The sebaceous glands increase in size, giving the skin, in addition, a fine "peau d'orange" texture. Sebaceous hyperplasia also produces raised moles or warts (made famous by Cromwell when he was to have his portrait painted). Hair follicles appear on the ears (where they never occur in young people), and coarse hair replaces the finer growth on much of the face. Thus the eye brows become bristly, and the hair in the nose more prominent. In only a minority of races (mainly Caucasians, the descendants of the Barbarians) can men grow beards on reaching sexual maturity; in everyone else (particularly the Chinese and Japanese) the appearance of facial hair is a signal of advancing adulthood, and, in many cultures, increasing wisdom! In all races the pigmentation of the skin becomes uneven and blotchy with advancing age.

The hair of the scalp darkens gradually in fair-haired persons, before turning grey, and it does not grow as long as it did in early adulthood. Men develop varying degrees of scalp baldness, usually on attaining maximum hair growth elsewhere on their bodies.

Growth of skin and subcutaneous tissue, as well as continued periosteal apposition of bone increases the thickness of the fingers, hands and feet. There is also a slow steady increase in body weight (adipose tissue and muscle) during adulthood. The average 50 year-old is therefore, on average, 20% heavier than the average 20 year-old. This occurs in all communities, despite large differences in food intake, and physical activity.



These age-related features which include a considerable degree of redundancy, allows members of the species accurately to guess the age of their fellows.

Other changes which affect the person's appearance, are:

Loss of teeth, with consequent reduction in the size of the face.

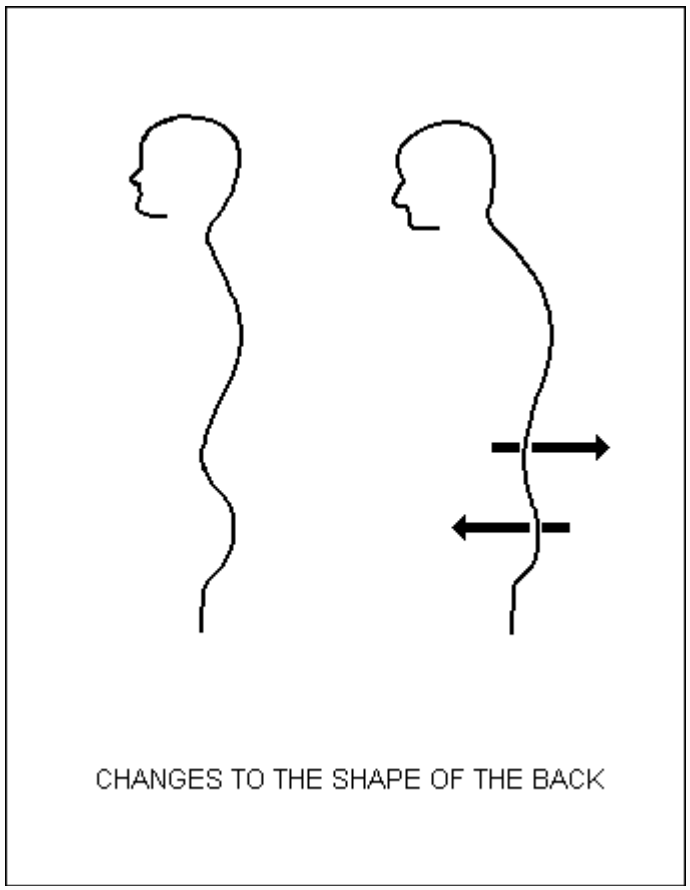
Thinning of the hair.

Greying of the hair.

Pigmented areas develop on the backs of the hands and on the forearms, called 'senile purpura'.

Flat warty lesions appear on the skin so that skin becomes increasingly blotchy (irregular pigment).

Flattening of the intervertebral discs, which causes loss of the lumbar lordosis, and therefore an accentuation of the thoracic kyphosis, and decrease in standing height. The loss of lumbar lordosis also pulls the sacrum into a more vertical position, causing the person to lose the prominent buttocks of the young adult.



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The Human Lifecycle
Part 12

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CAUSES OF AGEING AND DEATH

Ageing, or senescence is a phenomenon which has spawned many and varied theories, many of them facile and patently absurd. At the last count there were some 200 of these theories in the scientific literature!

Many of these theories revolve around the idea of 'wear and tear': the accumulation of mutations, or of toxins and oxidative damage in the cells, and therefore in errors of body function, be it of the

endocrine system or of the functioning of the heart or the kidneys.

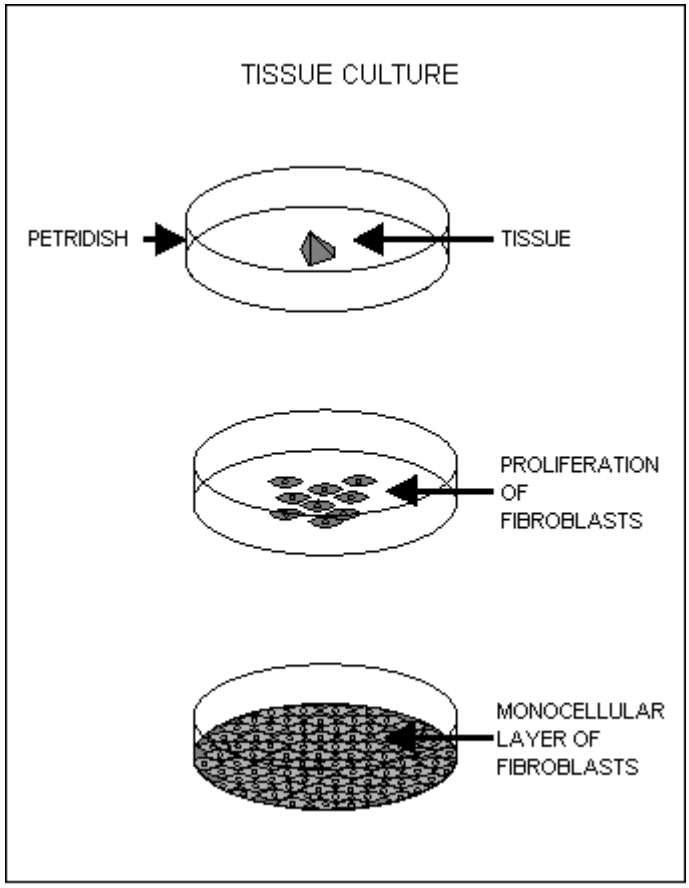
However, for a theory of ageing to have any value, even as a start for further investigation, it has to explain a number of important facts about ageing:

- 1. Different species have widely different and highly specific life-spans. And within a species the different genders or castes (e.g. in bees: queen, drones, workers) have highly characteristic life spans.
- 2. Babies are always born 'young', no matter what ages the parents are, or, for that matter, what generation since 'Eve' they are born. Certain cell lines within the body are therefore exempt from the ageing process.
- 3. Body materials, which show changes in composition with age, do not change because they rot or rust with age. The body actually keeps renewing all parts of the body right up to death. But it renews it with material which is characteristic for the age of the person. As Lansing once said: "The old organism does not contain old proteins, it always consists newly-formed proteins but they are of an 'old' character". Roughly speaking, the body's entire suite of proteins is replaced every 4-6 months. An old person is therefore as newly built as a new-born baby.

The inescapable conclusion is therefore that ageing, like puberty, or any other phase of growth and development, is genetically determined, with the environment, as always, playing a modulating role.

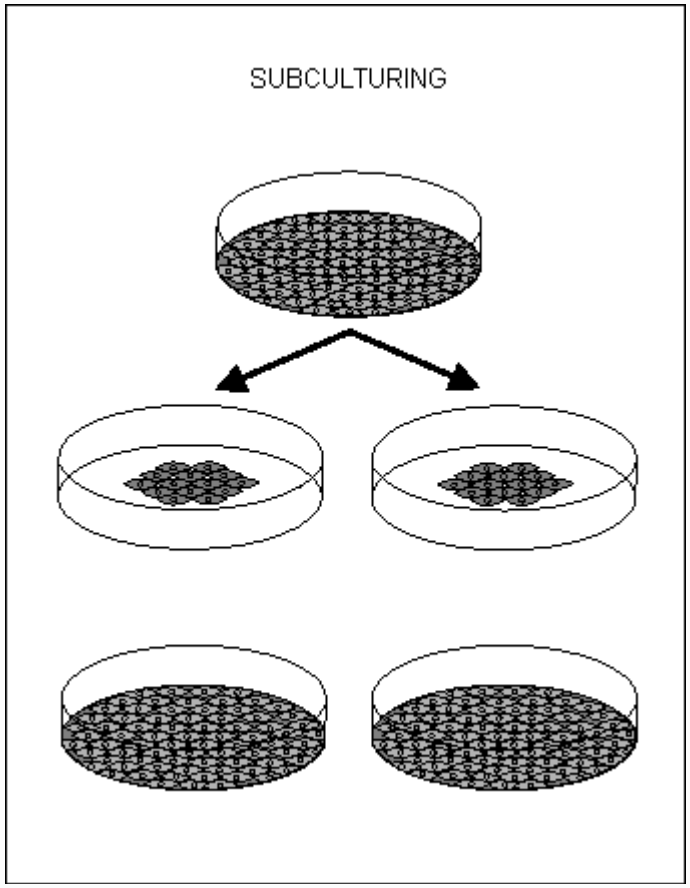
Before describing the discoveries which have convinced most scientists that ageing depends on an intrinsic programme, we must first describe how mammalian cells can be taken out of the body and can be made to grow in tissue culture bottles.

When small segments of embryonic or adult tissues are excised and placed in a Petri dish with nutrients, serum, oxygen and carbon dioxide, cells will grow out of the explant and start to multiply. Usually the dominant cell type is fibroblasts, but it is possible to grow other cell types in this way as well, though with some difficulty.



The cells that grow in this way will eventually cover the bottom of the dish. When that happens, their reproductive rate drops considerably until only enough cells are made to replace the few that die or fall off the dish. The result is that a monolayer of cells is dynamically maintained. The cells that are not reproducing are not dead, they are quiescent.

A small portion of these quiescent cells can be removed to a clean Petri dish with fresh medium, and immediately the cells will start multiplying again. This can then be repeated many times.



In the earlier part of the 20th century, Alexis Carrel (1873-1944), a noted cell culturist, described experiments purporting to show that fibroblast cells derived from a chick embryo heart could be cultured ad infinitum. The culture was voluntarily terminated after 34 years. This seemed to show that the ageing process is something that occurs at some super-cellular level, but that the cells themselves are immortal. Ageing, it seemed, was due to increasing disorganisation between cells.

The results of Carrel's experiments seemed to be borne out of the fact that there are now in existence cell cultures, derived from many tissues of a variety of animals which all show this striking ability to be able to replicate indefinitely. The best known of these cell lines are the HeLa cells derived from a human cervical carcinoma in 1952, and the L line cells derived from a mouse in 1943. They continue to flourish in laboratories around the world even to this day.

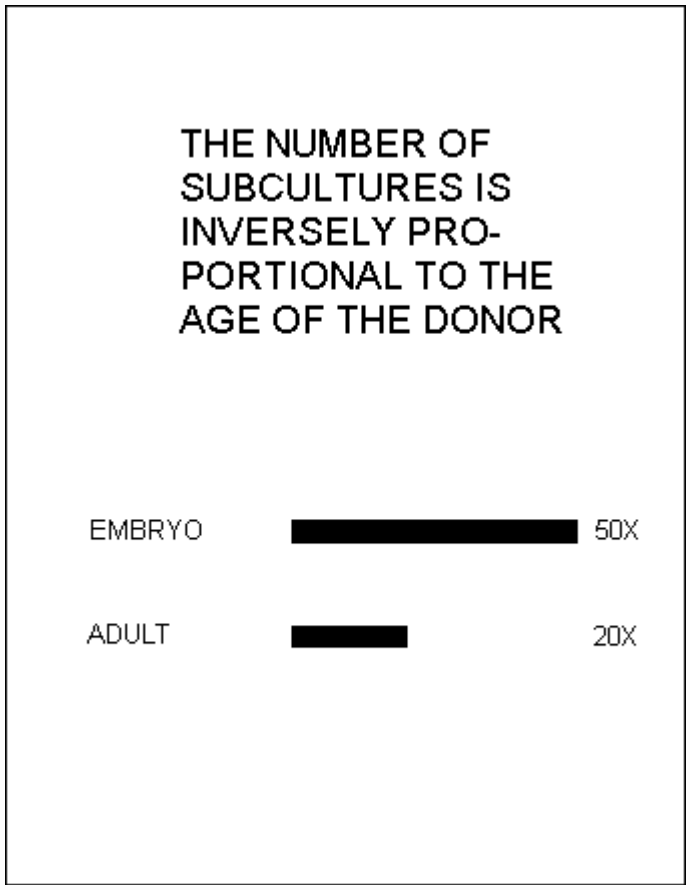
Of central importance to the question of ageing is whether these immortal cells are in fact normal. The HeLa cells are certainly not, being derived from cancer cells. The L line cells have an abnormal karyotype. It now appears that all these immortal cell lines are, in one way or the other, changed and different from normal cells.

The Hayflick phenomenon

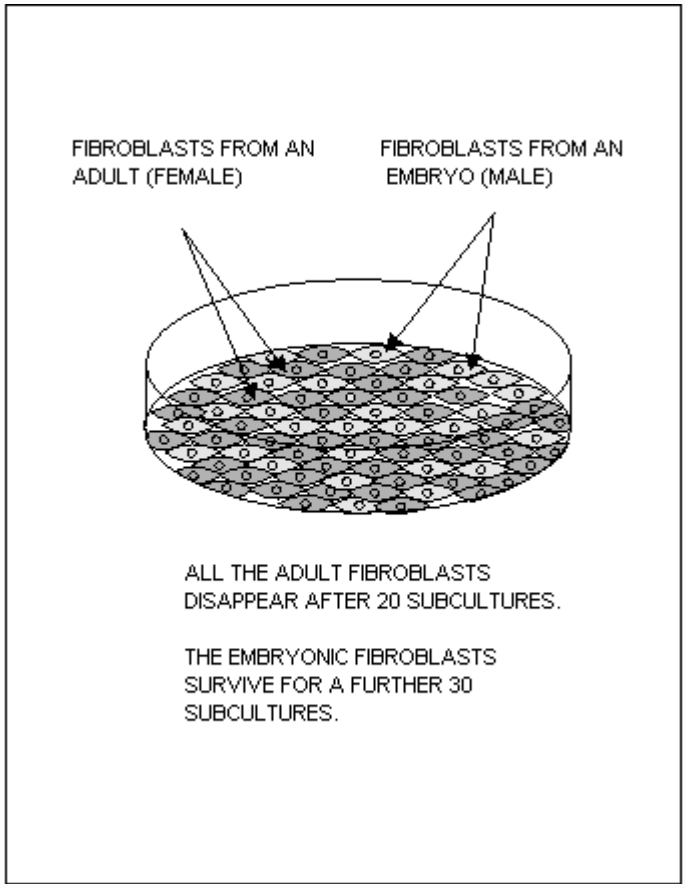
In 1960 Hayflick and Moorhead found that normal human embryo fibroblasts undergo a finite number of subcultivations (or population doublings) and then died. They demonstrated that under the most favourable conditions, death was inevitable after about 50 subcultures. This was not due to some trivial experimental blunder, since these results have now been confirmed in many

laboratories - normal cells can undergo so many phases of replication and then they die.

- 1. The remarkable thing is that the total number of subcultures is more or less constant for a particular cell type removed from a particular animal at a particular age.
- 2. Hayflick showed that the cells removed from old persons die after fewer subcultures than cells from an embryo.

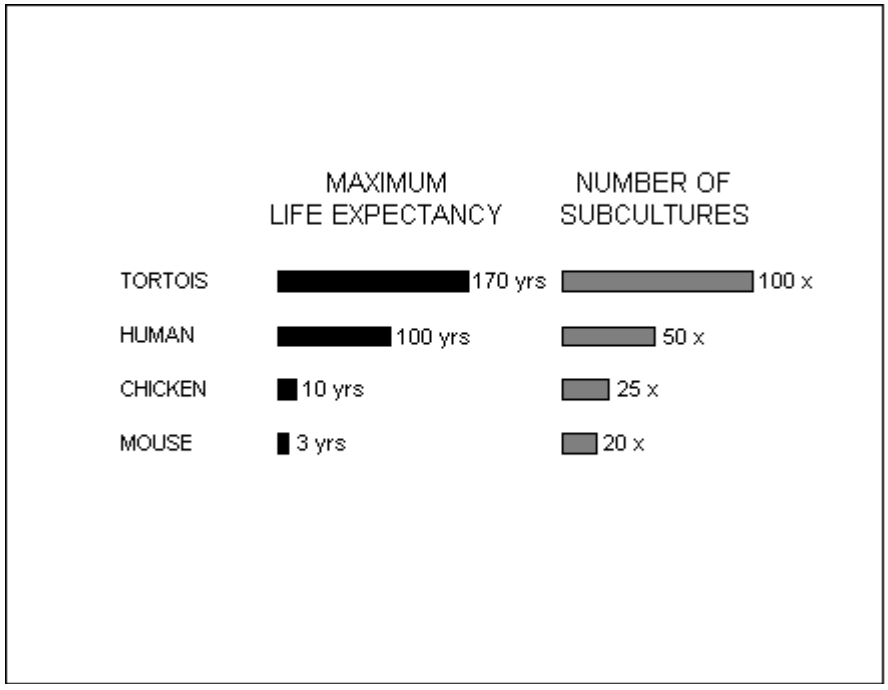


3. He showed that this was not just due to the methods of tissue culture, because when he mixed the cells from an older person with those from an embryo, the cells of the older person died out first, eventually leaving only embryonic cells which then underwent several additional subcultures before they died.

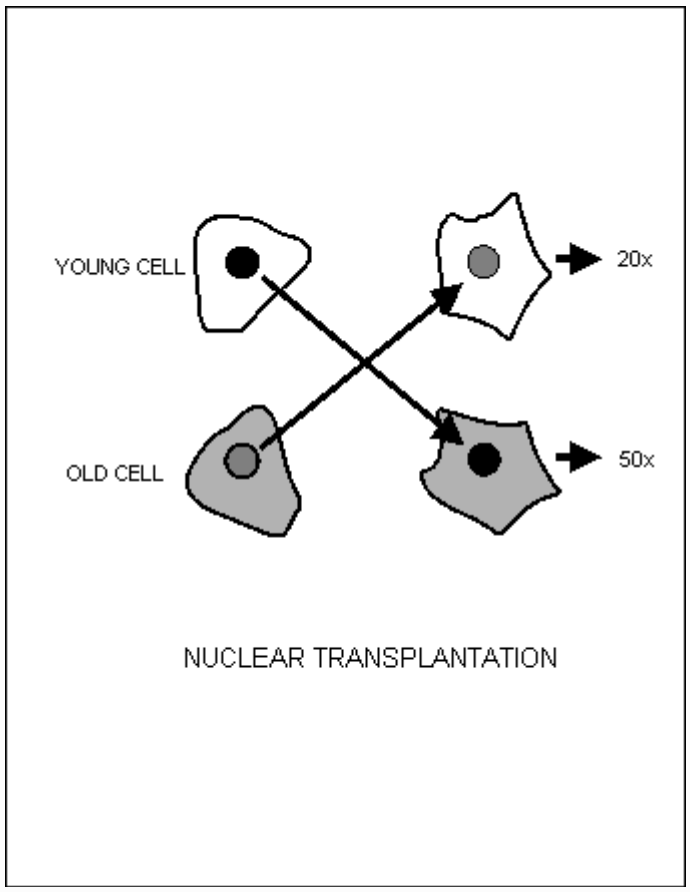


4. If the rate of subculturing is slowed down or arrested by sub-zero temperatures the culture lives longer; only to die after the characteristic 50 subcultures had occurred.

☐ 5. Embryonic fibroblasts from different species, with widely differing lifespans, showed that the number of subcultures which the cells can undergo is proportional to the life-span of the animal from the cells were taken.



6. The insertion of the nucleus from a cell that had undergone a large number of subcultures, into the cytoplast (enucleated cell) of a young cell, switches the subculturing capacity to the 'old' type, indicating that the ageing process occurs in the cell nucleus. Thus, if the a young nucleus is placed into an old cytoplast, the new cell has the subculturing capacity of a young cell.



Cancer cells are immune from this ageing process and will undergo subculturing indefinitely.

These results are intriguing, but they still leave us in some doubt as to whether this subculturing process is at the basis of animal ageing and life-span determination. Many cells in the adult body seldom or never divide (e.g. brain neurones, heart muscle cells etc.), yet there are undoubted ageing processes at work in these tissues. Also, there seem to be many more doublings available in fibroblasts than are required of them under normal circumstances in the adult body.

All that these experiments show us is that cells age, and that in the case of the fibroblast it is determined by the number of subcultures it has undergone. They also show us that the ageing programme and the 'death clock' are situated in the nucleus, where the cell's function is laid down in the DNA of the chromosomes.

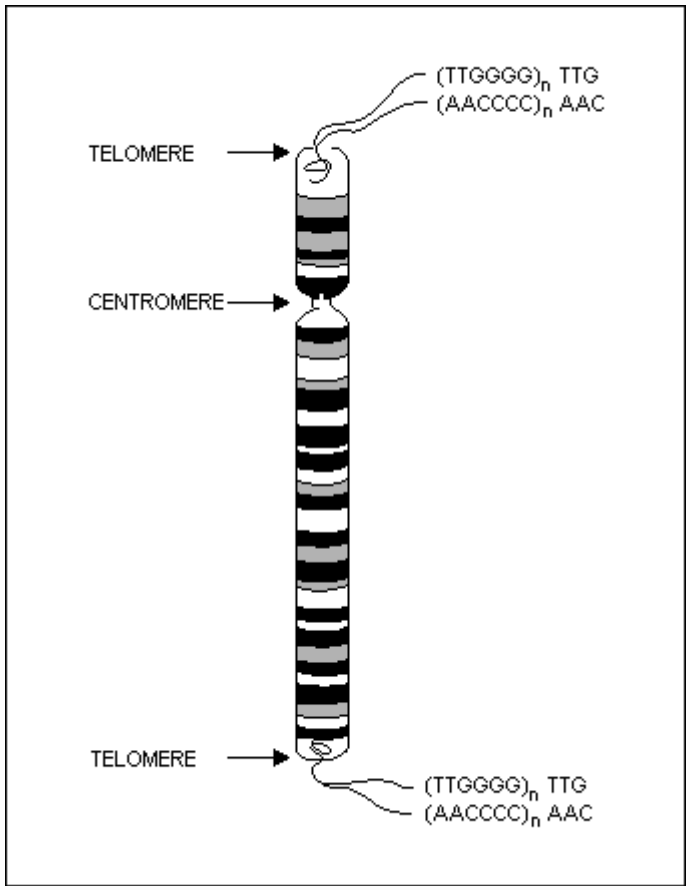
The cause of Alexis Carrel's mistaken conclusions appears to have been due to the medium he used to "feed" his cell cultures. He used filtered chicken meat extracts as his nutrient medium. Recent examination of the filters he used has revealed that they could easily have allowed fresh fibroblasts into the medium. He was therefore constantly reinnoculating his cultures with fresh fibroblasts!

Telomere shortening is associated with ageing in tissue culture

It has now been shown that Hayflick's death clock is closely associated with "telomere shortening" of the chromosomes. In metazoans each cell's DNA is arranged in a number of strands known as

chromosomes. This is different from the DNA in bacteria which forms rings. These DNA rings have no ends. Thus when bacterial DNA is replicated the DNA polymerase can attach itself anywhere on the ring and simply work its way round. When it reaches its starting point again it will have made a copy of the entire DNA ring. Not so when the DNA is in strands with ends. DNA polymerase can only attach itself, and start copying, some distance from the end of a DNA strand. The ends are therefore not copied. Copies of copies of metazoan DNA therefore become progressively shorter and shorter.

To deal with this problem the chromosomes of metazoans are capped with long nonsense sequences of DNA at both ends. These nonsense sequences at the ends of chromosomes are called telomeres. The shortening of the DNA with each replication now, therefore, means loss of only a portion of nonsense DNA. The coding portions at the ends of the chromosomes are thus protected from erosion (during replication) by these long non-coding additions to the ends of the DNA strands.



Obviously, since the telomeres are not infinitely long, a stage will be reached when they have been completely eroded away by repeated replications. It is at this stage that cultured cells refuse to undergo further subculturing, and die. The Hayflick phenomenon is therefore directly linked to telomere shortening.

Cancer cells and germ cell lines possess the enzyme telomerase. This adds nonsense sequences to the ends of chromosomes after each DNA replication. In these cell lines the telomeres therefore do not shorten with each cell division, with the result that these tissues are immortal. When normal cells are manipulated so that they express (i.e. make) telomerase, then they also do not age or die after a given number of replications. Then they too are immortal.

Telomere shortening is presently believed to be at the root of cell ageing, and programmed death.

Programmed cell death, or apoptosis

The death of cells and the destruction of tissues and organs is not the prerogative of old age, it occurs at all stages of development. During embryonic development several organs are formed which are later discarded.

The most obvious examples are the:

foetal membranes, umbilical cord and placenta.

the female genital organs in the male embryo.

the webs between the fingers of the developing embryonic hand.

the embryonic tail in humans.

the tail and gills in the tadpole.

the pro- and mesonephros in mammals.

and in postnatal development:

the thymus, tonsils etc.

the deciduous teeth.

and in the adult

the cells lining the gut.

the epithelial cells of the skin.

red blood cells.

white blood cells.

sperms.

These are all cells which have a limited life span in comparison with the animal as a whole. Their function is to die within a short space of time.

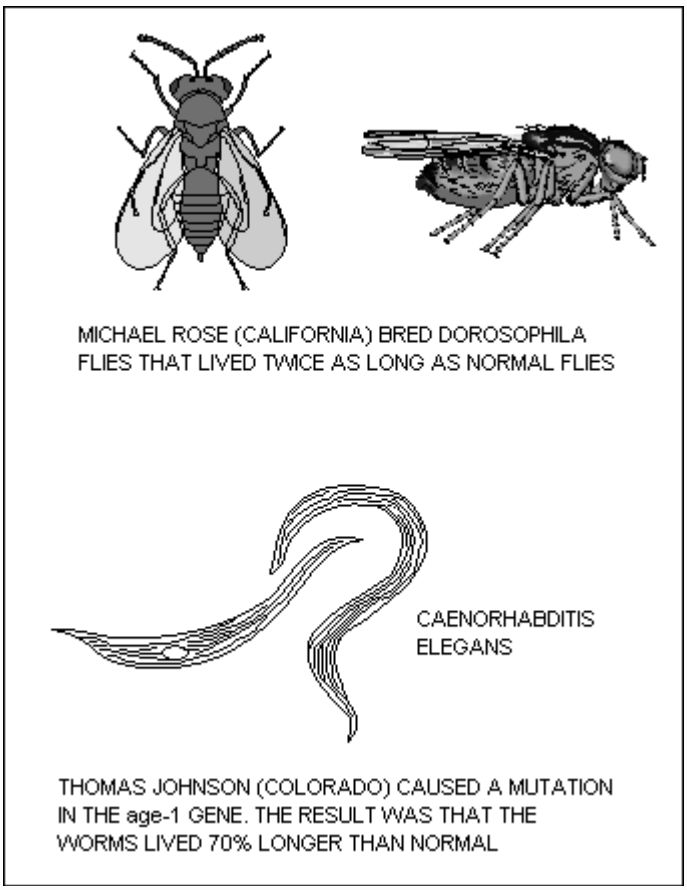
Thus cell death is part of development and normal adult life. "Death clocks" must function on time for normal body form and function. If they do not, then, especially in the case of epithelium, the immortal cells form a cancer!

Thus while cell death serves some very clear and obvious functions in a normal body, no one knows

the evolutionary origin or purpose of ageing in the individual. It occurs only in metazoans. It could simply be an inevitable consequence of multicellularity (i.e. the production of a massive asexual clone from a single ovum), or of possessing chromosomal DNA (instead of bacterial ring DNA molecules), or of any of the other features which distinguish the eukaryotes from the prokaryotes. Or it may serve an as yet not understood "function" shaped by natural selection.

Further support for the genetic theory of ageing and death

Michael Rose of California was able to breed a population of fruit flies (Drosophila sp.) that lived, on average, twice as long as normal fruit flies. By letting only long-lived flies breed Michael Rose was able to select for this feature to produce an entire population long-lived flies. Since long-lived flies were therefore able to pass this characteristic on to their offspring, longevity must be coded for in the DNA.



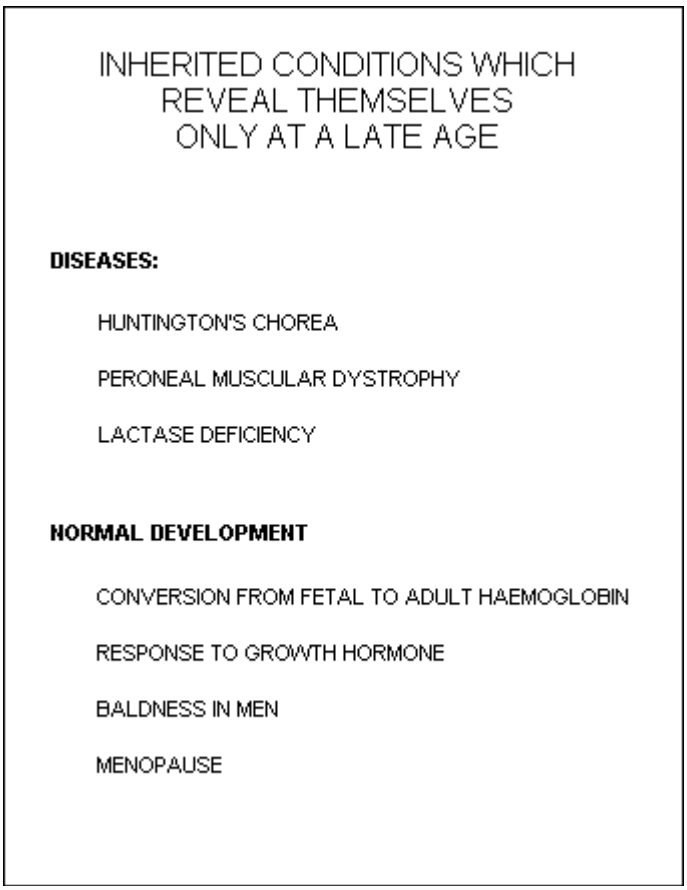
Thomas Johnson disabled a gene, with unknown function, in the worm Caenorhabditis elegans in a bid to discover its function. To his surprise the worms who inherited this disabled gene lived 70% longer than normal worms. He had therefore discovered a gene that is intimately involved in the ageing process. He therefore called it the age-1 gene.

From these experiments and those of Hayflick and Gurdon (below) it is therefore obvious that the metazoan life cycle is akin to playing a video. Different parts of the DNA are read off at different stages of the life cycle (and, of course, in different parts of the metazoan body). It should therefore not be surprising that inherited conditions are not always evident at birth, even though the baby already possesses the abnormal gene. In many cases the baby and child are perfectly normal, but then during adolescence, say, the abnormality becomes evident. Peroneal muscular dystrophy

(Charcot-Marie-Tooth disease) is an example. The disease is caused by a mutation in a gene for the manufacture of gap junctions in the Schwann cells that form the myelin sheaths round peripheral axons. How gap junction are involved in normal myelinisation is not known. But in peroneal muscular dystrophy the child manufactures perfectly normal and healthy myelin round its nerve fibres, but during puberty obviously switches to another gene in order to make the appropriate gap junctions. But the gene that is then switched on in peroneal muscular dystrophy is defective, and produces the symptoms of this disturbing condition.

In Maturity Onset Diabetes of the Young (MODY) the diabetes is caused by inherited defects in the glucose metabolism of the beta cells of the pancreas. But these persons are perfectly healthy during childhood and adolescence, developing the symptoms of diabetes only in early adult life. Once again, the question arises: what genes were they using during childhood, and why do they switch to other genes (which, in their case, are defective) during early adulthood?

Huntingdon's chorea illustrates the same principle. Here the person enjoys perfectly normal brain function till about the age of 40 years, and then obviously switches on a gene, not used before, which, since it is defective, now suddenly produces dementia.



It is not known why different genes are used, apparently for the same basic purpose (e.g. the production of gap junctions) at different stages of the life cycle. In the case of haemoglobin it is obvious. The foetus clearly needs to produce a haemoglobin that is different from the one needed after birth, when the lungs start aerating the blood. But why switch to a hitherto unused gene to produce a different brain protein at the age of 40 years than the one used up until that time?

However, if such switchings to new parts of the DNA life cycle programme are a "necessity" in metazoans, then it is also imperative that each new physiology caused by this "paging through the DNA book", as it were, be signalled to other members of the species. This has, of course, been the

major theme of these essays.

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Part 13

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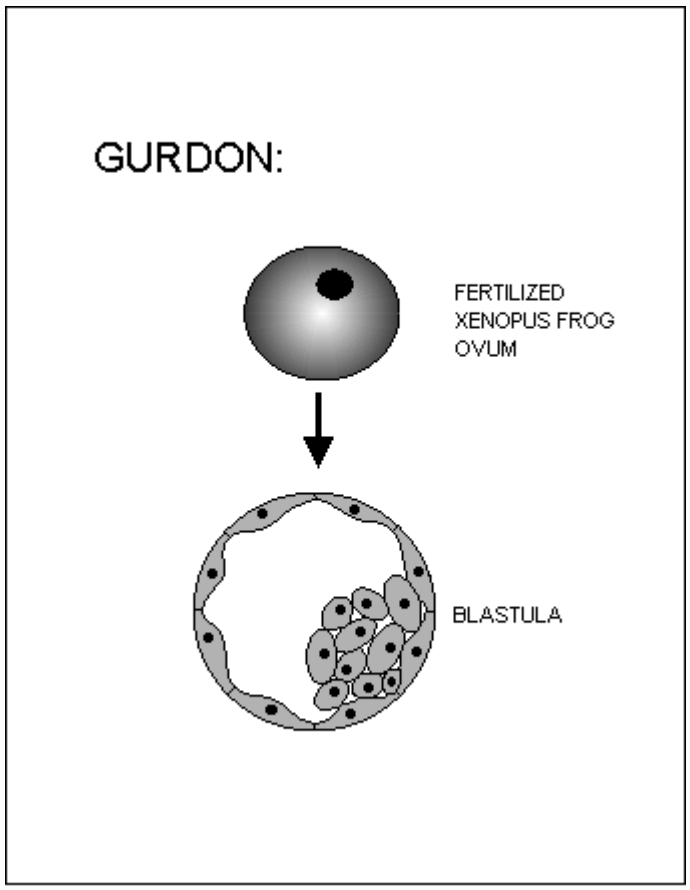
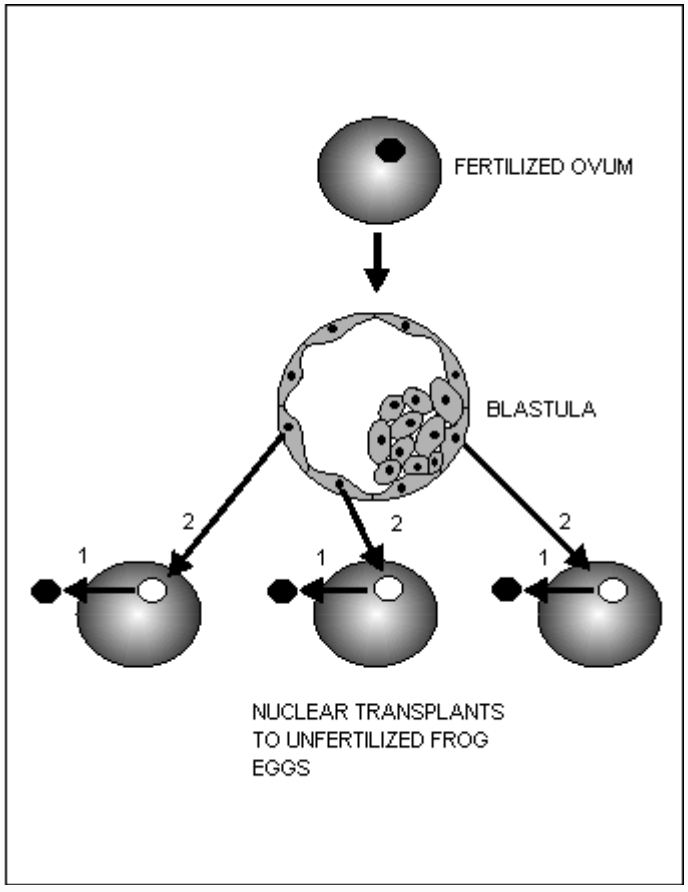
CLONING INDIVIDUALS

This brings us to another set of key experiments. The cells of our bodies all contain the 23 pairs of chromosomes which are established at the moment of conception. Apart from telomere shortening, these chromosomes do not change in appearance as the person gets older, or as they are spread to the different tissues of the body during embryonic development. Yet the cells of the different tissues have vastly different functions, appearances, and capacities to multiply. They are, for all intents and purposes, cells with different genetic blue prints, and, if you did not know better, you would say that they could quite easily have different sets of chromosomes.

This question intrigued J.B. Gurdon at the University of Oxford in the 1960's, who performed the following experiments:

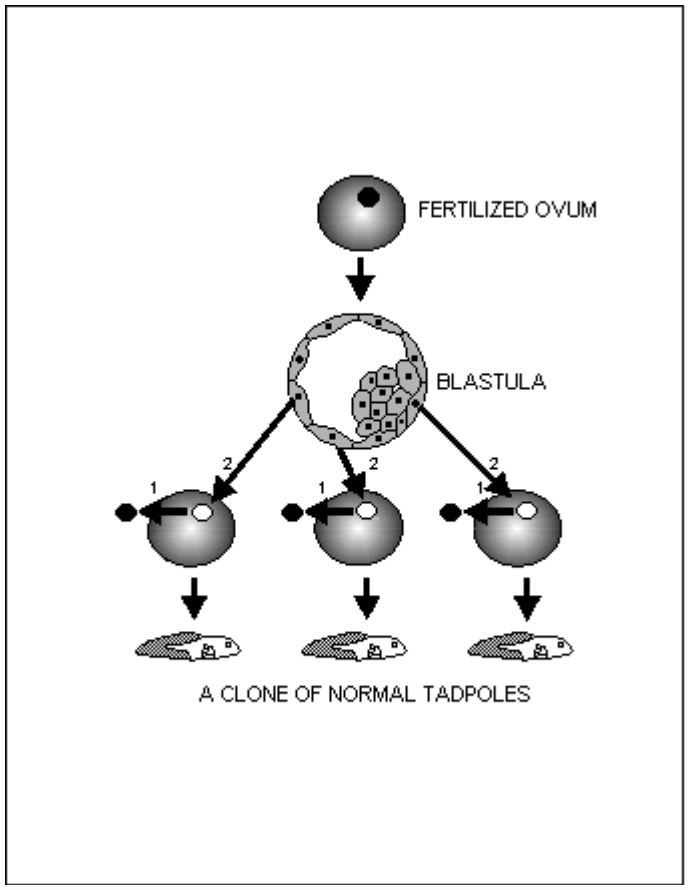
Like Hayflick, he created cytoplasts out of unfertilised frog's eggs, by removing their nuclei. Into these cytoplasts he then transplanted the nuclei from various embryonic tadpole tissues, to form 'transplant zygotes'.





The transplant zygote would start to divide, but the end result of this multiplication depended on

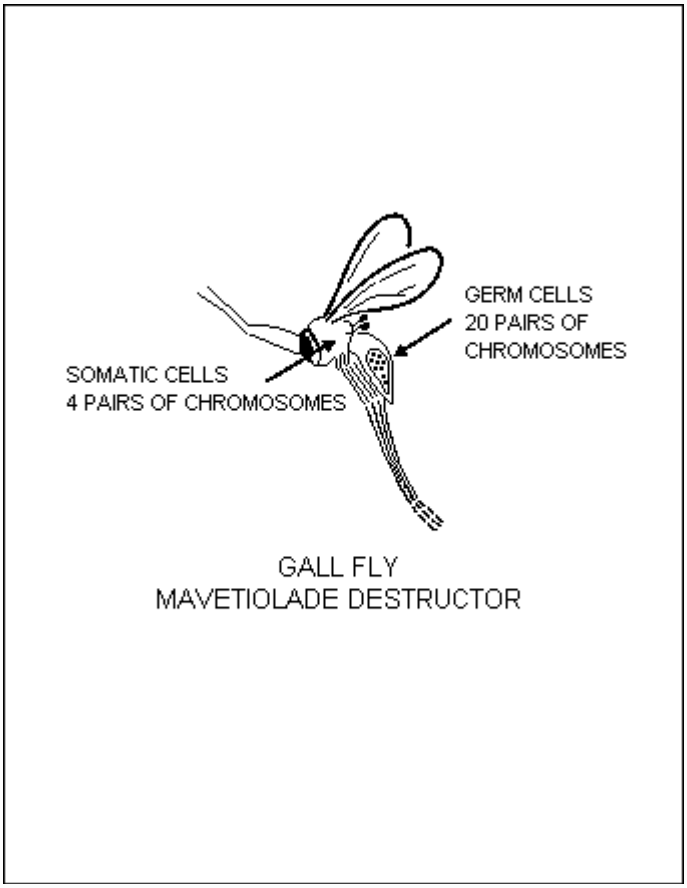
the stage of development which the donor embryo had reached. Thus, if the donor was a blastula all the transplant zygotes developed into normal tadpoles.



Gurdon spent many years trying to discover a way of circumventing this phenomenon, but no matter what manoeuvres he applied, the nuclei from more developed embryos could never be persuaded to direct the development of an egg into a normal tadpole. It was as if the DNA had been chemically altered during the process of embryonic tissue differentiation. A cell nucleus that had undergone a certain number of cell divisions in a specific location in the embryo became more and more committed to become a liver cell or a brain cell or a skin cell etc. It lost the youthful characteristic of being able to direct normal embryonic development from the egg stage.

These experiments also show that the cytoplasmic environment of the nucleus determines which part of the developmental programme is switched on, if it can still be switched on. The nuclei of early embryonic endodermic cells, which are clearly destined, under normal circumstances, to become cells which line the gut, revert to the egg nucleus stage when placed in an egg cytoplast, and will differentiate into all the tissues of a normal tadpole. Clearly this instruction must come from the cytoplasm, as that is the only thing that is changed during the nuclear transplantation. Even when a nucleus from a more developed embryo is inserted into an egg cytoplast, it behaves differently from what it would have done in the donor embryo. Proteins are produced which are only produced in egg cells, and the cell divides fairly normally at first, and quite unlike the way the donor cell would have done. Only later does the cell division become chaotic, indicating that the nucleus has lost its ability to direct normal embryogenesis.

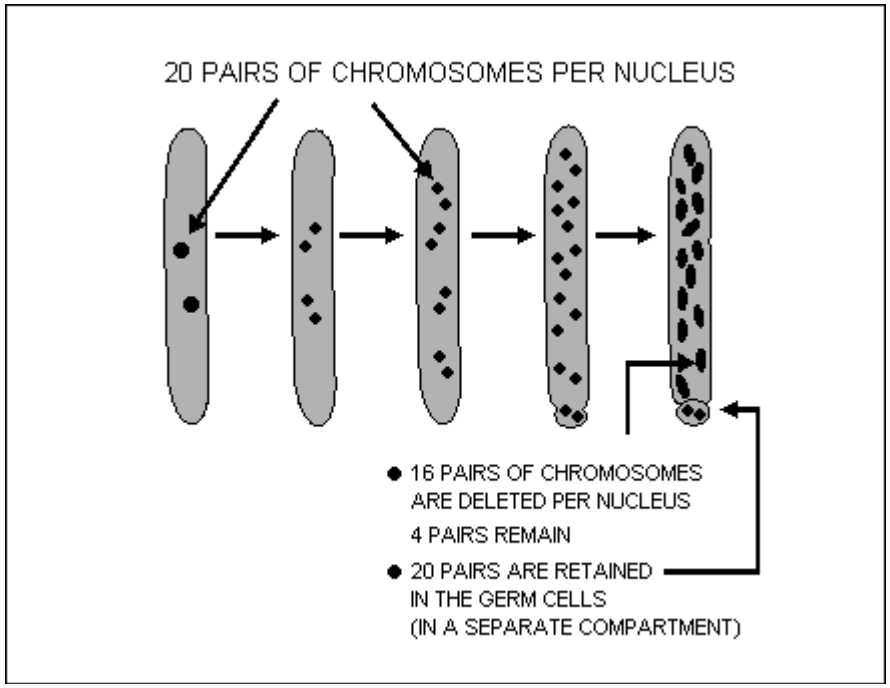
Thus, although the chromosomes appear normal under the microscope, chemically there must be dramatic changes to their DNA structure. That development is in fact associated with genetic change is seen in an insect: the gall midge (Mayetiola destructor).



The adult gall midge has only 4 pairs of chromosomes in its somatic cells, but 20 pairs in its germ cells.

After fertilisation the zygote has 20 pairs of chromosomes, which it gets from the union of 2 mature germ cells (each of which contained only one of each pair of chromosomes in their nuclei).

The zygote's nucleus then starts to divide into 2, 4 and then 8, but no cell walls are formed, so that the nuclei, each still with a full complement of 20 pairs of chromosomes, lie scattered evenly throughout the cytoplasm of the cell.



At the 8 nuclei stage one nucleus migrates to the lower pole of the egg, where a specialised type of cytoplasm has accumulated (the germ plasma - although no one knows exactly how it differs from the cytoplasm in the rest of the cell). The first cell wall now forms cutting this nucleus off from the rest.

During the 5th nuclear division the nuclei in the main chamber all undergo a very peculiar division in which all but 4 pairs of chromosomes survive. The rest just dissolve and disappear. The genetic programme which they contained is obviously no longer needed, and, in the gall midge, it is physically deleted.

In the germ cell, however, the nucleus divides normally and retains its 20 pairs of chromosomes which will form the basis for the development of the next generation.

The somatic cells, on the other hand, have undergone an irrevocable genetic change, which will lead them along the path of differentiation and development and ultimately to senescence and death. The germ cells do not differentiate, but retain their totipotentiality and also their immortality.

Here then is dramatically illustrated the way in which the genetic programme can be read off only in one direction, with only minimal scope for backtracking. Once cells are set on a course of development they will also age and eventually die. The gall midge displays a specially dramatic example of genetic change with increasing cell specialisation. But in mammals too there are instances of DNA deletions during somatic cell differentiation. Mammalian red blood cells loose their entire nucleus on reaching maturity, as do skin epithelial cells. In both cases the cells end up being little more than bags full of haemoglobin in the one case, and bags full of keratin in the other. A more dramatic form of "genetic change" cannot be imagined.

Vertebrates do, however, modify their DNA in more subtle ways during their progression through the life cycle. This is best understood in lymphocytes where a considerable amount of DNA shuffling, alteration and deletion occurs during the course of generating the genetic diversity which accounts for the staggering variety of antibodies and T-cell receptors that are made during an individual's life time. Once a lymphocyte has rearranged and altered the DNA responsible for its particular antibody

production, those changes are irreversible.

If lymphocytes can alter their DNA at will, as it were, it is not at all unlikely that other somatic cells do the same, and will never be able to support embryogenesis again. Possibly the only cells that retain the germ-line DNA are the germ cells themselves and various varieties of "stem cells", which are now recognised as being far more totipotential than they were thought to be previously.

Thus, during the past decade a group of experimental biologist in Scotland eventually achieved what Gurdon had tried to achieve, but never succeeded. They managed to clone a sheep, using a nucleus obtained from an adult sheep's udder. The nucleus was transplanted into a sheep egg cytoplast, and "Dolly", an apparently normal lamb, was born several months later. (The lamb was named "Dolly" after Dolly Parton, since both owe their fame to mammary tissue!)

The precise reason why the Scottish group was successful where Gurdon was unsuccessful, is not known. Possibly they unwittingly used a 'stem cell' from the udder of the sheep. The experimenters cultured the large number of mammary gland cells, and then starved them to the point that they could no longer divide. It was hoped that in this way all the cells would be in the same resting stage of the cell cycle. Out of the many hundreds of nuclei that were then transplanted into egg cytoplasts, only one developed normally, and eventually produced Dolly.

This experiment has now been repeated in other species, indicating that the DNA of adult metazoans is not always altered in a completely irreversible manner, but can, under very rare and special circumstances, be changed back to the form it had been in the egg. The nature of the alterations to the DNA during development (except in cells of the immune system, and in red blood cells), and how they are reversed by the manipulations of the experimenters, is still unclear.

It is interesting to note that Dolly had shorter telomeres on her chromosomes than she should have had for her age. She aged prematurely, developing a number of "degenerative" symptoms, for which she eventually had to be euthanased at a comparatively young age. (This indicates that it is not telomere shortening as such which prevents reversion of an adult nucleus to the totipotentiality of an egg nucleus, despite appearing to be associated with the ageing process of the animal as a whole, as well as with the ageing process in cultured cells.)

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THE CONTROL OF CELL DIFFERENTIATION AND PATTERN FORMATION

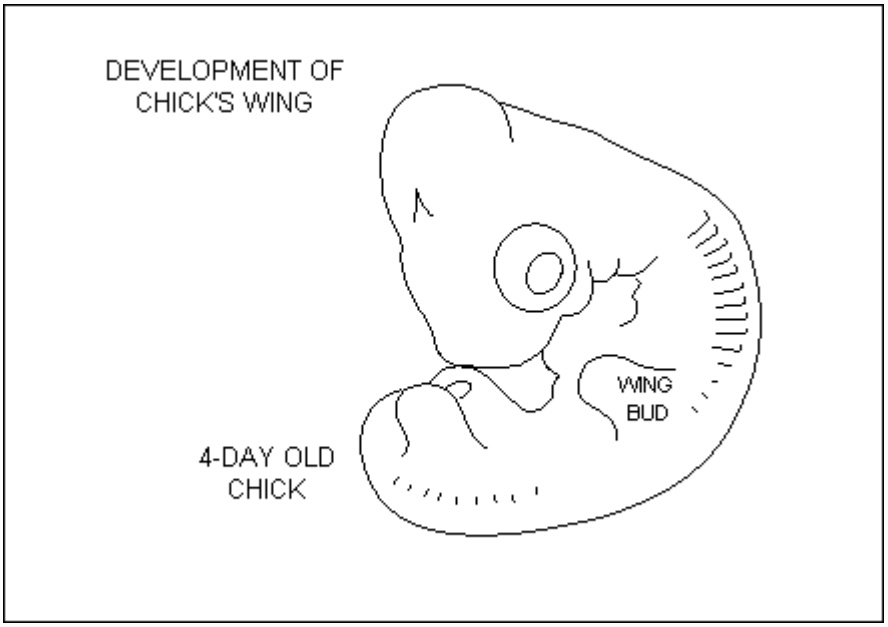
That cells differentiate and eventually die during the course of an animal's life-time is now obvious. What concerns us now is what makes certain cells turn into skin cells, others into bone, and yet others into lung etc. More that that: we have to ask ourselves why two cells can turn into chondrocytes (for instance) and yet behave quite differently during development and growth, depending on where they are situated in the body.

To form a functionally useful body it is no use just forming the 200 or more different cell types which make up the adult vertebrate body - the cells must also arrange themselves in patterns which will make a useful limb, heart, lung, or intestine etc.

The fruit fly, Drosophila, occasionally gives rise to a mutant form which develops a leg where the antenna should be. Now it is possible to graft a piece of normal Drosophila embryonic tissue onto part of the part of the head where the antenna will develop. It turns out that the normal issue develops into a portion of normal antenna. If only part of the future antenna area of the developing head is replaced by normal tissue, then the normal tissue develops into an antenna while the rest turns into a leg! Had that transplant been done onto a developing leg in the normal position the graft would have turned into leg!

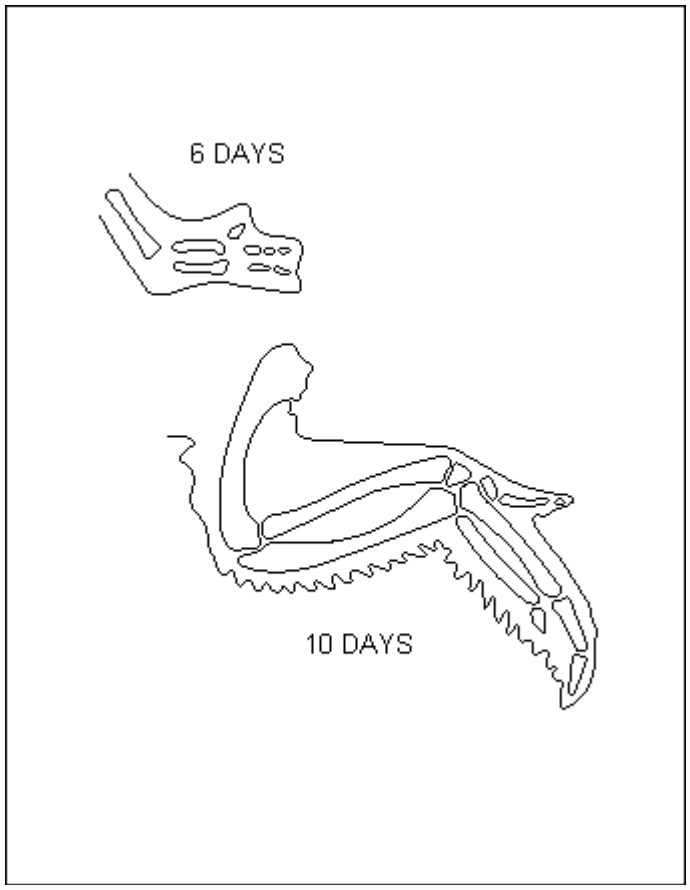
In other words cells behave according to their position in the embryonic body. The problem in the mutant Drosophila is that the cells are genetically incapable of forming an antenna, and respond to their positional information by forming a leg instead.

But how are cells informed about their position in the embryo? This has been extensively studied in the formation of the wing in a chick embryo. Much of this work was carried out by Lewis Wolpert at the Middlesex Hospital in London.



The wing of a chick develops from a paddle-like bud very similar to the arm bud of a human embryo. It starts off as a small bulge that appears about 2 days after the egg is incubated. Cartilage, muscle and tendons make their appearance and after 10, days the basic pattern of the limb - with a

humerus, radius and ulna, wrist and digits - is well established. The bones at this stage consist of cartilage which can be stained so that they are visible through the skin.



To form a structure like that, consisting of a mixture of tissues, the cells must somehow be provided with a set of co-ordinates to inform them of their exact position in the limb. This positional information determines which part of the genetic code will be read off, and whether the cell will become a chondrocyte in the humerus, or a chondrocyte in the wrist, or will form a fibroblast in the soft tissue of the fore arm or its skin covering, etc.

Three co-ordinates will pin-point a cell's position in the developing limb:

- 1. distance along the length of the limb from the shoulder to the digits.
- 2. distance from the front or back edge of the limb.
- 3. distance from top to bottom, through the thickness of the limb.

How are these co-ordinates imparted to the different cells that make up the growing limb bud?

Distance along the length of the limb

Running across the tip of the limb bud is a thickened ridge of ectodermal cells which is associated with a layer of cells about 350 µm thick called the progress zone. It contains dividing cells which look

very much like fibroblasts.

If this ridge and the progress zone are removed at an early stage only the humerus will be formed. If it is removed later only the digits may fail to develop.

If the apical ridge from an early embryo wing is grafted in the place of an apical ridge which has already undergone some development, a new limb will grow out of the existing limb.

Conversely, if an older progress zone is grafted on to a young bud, a wrist and digits form but no humerus or radius and ulna.

Wolpert has therefore postulated that the proximodistal co-ordinate (distance along the length of the limb) is established by the number of cell divisions which have occurred in the progress zone. The cells here divide, producing one daughter cell which remains in the shoulder region of the arm. The other daughter cell remains in the progress zone, and when it divides again it leaves a second daughter cells further down the limb from the first. But in the process of cell division the second daughter cell is slightly different from the first. With each cell division a different portion of the genetic programme is switched on, and one ends up with a limb where each layer of cells from the shoulder to the digits is correctly informed as to what tissues need to be developed in that slice of wing.

Notice that this is similar to the Hayflick phenomenon, in which it is also supposed that cells (or their nuclei) keep a record of the number of cell divisions they have undergone. Here we see that each cell division moves the reader of the genetic programme on one notch to produce daughter cells which will now behave differently when exposed to the same stimuli.

Distance from front to back of the limb

Position along the antero-posterior co-ordinates of the limb seems to be specified by a 'morphogen' (a sort of hormone) which is secreted by the ectodermal cells along the posterior edge of the limb. This morphogen, possibly retinoic acid, seeps through the tissues of the limb, but because it is presumed to be rather unstable, it barely gets to the anterior border in any appreciable quantities.

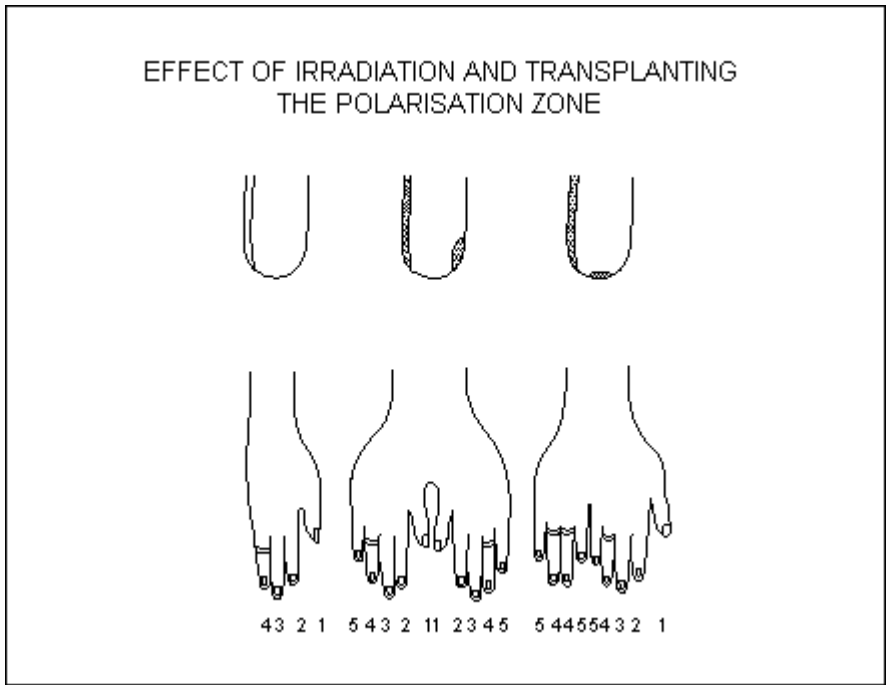
There is therefore a gradient of concentrations of this morphogen in the developing limb. The highest concentration occurs along the posterior border where it is formed, and the concentration gets less and less as you move forward.

It is supposed that cells respond to the different concentrations of this morphogen, thereby gauging their position from front to back of the limb. They adjust their development accordingly.

(Note that the posterior edge of the limb must somehow already know that it is "posterior edge" for it to start secreting the morphogen. This means that there is no reason why the other tissues should not also already know their antero-posterior position, and should, therefore, not require the morphogen to impart this information! This is a deep mystery, to which we do not, as yet, have an answer. However...)

If a piece of posterior border is grafted onto the anterior border of the hand region, for instance, a hand is formed with digits numbered 5, 4, 3, 2, 1, 1, 2, 3, 4, 5, instead of the normal 1, 2, 3, 4, 5 (if it

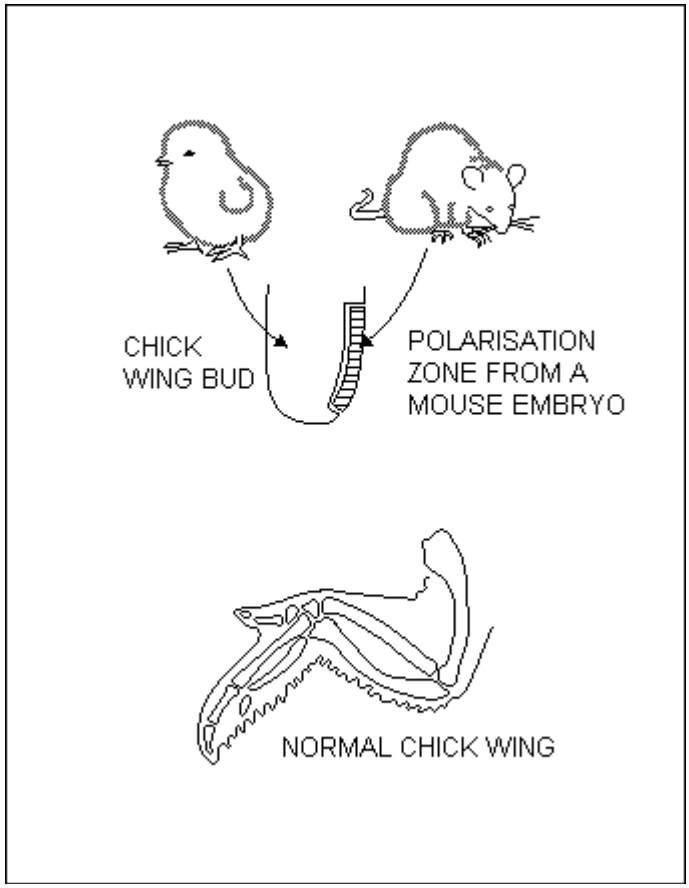
was a human hand).



If a portion of posterior border 'polarising zone' (as it is called) is grafted into the middle of the limb bud, the morphogen would seep from 2 places giving a hand with digits 1, 2, 3, 4, 5, 5, 4, 3, 4, 5.

If the polarising zone along the posterior edge of the limb bud is partially destroyed by irradiation, then less morphogen is produced, and the tissues of the wing all behave as if they are further forward than they really are. Thus no 5th digit is formed, as the concentration of morphogen never becomes high enough for the tissues to differentiate into tissue that far back. If the irradiation is more severe, then the 4th and 5th digits do not form.

Interestingly, you can graft a polarising zone from a mouse or hamster embryo onto the limb bud of a chick embryo and produce the identical results as with a homograft.



In other words, the morphogen is the same in all vertebrates, but the genetic material on which it works is different in different species. This is not unusual in physiology. The male hormone, testosterone, is the same in humans as it is in domestic fowl. Administered to a human it causes the beard to grow, but administered to a chicken it causes the comb and tail feathers to develop into those of a cockerel.

Distance from top to bottom through the thickness of the limb

Unfortunately we know nothing about the manner in which developing limb cells are informed of the 3rd co-ordinate they need to fix their positioning the limb. We can only guess that it is possibly another morphogen.

EQUIVALENCE AND NON-EQUIVALENCE IN DEVELOPMENT

It should be noted that the positional value, which the co-ordinate system imparts on a cell, specifies not only what sort of cell it must become, but it also specifies how much it must grow. Thus cartilage is formed proximally in the humerus, and distally in the wrist. The humerus however grows to 16 times its initial length in the next 10 days in the chick, while the wrist only doubles its length in that

time.

Once the wrist region has received its co-ordinates and has differentiated into a wrist, it refuses to grow fast no matter what you do to it - you can move it to any other part of the body, or place it in a culture dish, and it will grow at a rate that is characteristic of the wrist of a chick. Wolpert has called this property whereby the same tissue, in different positions in the body, behaves differently to the same stimuli or circumstances, as 'non-equivalence'. It occurs in the adult body too. For example the hormone testosterone stimulates the development of air follicles in the beard region (in humans), but causes hair follicles to degenerate on the top of the head. Hair follicles are therefore non-equivalent in the adult. Similarly, the female sex hormone, oestrogen, causes fat cells to multiply in certain regions of the body (notably the breasts), but to atrophy, or be retarded in other regions. Adipose tissue is therefore also non-equivalent in the adult.

Other tissues appear to be entirely 'equivalent', certainly during embryonic development. The skeletal muscles of the limbs are an example. When the wing of a chick forms and differentiates, no muscle cells are formed. These migrate into the limb from the trunk of the embryo. And it does not matter where in the trunk they come from, they are all 'equivalent' and simply move into positions which are prepared for them by the non-equivalent connective tissue fibroblast. These fibroblasts have arranged themselves into moulds or templates for the muscle cells to adhere to, during limb pattern formation. These moulds are, of course, determined by the co-ordinates specifying position in the limb. The muscle cells simply fill the moulds and form the required muscles of the limb.

Nerves then grow into the limb along paths determined by non-equivalent connective tissue. As each nerve fibre grows and extends itself into the limb its finger-like ends palpate the different cells the growing end comes into contact with, rather like a shopper at a supermarket looking for a fresh, soft loaf of bread. If the cell being palpated is a fibroblast the nerve ending grows on until it finds a muscle cell, which presumably feels and smells right. When this happens the nerve ending establishes permanent contact in the form of a neuro-muscular junction. Once contact is established, this precludes other nerve endings, in search for a juicy muscle cell, from establishing contact. One nerve cell can, however, make contact with several muscle cells.

The way the muscle is then stimulated by the nerve, usually after birth, determines how that muscle cell will differentiate into either a red or white muscle fibre.

The white muscle fibres, which form the 'white meat' of different animals, are stimulated via the nerve only now and again, in emergencies. Most of the time the nerve, and therefore the muscle, is quiescent. But when it is stimulated to contract white muscle fibres contract very fast and very powerfully - hence they are also called 'fast-twitch fibres'. These muscle fibres make up the pectoral muscle of the chicken, who uses this muscle only when it is in a hurry to get out of danger, or to fly up to its roosting place. It is also the predominant muscle type in the cat family. Cats are capable of tremendous bursts of very fast activity for short periods of time. They tire very quickly, and are quite incapable of going for a walk with you as can a dog. White muscle fibres fatigue very quickly.

Red muscle fibres, also called slow-twitch fibres, are fatigue resistant, but are not capable of the speed of contraction that the white fibres are. Red slow-twitch fibres develop after birth in response to continuous stimulation via the nerve fibre, at a rate of about 10 Hz. This occurs in those situations where the muscle is needed for the maintenance of the upright posture, or if the animal uses its muscle for long migrations etc.

Summary of the factors influencing cellular differentiation

During embryonic and foetal development there are therefore at least 4 mechanisms which determine which part of the genetic code (which is present in nearly every cell) will be read off in a given cell.

- 1. The cytoplasmic environment of the nucleus. A blastocyst cell nucleus moved into the cytoplasmic environment of the ovum, once again starts reading its DNA programme from the beginning. (Gurdon's experiments).
- 2. Cells will switch to new parts of the programme each time they divide (Hayflick's and Wolpert's experiments).
- 3.Chemical messengers (morphogens and hormones) will affect the behaviour of cells depending on their concentration in the fluid surrounding the cell (the morphogen concept).
- 4. Nervous stimulation, particularly the pattern of nervous activity when the organ or tissue is not obviously in use, seems to provide signals for the cell to read the appropriate portion genetic code.

Not always does the "turning of the page" in the genetic code mean that the cell cannot revert to an earlier code. Sometimes the change is permanent and irreversible, but at other times the cell needs to receive the message about what it should be like all the time or it will revert to another portion of the code. The differentiation of the muscle into red fast twitch fibres is an example. If the nerve stops stimulating the fibre at 10 Hz while it is apparently at rest, the fibre will become a white fast twitch type again.

Illustrations and website design by Ann Koeslag

The Human Lifecycle
Part 15

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ENDOCRINOLOGY OF POST-NATAL GROWTH

By the time the baby is born pattern formation in the body is complete and the human individual is in possession of most, if not all, the organs and tissues which it will have till old age. These organs and tissues are not at their final size or proportions yet, as we have seen. But, at least, the organs and tissues are in their final positions in the body, and all they have to do is grow and develop along the lines which are genetically laid down for each tissue, in different parts of the body.

Much of this growth and development depends on the presence or absence of, predominantly, the fat soluble hormones, which regulate the process of growth and development in post-natal life, producing the correct body shape and function for each stage of development, right into old age. But they do not affect the ageing process that occurs in the cells. Thus it is possible to arrest the normal changes in appearance that occur with age, but that does not prevent cell ageing and ultimate death, at more or less the usual time for that species. A cretin may thus not develop past childhood, retaining a childlike physical appearance, physiology and behaviour throughout their lives, but this does not cause them to be immortal. They die "of old age" (whatever that might mean) at the normal time, unless the complications of their myxoedema cause them to die earlier.

Endocrinology of growth during puberty

After the very active endocrine events associated with sexual differentiation during embryonic life, there is the relatively quiescent period during the pre-school years.

Between the ages of 5 and 8 years in both sexes, there is an increase in adrenal androgen production, which is most often registered as an increase in the dehydroepiandersterone concentration in the blood, but it can also be detected in increases of progesterone, 17-hydroxyprogesterone and androstenedione in the blood. This increase in adrenal androgen production is termed "adrenarche". It is believed that these adrenal sex steroids trigger the activity of the hypothalamic-pituitary-gonadal axis at puberty in humans. Dogs and cows do not undergo an adrenarche similar to humans.

In the adult man, luteinizing hormone (LH) promotes secretion of testosterone from the Leydig cells of the testes, and testosterone exerts a negative feedback on the pituitary's release of LH. Follicle stimulating hormone (FSH) causes maturation of the seminiferous tubules and spermatogenesis. Feedback is believed to occur via a hormone called 'inhibin'.

In the adult woman LH is responsible for initiating steroidogenesis (steroid production) in the ovarian follicle, but FSH is responsible for the aromatisation and release oestradiol. The gonadotropins are secreted cyclically in women, but not in men.

The way in which the pre-pubertal child develops this system during puberty is controversial. All available evidence suggests that there is one gonadotropin-releasing hormone (GnRH) from the hypothalamus which stimulates the secretion of both LH and FSH from the pituitary. This decapeptide (GnRH) is available commercially, and much clinical experience has been gained with it.

It appears to be secreted episodically probably every hour or so in the adult, and the amount does not vary greatly under most physiological circumstances. Steroidal feedback; and the monthly cycle etc. seem to reside in the pituitary.

What seems to happen during childhood is that the pulses of GnRH are initiated by adrenarche. The pulses are relatively infrequent to start with, but become more and more frequent during late childhood, and start to occur at about 1 per hour at puberty. This then initiates the secretion of LH and FSH from the anterior pituitary, cyclically in the girl, and non-cyclically in the boy.

The proper functioning of the rest of the endocrine system is also important for the normal completion of puberty. Growth hormone the thyroxin are crucial, but there are many other hormones which also have important roles. Parathyroid hormone and vitamin D have to maintain the skeleton, and insulin is necessary for the enormous anabolism associated with the growth spurt.

SECONDARY SEX CHARACTERISTICS

The gonadal steroids are primarily responsible for the development of the secondary sex characteristics (i.e. the signals which advertise the individual's gender to other members of the species).

In boys

Testosterone is responsible for the growth of the penis, prostate and seminal vesicles. It is essential for the development of the seminiferous tubules and the production of sperms, under the stimulatory activity of FSH.

Pubic hair appears when the penis starts to grow, but axillary hair and apocrine sweat glands appears only when there is quite a lot of pubic hair. Facial hair appears later, and hair elsewhere on the body, conspicuously on the chest, appears later still. This means that there is considerable non-equivalence of hair follicles in different areas of skin, expressed in the sequential maturation of testosterone receptors in the skin of different parts of the body.

Testosterone prevents the development of the female pattern of fat deposition. In its absence the person develops the female pattern of fat deposition, though without the breasts.

In girls

The breasts develop in response to even the smallest amounts of circulating oestradiol, and constitute a very sensitive bioassay for this hormone. The breast area is so sensitive to the presence of oestradiol that very young girls, at the age of 4 or 5, often develop breast buds, which may regress gain, as small amounts of oestradiol are secreted ("by mistake") in the pre-school child.

A substantial number of boys also develop breast buds, but at puberty, due to small amounts of

oestradiol secretion from the testes. It is only the high levels of testosterone secretion in adulthood that suppresses the formation of breast tissue in the men.

Oestradiol is responsible for the promotion of the growth of the uterus, vagina and its associated glands.

It is believed that oestradiol promotes the growth of the pubic and axillary hair, but that in the normal woman the adrenal androgens make a substantial contribution to this growth. Oestradiol is however primarily responsible for the development of apocrine sweat glands in the axillae, round the nipples and in the pubic region.

From an endocrinological point of view, menarche (a girl's first menstrual period) is relatively unimportant. It simply represents the time when the uterine mucosa has become sufficiently thickened to become unstable when the oestradiol concentration falls for any reason. Menarche is not in any way associated with the first ovulation. That occurs at some unknown time later. Anovulatory cycles are the rule during puberty in girls, which is why the length of the cycle varies, and why bleeding is sometimes intermittent. Only as time goes on do ovulatory menstrual cycles occur more and more often, and the cycles become more regular.

The pattern of fat deposition in the young woman is due to a mixture of the effects:

- 1. an absence of testosterone
- 2. and the effects oestrogen

Persons who secrete neither of the sex hormones in their teens, for one reason or the other, develop a body shape which is very much more like that of a woman than that of a man, but without the breasts . Oestradiol adds the breasts to this, and does a bit of extra sculpturing around the hips, but not much.

THE ADOLESCENT GROWTH SPURT

The adolescent growth spurt results from synergism between the sex hormones and growth hormone, as long as the other endocrine functions are normal.

The sex hormones have a double effect:

- 1. They stimulate skeletal growth, particularly of the vertebral column, and less of the limbs.

  2. They cause accelerated maturation of the bones, closing the epiphyses of the long bones. When the epiphyses are closed no further growth in the length of the long bones can occur. Growth in height of humans therefore ceases.

Hence if you give the sex hormones, and it does not very much matter whether you give testosterone of oestradiol, to a prepubertal child he or she will start growing very quickly, but within a year or two this growth stops. At that stage the child will be taller than his/her peers, but much

shorter than a normal adult, whose height will never be attain because the long bones have lost their capacity to grow any longer. Much of his extra height gained while on the sex hormones will be due to a relatively long trunk. The legs grow in length too, but not to the extent that they do during normal childhood growth, when the emphasis is particularly on the growth in length of the limbs.

This is, in fact, what happens naturally to girls, and is responsible for the sexual dimorphism in height and in leg-trunk ratio. Since the secretion of sex hormones occurs earlier in girls than in boys they overtake the boys in height at first, but then stop growing.

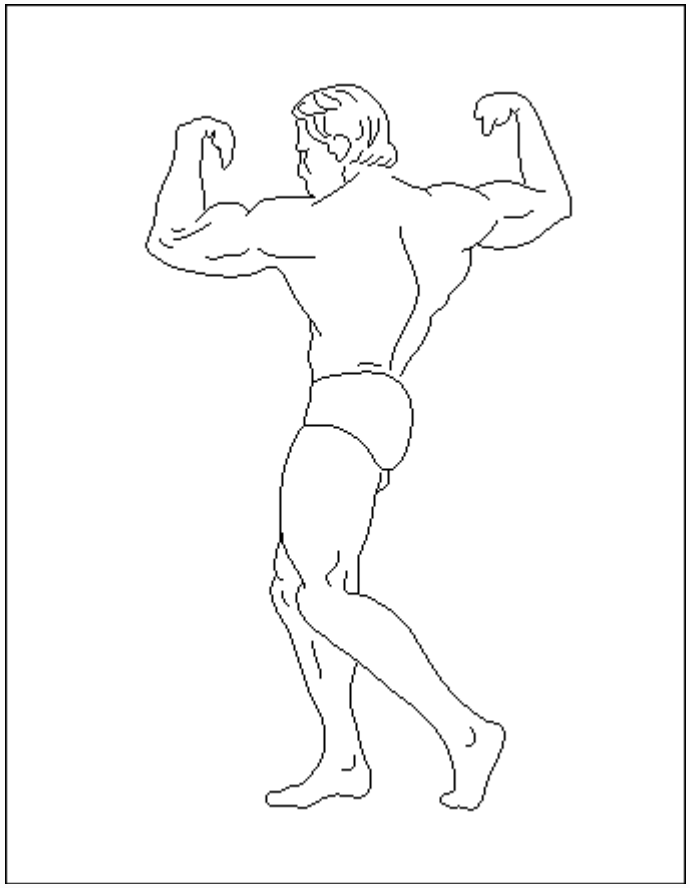
The boys continue growing under the influence of only growth hormone for an extra 2 years, and therefore have much longer legs and arms than girls at the start of their puberty. Their vertebral columns then begin to grow under the influence of testosterone and growth hormone. When it is all over, they end up about 12 - 13 cm taller (on average) than the girls, and most of this difference is due to extra leg length. Men and women's sitting height therefore does not differ very much. When they stand up however, marked differences immediately become evident.

In addition to causing a growth in the length of the vertebral column, the sex hormones are also responsible for growth in width of the shoulders and the hips. Both sexes become wider in relation to their height during puberty, which is an important distinguishing feature between pre- and post-adolescent individuals.

Testosterone causes greater widening of the shoulders than of the hips, whereas the oestrogens have relatively greater effect on the hips than on the shoulders.

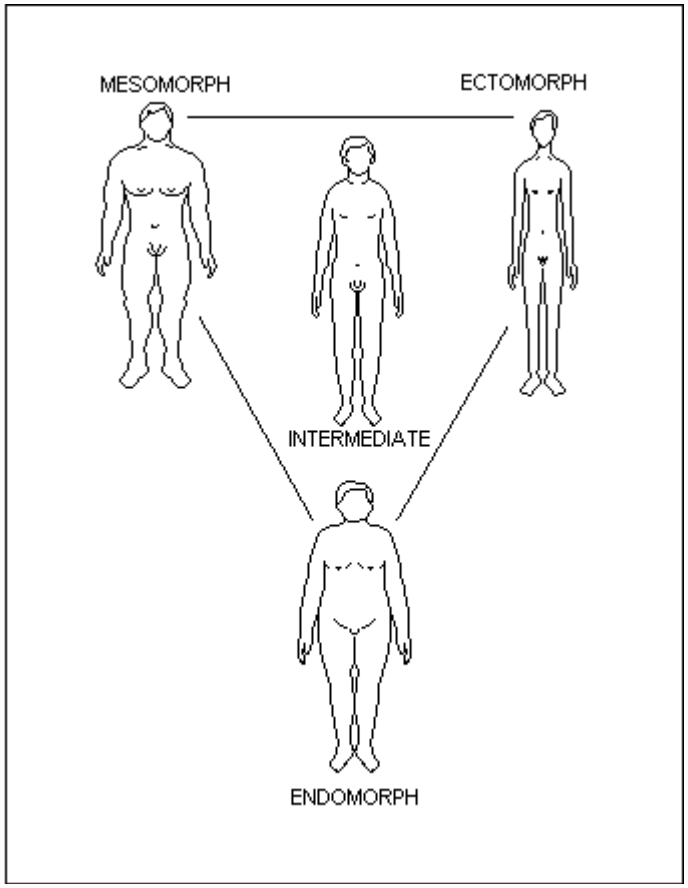
NORMAL VARIATIONS IN ADULT PROPORTIONS

After any discussion on the attainment of sexual dimorphism at puberty, one is often left with the impression that the action of the androgens is to produce a person who looks like this:



Narrow hips, wide shoulders, masses of muscle and almost no subcutaneous fat. In fact many people who wish to look like this take androgens by mouth or by injection in the hopes that it will help them achieve their goal more easily.

The action of the androgens is however to produce these types of body forms:



The androgens are as likely to produce an endomorph as they are likely to produce an ecto- or meso-morph. The most likely result of androgen secretion in the body is the intermediate body form, with more or less equal contributions of endo- meso- and ecto-morphy. Giving an endomorph more androgens is no more likely to change his body shape into that of an mesomorph than it is likely to turn him into more of an endomorph, or into an ectomorph. In fact additional testosterone in a normal adult man has no effect other than to suppress his own androgen secretion, and to produce side effects due to the similarity between the androgens and cortisol and aldosterone.

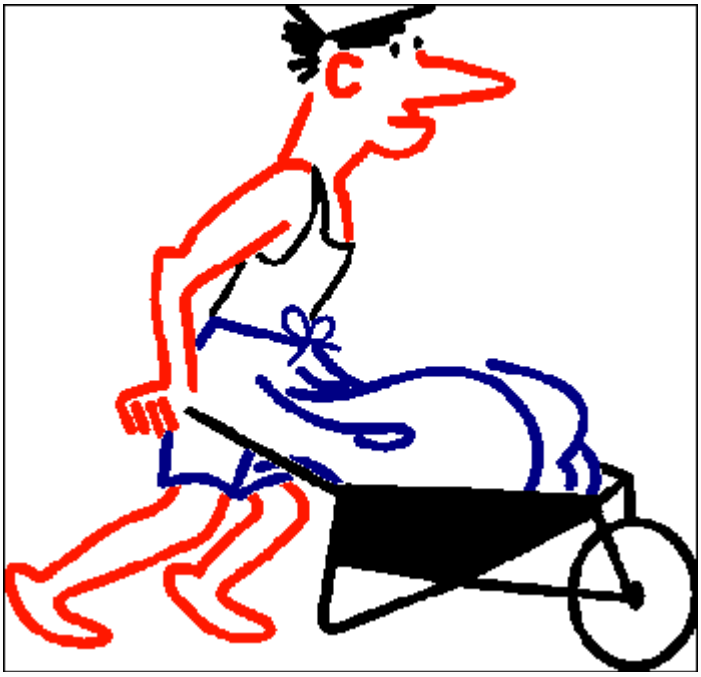
The sex hormones act on the genetic material in the nuclei of cells. They are in fact taken up by cells and transported into the nucleus where they act direct which part of the genetic code should be read off in that particular cell.

We are all born with the genes for both a female body form as well as a male body. Which group of genes will be expressed depends on the hormones secreted during embryonic and adult life.

If your complement of 'male genes' specifies an endomorphic body form then that is what you will turn into when the androgens are secreted during puberty. There is nothing the matter with your masculinity, nor with the amount of testosterone in your blood. You are just unfortunate that you have an unfashionable body form, nothing more.

If you do not have the genes for a Mr Universe body form, testosterone will not create them.

In other words, it is strictly speaking incorrect to say that the androgens promote the growth of muscles, or the enlargement of the penis. They simply cause the genes to be switched on which specify 'maleness' in your particular case. Thus the androgens do not strictly speaking "cause enlargement of the penis", producing results like this if given in excess:



...but rather, they "cause the penis to grow to the adult man's penis size" (and no further!).

These hormones are therefore very similar to the morphogen we encountered in embryonic development. The morphogen does not cause particular structures to form in the embryonic limb, it merely provides the information as to which part of the genetic code must be decoded in a particular place.

The same considerations also, of course, apply to the action of the oestrogens.

Each particular body form produced at puberty develops in its own characteristic range of ways through adulthood and into old age, producing an enormous amount of variation in body shapes and functions towards the end of life which is a feature of the aged in any species.

Of course, body form is determined by factors other than genes, and the hormones acting on them. Nutrition, exercise, exposure to the elements, injuries, illnesses and cultural demands acting through one or more of these, interact with the effects of the person's genes and his or her hormones, to produce the individuals you see around you.

Illustrations and website design by Ann Koeslag

The Human Lifecycle
Part 16

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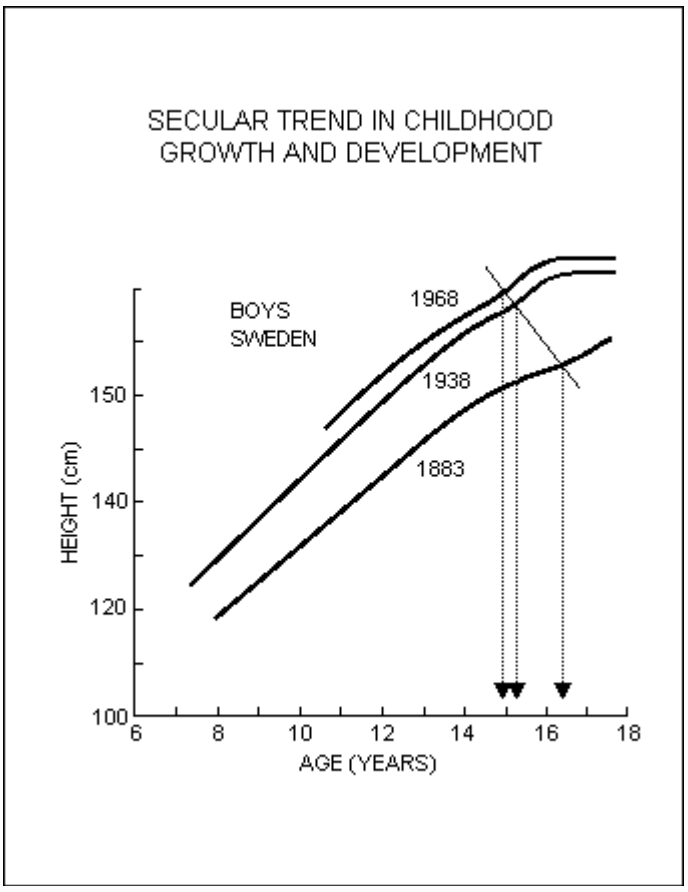
SECULAR TREND

During about the past 150 years in industrial countries, and recently in many developing countries, children have been growing faster, and have been proceeding to maturity more rapidly. These changes in the rate of childhood growth with time have been dubbed the 'secular trend' in growth.



The above graphs show Swedish data, which are the most comprehensive available for any country over the whole period. The differences in children's heights between 1883 and 1938 amount to nearly 1œ years of growth (i.e. 8 year-old boys in 1938 were as tall, on average, as boys aged 9.5 years in 1883). Differences between 1938 and 1968 are much less.

These differences in height between persons born during the 19th century and those born during the 20th century are also present in adulthood, but are less prominent than in childhood. This is partly because when children grew more slowly in the past they also carried on growing for much longer than they do today, often well into their 20's. They therefore made up for their slow growth

by growing for a longer period.

The occurrence of the secular trend in height and mass and been documented in nearly all European countries including Sweden, Finland, Norway France, the UK, Italy, Germany, Czechoslovakia, Poland, Hungary, Soviet Union, Netherlands, Belgium, Switzerland and Austria. From about 1900 to 1980 children aged of 5 - 7 years, in average circumstances, increased their height at the by about 1 - 2 cm per decade.

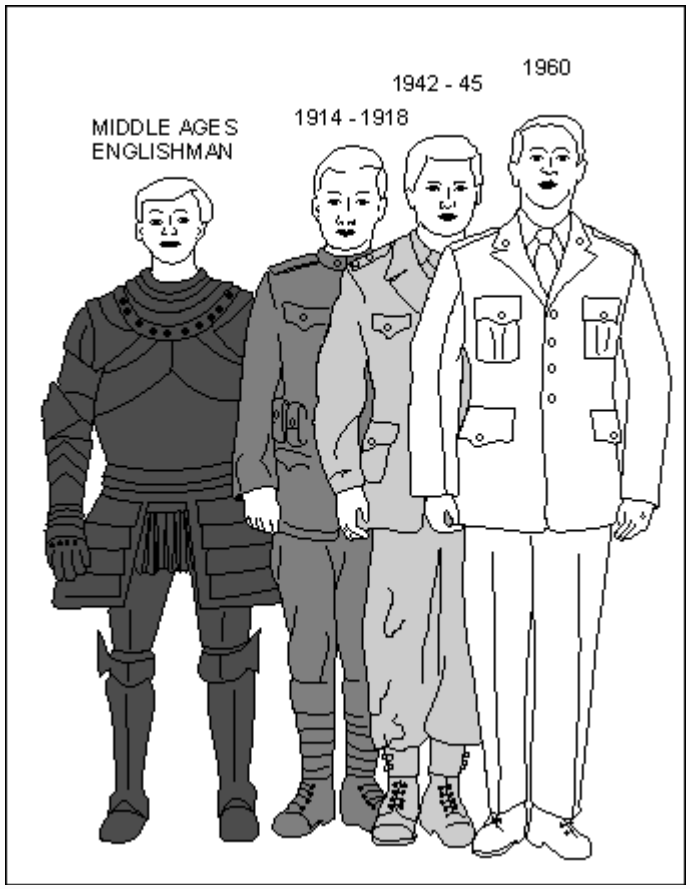
In Japan the trend has been particularly dramatic. There it averaged 3 cm per decade in 7 year olds between 1950 and 1970. Before that it had been less than 1 cm per decade.

The trend has been most noticeable amongst the children from the lower classes of society. The heights of upper class children in Britain changed very little over the past 150 years.

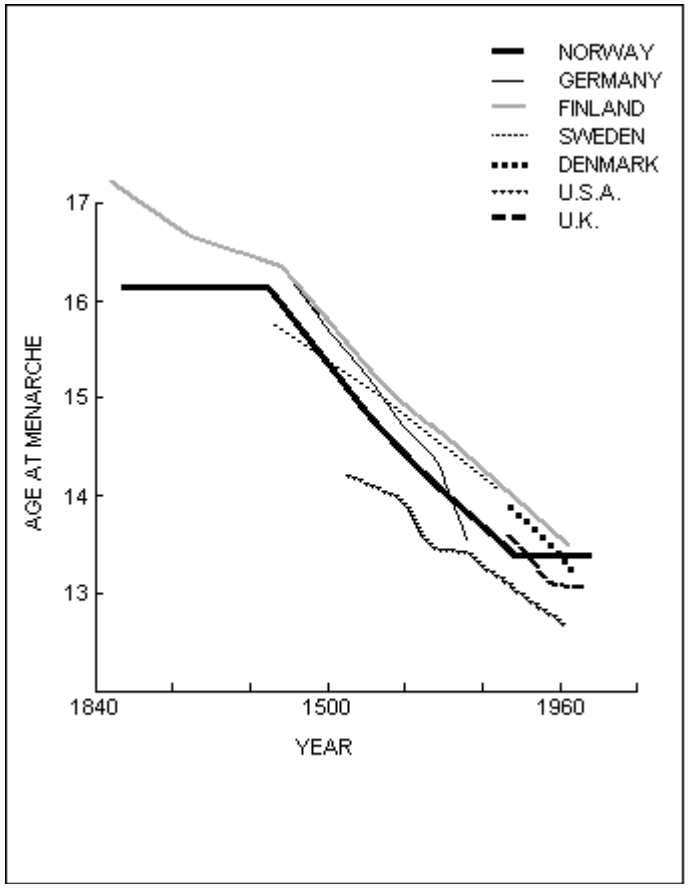
In Holland it has been shown that the trend stopped, and was even temporarily reversed, during periods of economic set-back like the Great Depression of the 1930's.

In most industrial countries the trend has almost ceased now.

In addition to growing faster, children are also maturing earlier. This means that they are reaching their final height sooner, and that a certain amount of difference in height which existed during childhood is made up by children in the past growing for a longer period of time. The increase in the height of adult men has therefore increased at a rate of only about 0.3 cm/decade in most European countries.



The earlier maturation of children is nowhere better illustrated than in the secular trend for age at menarche.



The causes of the secular trend

These are probably multiple:

- 1. Nutrition has no doubt played a role. Children are getting more protein to eat today than they were in the past. Food is more palatable today, causing more to be eaten. This is almost certainly due to surplus food production leading to food having to be marketed (i.e. made attractive and tasty):

  Vegetables are picked younger and more tender than they were in the past.

  Refrigeration keeps food fresh, without having to dehydrate, salt or smoke food to preserve it, nor are children forced to eat rotten food at the end of the winter.

  The international food trade ensures a regular supply of fresh food, so that middle class children are no longer exposed to intermittent famines and malnutrition.

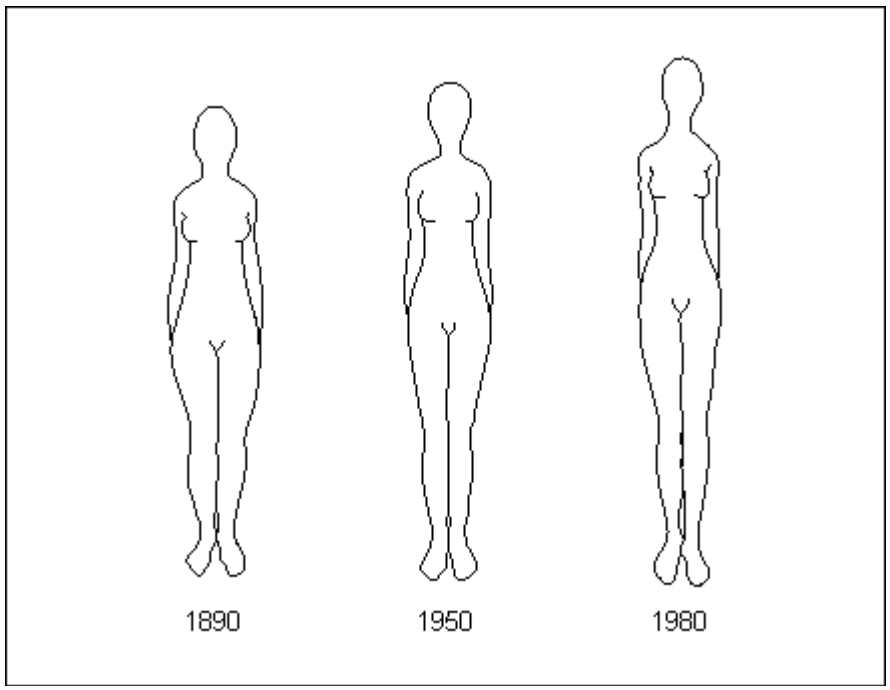
  Food is cleaner than in the past.

- 2. Children are also subject to fewer diseases today than in the past. Repeated serious illnesses would certainly retard growth, catch-up growth not-withstanding.
- 3. Abolition of child labour.
- 4. Fewer orphans (because of lower death rate amongst parents). This causes less neglect, more attention, and consequently fewer instances of deprivation dwarfism.

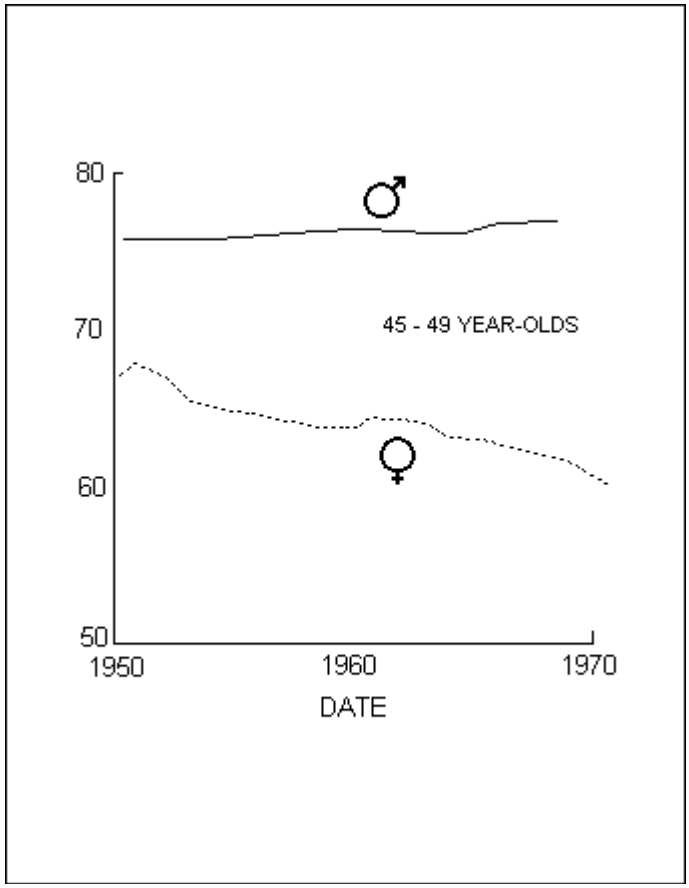
- 5. Warm, clean houses.
- 6. Another factor that may have played a role is the greater degree of heterosis (or outbreeding) that occurs today compared with the past. It is known that heterosis in animals produces an increase in adult size for a generation or two. Ever since the introduction of the bicycle, and rail transport, people have become very much more mobile. This has enabled people to find mates outside their little village, and many times outside their country of origin. The reason for this 'hybrid vigour' (as the phenomenon is also known) is not known.

Secular trend in the shape of women

Less well documented, though noticeable nevertheless, has been the secular trend in the shape of adult women, particularly in USA. I suspect that this trend is not as universal as the trends in the growth of children, as for a long time it was only noticeable in the USA and Britain. Only fairly recently does it seem to have spread to middle class women in other countries. The trend has been for women have been getting taller and slimmer.



The diagram shows in an exaggerated manner the trend as it is supposed to have affected the adult shape of USA women over the past 100 years. Documentation of the trend has however occurred only since about 1950.



The cause of this trend is a little more difficult to explain than the changes in the rate of growth and maturation of children, though it does seem to be associated with the overall trend for the population as a whole to grow up and look more like the upper classes of Britain a century ago.

Women in the lower income groups tend, generally, to be heavier and carry more fat than the women in the upper income groups. As the population as a whole becomes more prosperous, and the lower social classes (and really "low income groups") gradually disappear, one sees fewer and fewer women, who by today's middle class norms would be termed "obese".

If one examines human shapes through history, as recorded by artists and sculpturers, one finds that the fashionable shape of women (if not the shape of the average woman) has changed considerably from time to time, and from culture to culture.

On the other hand the shape of men, especially young men, has remained remarkably constant, if statues, paintings and drawings of young men are taken as true representations of the shapes of the general population.

It is interesting to speculate what might be the cause of this interesting discrepancy.

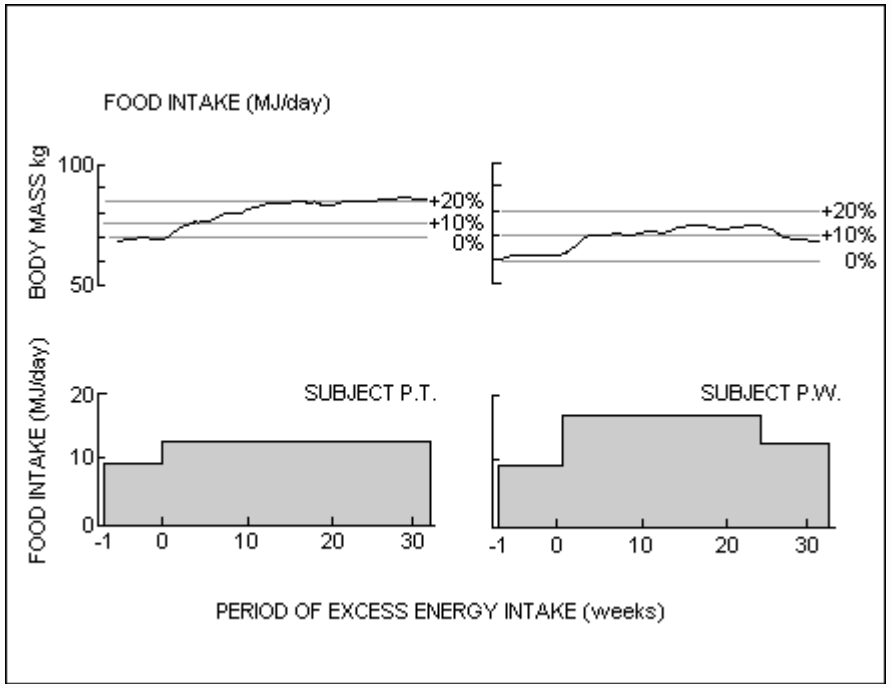
Can overeating cause obesity?

In 1976 Sims at the University of Vermont set out to study the biochemical and hormonal effects of obesity. He was under the impression, like everybody else at the time, that obesity was due simply to overeating. He therefore asked a group of students to eat as much as they could for a period of 12 weeks so that he could study them before and after they had become obese. To his surprise his

subjects gained very little weight considering the amount they said they were eating. Either they were overestimating what they were eating, or they had somehow started to do more exercise, he thought. So he turned his attention to the inmates of Vermont state prison where he could control the amount eaten as well as the physical activity of the subjects.

The prisoners were only too willing to volunteer for an experiment in which they could, or had to eat as much as they could! On average these men consumed about 75% more mixed food energy per day than their normal prison fare, with some taking in over 40 MJ of food per day (normal prison rations amounted to 9 MJ/day. A normal young man eats on average about 12 MJ/day).

As shown in the figure below, some subjects gained mass much more easily than others, but all achieved a new equilibrium mass after a few weeks on their high energy diets. The new equilibrium masses of the individuals eating 40 MJ/day were only about 20 - 25 % greater than their normal masses.



Sims also studied two obese subjects who had reduced their masses to that of the lean subjects after overeating. To maintain their masses at this level (about 80 - 90 kg) these spontaneously obese subjects had to eat as little as 5 MJ/day, compare to the 40 MJ which some of the spontaneously lean subjects needed to remain at this (80 - 90 kg) mass!

On returning to their normal diet, all the subjects rapidly regained their starting masses. They did not need to "diet" to get rid of the excess mass gained during the overeating period.

Although these experiments were conducted over a period of only 12 weeks, they indicate that young men cannot gain weight willy-nilly. A study of the weights of adults who had been brought up in foster homes has shown that the weights of these people (as adults) correlated closely with the weights of their biological parents. There was no correlation between their weights and those of the foster parents who had brought them up, and whose eating habits they had adopted. Weight, and body shape and composition, therefore, appears to be genetically determined, and it is very difficult for normal people to change it upwards, because the metabolic rate is automatically increased. Sims' subjects who were eating 40 MJ/day were also burning 40 MJ/day despite not doing any extra

exercise.

Since people have the capacity to starve themselves (sometimes to death!) a deliberate change in weight downwards seems to be easier, and more certain of success (if one has enough determination), than is a deliberate, planned change in weight upwards. Whether this statement applies equally to the two genders is not known. Sims used only men in his study. It is, however, known that when Speke and Grant were searching for the source of the Nile in the mid-1800's, they came across Chief Rumanika of Karagwe whose harem consisted of a number of women who were force-fed with the intention of making them as obese as possible. Obesity in women was considered sexually highly attractive in that culture. Speke measured the arm, chest, thigh and calf circumferences of the "Queen" of the harem.

Height: 172 cm

Upper arm circumference: 58 cm

Chest circumference: 132 cm

Thigh circumference: 78 cm

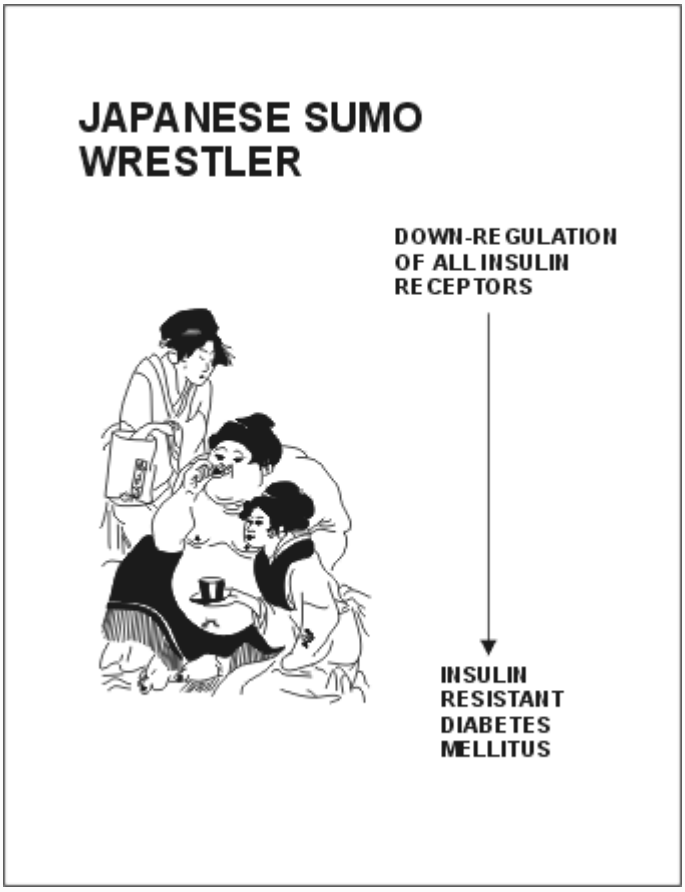
Calf circumference: 50 cm

These dimension do not strike one as particularly excessive. One sees many rural women, who are not obviously over-eating, with arm and thigh circumferences of that size. This would therefore suggest that women's weights are also capped in the same way that Sims' men's weights appeared to have upper limits beyond which no amount of over-eating could take them.

However fully mature women who are not dieting have substantially more subcutaneous fat than men who are not dieting. The capacity for women to change their weight (from their natural "obese" state downwards to a state of near emaciation) is therefore obviously greater than that of men (who can only go, in the average case, from moderate chubbiness or less, to emaciated). It is therefore not unlikely that fashion might make greater demands on women for changes in fashionable body shape than it can demand from men.

In recent decades, in many Western countries, but particularly the USA, there has been a very noticeable increase in the number of children and young adults who seem to be candidates for the Sumo wrestling clubs of Japan. It therefore seems that there is more to body shape maintenance than Sims' experiments suggest.

It could be that Sims' experiments were conducted over too short a period of time, and that the body's defences against unlimited weight gain can be overwhelmed by prolonged overeating. But there are a number of of other possibilities. It could be that only some people have the "Sumo wrestler" genes. The Japanese population as a whole consists largely of fairly slim persons, and only the occasional individual attains a size that makes him a candidate for the Sumo wrestling sport. Considering the popularity of the sport in Japan, it must be more than the occasional teenager's dream to become a champion Sumo wrestler, but somehow their bodies refuse to fulfil their dreams, and most young Japanese men remain slim. The wrestlers, however, do eat enormous quantities of food before major competitions, but they do not grow endlessly fat.



It could therefore be that their genetic make-up is such that they can, or do, gain weight disproportionately (compared to average individuals) when food is plentiful, in the way that the Pima Indians of the USA have become an "obese nation" now that food is in regular, plentiful supply. Another possiblity is that there is a component of the Western diet that does not stimulate adaptive thermogenesis the way that a more traditional diet does. Sims' subjects who ate 40 MJ of food stopped gaining weight after a few weeks because they started to burn 40 MJ of fuel even though they were not exercising more than before. How this works is not known. However, it is easy to imagine that whatever stimulates normal people to step up their metabolic rates when they eat more (and decrease their metabolic rates when they eat less), that this mechanism can be interfered with by some novel component of the diet that evolution had not taken into account when it developed adaptive thermogenesis.

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The Human Lifecycle
Part 17

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CULTURALLY DETERMINED INTERFERENCE WITH BODY CONFIGURATION

Humans are notorious for interfering with their body appearances. A name has been given to it - decoration and self-mutilation. Almost everything that can be interfered with has been interfered with. No culture or group of people is exempt. It is a fundamental characteristic of the human race.

Such mutilation is sometimes aimed at exaggerating sexual dimorphism, at other times reversing it, but most of the time it is performed simply because it can be done, and that it can be used to distinguish one social class from another, or one culture from the next. It is a way of indicating to other people, what prejudices you adhere to!

Thus men's jackets are equipped with padded shoulders, and women pad their bras to exaggerate those aspects of sexual dimorphism, while at the same time the removal of the beard, or wearing of high heels reverse other natural features of sexual dimorphism.

We cut and comb our hair, paint our faces, deodorise and perfume our armpits, mouths and genitalia.

People tattoo themselves, or cicatrise their faces. They may even file their teeth, or ritually extract some of them. Ritual circumcision is a great favourite among many societies, both ancient and modern. Most such societies prefer to do the circumcision during puberty when it is likely to be the most painful and frightening! And we, of course, all wear clothes and ornaments with which we can alter our outward appearance at very short notice.

More drastic forms of self-mutilation have occurred and still occur in different parts of the world. The Chinese used to bind the feet of girls and women, and in Africa certain societies make their women wear heavy rings round their necks, or in their lips and ears to pull them completely out of shape.

It is therefore not surprising that people should try to interfere with their 'natural' body shape by dieting. Speke and Grant's discovery of a harem full of women who were force-fed an uninterrupted flow of milk sucked from gourds through straws is therefore no less surprising than the demands western societies place on their women to eat as little as possible to remain unnaturally thin.

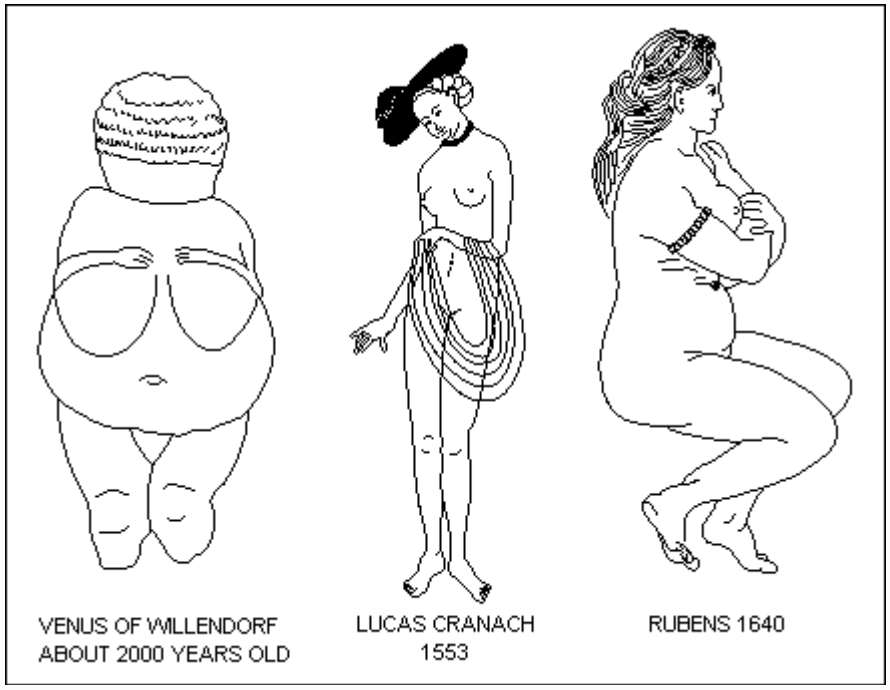
The fact that these attempts at changing body shape by over-eating or "dieting" are almost exclusively confined to women, would seem to me to indicate that women can change their shapes, but men generally can't. If men could successfully change their outward appearance by dieting, I am sure they would have done so at some time in someplace. Furthermore I would venture to guess that given an opportunity most of the men would readily swap their present bodies for bigger, more mesomorphic ones!

The present author weighed exactly the same at the age of 45 as he did at 20 years of age - 66 kg!

During the intervening 25 years he absorbed well in excess of 4 tonnes of food from his gut! All of which his body carefully and meticulously burnt as fast as it entered, much to his dismay in the early

days when he thought he might still make it into his Varsity's first team in Rugby. Had that been successful, he believed, his University's rugby team might have won the Inter-Varsity Rugby for a change. Assuming that this person was not too abnormal, this experience would indicate that body shape is physiologically rigorously defended; in some people better than in others, but defended none the less. It always produces a snigger when this person claims he has aspirations to become a Sumo wrestler. People "know" that this is just a physical impossibility.

Pain, sometimes considerable pain, and discomfort is not considered a valid excuse for the avoidance of self-mutilation. If men have therefore not had different body shapes at different stages in history, then it is almost certainly because they have not been able to do so. For women the situation seems to be different. For them it appears to be easier to diet themselves into different shapes, and consequently the fashion keeps changing. Poor women - but how human.



The thread we have been following throughout these essays has been that there are highly visible signals informing our neighbours of our age and sex. The purpose is obvious: if there was no sexual dimorphism we would be equally attracted to either sex and only half of matings would be heterosexual. From a biological point of view this would be very inefficient. Similarly, if there was no age-related polymorphism we would be equally attracted to an 80-year-old as to a 20-year-old, or a 5-year-old. This would be even more inefficient from a reproductive point of view, as only about 4% (P = 0.2 x 0.2) of matings would be between young adults!

In addition, humans are highly adaptable, and can live as hunter-gatherers, pastoralists, agriculturists, industrialists, or as office workers. And even within these broad categories there are many different social solutions to the problems of gregarious living, and adaptations to local circumstances. It is this ability that has allowed humans to spread to every corner of the world. Each unique solution to the problems of survival is complete and has its answers to all of its own problems (problems are inevitable). Individuals have therefore to abide by the rules of their particular community. It is therefore important to be able to recognise whether someone you meet, and may or may not be attracted to, lives by the same rules as you do. Hence the culturally-determined decorations and mutilations. Even within a society it is important to be able to recognise ranks and the distribution of duties. Thus we generally have no problem recognising whether the person getting out of a car at a neighbour's house is a doctor or a plumber. This is important because

the one has the right to ask the occupant to get undressed and the other has not!

Next we have a look at another set of signals which are important in the regulation of society: non-verbal communication.

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Part 18

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NON-VERBAL COMMUNICATION

Back-ground ethology

If an animal is to react appropriately to environmental stimuli (and thus to survive) it has to have a "memory" or store of remembered situations which commonly arise in the environment, and of the most advantageous courses of action to be take in each situation. In other words it is not only necessary to be able to perceive a lion or a butterfly in great and colourful detail by our senses, but, in order to survive, it is essential also to "know" (or "remember") that the potential consequences of meeting a lion or a butterfly are vastly different.

Memory can be inbuilt, in which case it is inherited in the same way as body form and function are inherited. Alternatively the memory may be stocked with learnt information.

When the memory is inherited the animal can be expected to react appropriately to a given set of stimuli even though it has itself never encountered the situation before, or could have learnt about it from other members of the species. Thus a weaver bird, which has been reared in captivity (possibly by parents who were also cage birds) will build a perfect weaver-bird nest, the plans for which it could never have seen before. This phenomenon, which is particularly well-developed in birds is called "instinct". It governs the feeding habits of birds, courting, mating, nesting and migration.

An inherited memory has the advantage that the information in the memory is passed on, in its entirety, from one generation to the next complete and without error. The disadvantage is that it lacks versatility. An inherited memory that cannot be modified by learning is a positive danger when the environment changes. If an animal continues to rely on instinctive behaviour under these circumstances it is very likely to react inappropriately, possibly with fatal results.

A memory acquired by learning is more versatile than instinctive memory, since individuals can learn

from any new situation which might confront them. Thus they can modify their behaviour to suit the changes in the environment. An acquired memory does, however, suffer from the very serious drawback that in the process of gaining experience the individual will make countless mistakes. Furthermore, one can never make a fatal mistake more than once. In fact you cannot learn from fatal mistakes - the very ones one wants to learn about and avoid!

Those animals which rely predominantly on learnt memory are thus forced to be gregarious by nature so that the experience of the troop can be passed on to the individual by way of example, traditions and advice. In this way the individual is spared from having to learn from all the mistakes himself.

All animals, even amoebae, have the capacity to "learn" to a certain extent, and to modify their behaviour in response to new patterns of stimulation. Presumably instinct is also present throughout the animal kingdom, but the extent to which it regulates behaviour varies from one species to the next.

The higher primates, including humans, rely very heavily on learnt behaviour, and are therefore predictably social animals. During the prolonged formative years, in these species, the young animal absorbs attitudes and traditions at an astounding rate, and gradually builds this up into a fund of principles which will guide his adult behaviour in a wide and varied set of circumstances. It has been shown for instance that 4 - 5 year-old American children, during the 1960's, unhesitating ranked Russians, the English, the French, Mexicans and African Americans in order of goodness through to badness exactly in accordance with the order accepted by American society, even though those children had never met representatives of some of these cultural groups, or would even be able to explain why they were so good or so bad.

To what extent humans rely on inherited memory is not known, but if one extrapolates from observations on the other primates, such as the chimpanzee, the baboon or the gorilla, one would doubt whether there are many spheres in which learnt memory does not play a decisive role. These higher primates are quite clueless about courting, mating, and the rearing of their young if they themselves were brought up in isolation from other members of their species. At one particular zoo an attempt was even made to teach gorillas the art of courting and mating through the medium of videos made in the wilds, but his appears to have been a failure. The gorillas showed no interest in the TV screen once it had become an established piece of furniture in their cage. Gerald Durrell in his book "The Stationary Ark", however, gives a very amusing account of how they had to teach a very proud, doting young Urang-Utang mother how to breast-feed her baby. She eventually did put her baby to the breast, although she made it abundantly clear that she thought that this was a very strange and unusual thing to do with a baby. She seemed only to be doing it to humour her human attendants!

The acquisition of food seems similarly to be governed by learnt memory. A baboon taken from the Kalahari does not know what can be eaten, and what can't be eaten on Table Mountain; and vice versa, with baboons taken from the Cape Peninsula to the Kalahari.

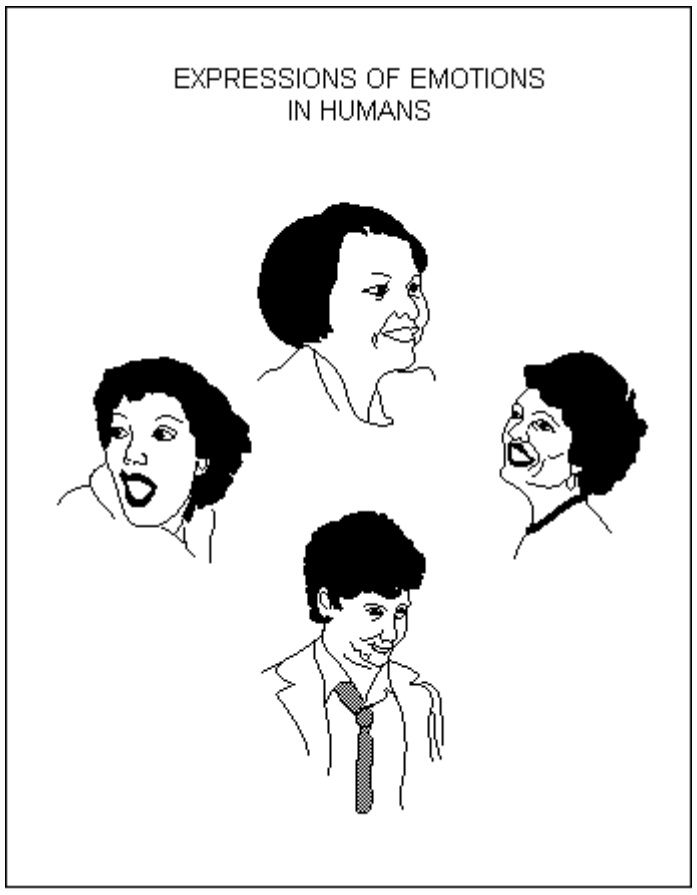
It is thus clear that in the higher primates, and presumably therefore also in humans, even these fundamental survival requirements are regulated to a very large extent by learnt memory rather than by "instinct".

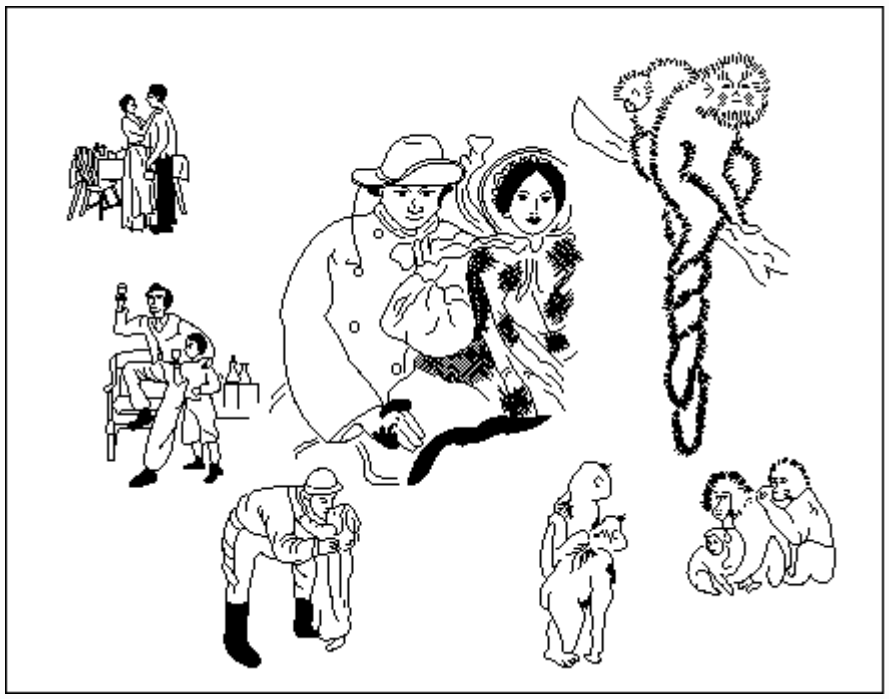
It is therefore not strange that human physiological needs are satisfied in so many different ways amongst different societies and cultures around the world. Tradition dictates what the individual should eat, how he should be clothed, and how he should react to members of the same, and of the

opposite gender, to his superiors and to his inferiors etc. etc. That humankind adheres to traditions as if they were instincts is to be expected since the traditions take the place of instincts. What is, however, more remarkable, is the human capacity to discard obsolete traditions in favour of more appropriate traditions in a changed environment. Thus, there are virtually no precedents for life in a modern industrial city comprising many millions of people, yet humans have adjusted to the altered environment extremely well, and have built up an entirely new set of values and traditions, virtually within one generation.

Facial expressions of the emotions

For social animals to live together they must have a good communication system, to display their feelings of irritation, happiness, sadness, alarm, embarrassment, camaraderie, boredom, anger, sexual interest, playfulness, superiority and servility to others. This non-verbal communication is extremely well developed in humans, and finds expression in facial expressions, tone of the voice, posture, dress, hair style, and choice of jargon etc.





To a certain extent the facial expressions of the emotions are inherited. Thus a congenitally blind child will smile as a symbol of recognition and benevolence, even though she has never seen a smile or has been able to appreciate the effect it has on other people. On the other hand, many of the more subtle forms of non-verbal communication are learnt and therefore vary from one culture to the next. Since a person from one culture does not automatically understand the non-verbal communication of someone from another culture, she may find the other person "unpredictable" and "capable of anything", and therefore presumably dangerous. This is a very potent of

intercultural mistrust and suspicion.

Sheila Hocken was congenitally blind, but after a cataract operation in adulthood was able to see for the first time. This is what she wrote about faces when she was first able to see them:

From 'Emma and I' by Sheila Hocken. Victor Gollancz, London 1977 pp. 186 - 187:

> I took some time to get used to the idea of facial expressions. I looked at Don from time to time, and thought: people don't have one face, they have hundreds. In a blind world there is only one hazy idea of what a face might be. There is no thought for that face being capable of change through laughter, sadness, or any other expression. And my face too, was changing. During that first week our friends Eddy and Mike Blain came round, and after they had been with us about half an hour, Mike said,
> "You've changed."
> "Whatever do you mean?"
> 'Well, your face has changed."
> "My face? How?"
> "I don't really know. But it is different. I don't know, I suppose it looks somehow more alive, Sheila. You're using expression."'
> And it suddenly came to me that he must be right, and that the slight stiffness I had begun to feel in my face was nothing to do with the operation, as I had thought; instead it was caused by using facial muscles I had never used before. I suppose that children pick up expressions from their parents and from other children. But, never having seen a face well enough to mimic, I was now making up for lost time. I was glad Mike had told me that my face had become alive.

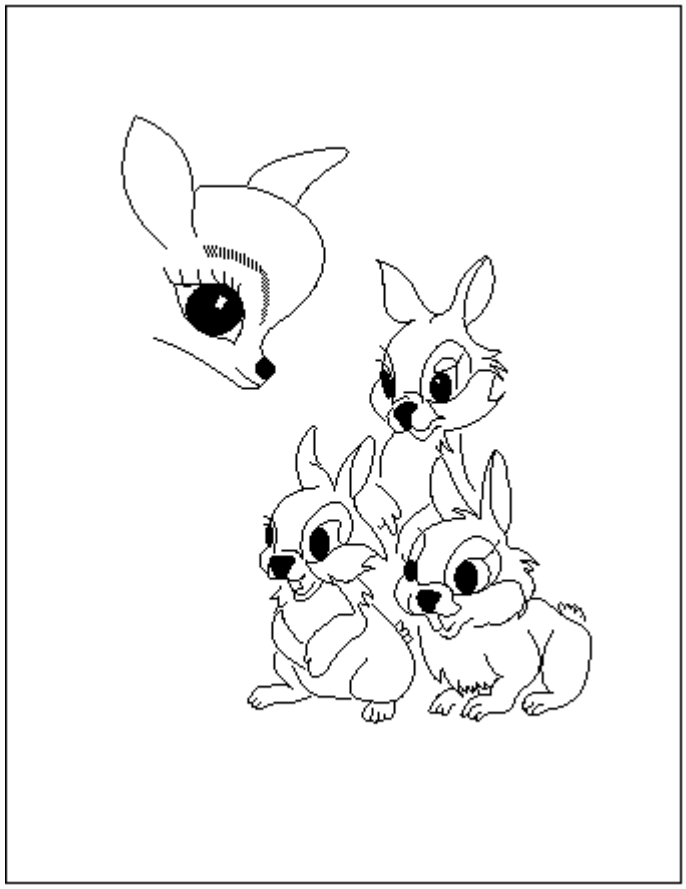
This is in contrast to the non-social animals, who have a very small repertoire of signals to reflect their emotions, because they very rarely come into contact with other members of their own species. Such animals (the bear for instance) make very dangerous pets, since you can be annoying them unwittingly and not have any communication to this effect till the animal retaliates. On the other hand, if you annoy your pet cat, you will get plenty of warning before kitty takes action: the tail begins to swish angrily, the ears fold back, the pupils dilate and finally the whiskers come forward, before the cat lashes out. If you had understood the language of you feline pet you could have avoided the final episode and bloodletting.

Supernormal stimuli

If one understands these forms of non-verbal communication, it is often possible to make a caricature of the message, such that it will elicit a response far more powerfully than the real thing. It has been found that gull chicks will open their mouths when they see the yellow beak of the mother. When presented with a cardboard replica of the beak, with exaggerated features the chicks will ignore the real mother and open their mouths at the cardboard caricature instead. Several forms of natural piracy make use of this phenomenon - when the cuckoo chick, for instance, opens its mouth it displays a pattern of colours which is designed to induce the foster mother to feed the intruder in preference to her own chicks.

The body form of a human baby elicits a behaviour pattern in adults which, for the sake of brevity, will be called "parental instinct". (That it is not a true or complete "instinct" is evidenced by the frequency with which it breaks down and gives rise to neglect and battering.) To reinforce the parental instinct, however, nurseries are often decorated with pictures of baby animals with

exaggerated "baby features" such as the large head, doe-eyes, and dilated pupils of Walt Disney's Bambi and Thumper etc.



These designs probably have no effect on the baby, but they are recognised by adults in whom they can bring out the "parental instinct" more powerfully than the real baby herself does.

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The Human Lifecycle
Part 19

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DEVELOPMENT OF COMMUNICATION

A baby enters the world at birth as a creature programmed by evolutionary forces to survive in human society. It is not helpless, but is armed with a number of powerful aids to enable it to survive. However it cannot do so on its own, so these aids are directed at other human beings.

Aunt behaviour

In the first place a baby confers on the "caregiver" a special place in society. This is true of humans as well as of the other primates, and even of hens. We will concentrate on primate behaviour.

First of all, the possession of a baby attracts the attention of the adult (and sometimes the sub-adult) females in society, who not only are expected to admire the new arrival, and make baby noises at it, but who will also attempt to hold it, and consider it their right, or their duty, to offer advice on baby care to the parent. In human society this is particularly so if it is the father who is holding the baby. Completely strange women, who would normally ignore you, will under these circumstances cross all the social barriers of class, language, status, religion etc., and attempt to take the baby from you. This is resisted by the caregiver, but not always successfully. This sort of behaviour is seen in most of the higher primates, where the females in a community also gather round a new born baby, and make very determined efforts to touch, fondle and behave motherly towards the new arrival. The purpose of this type of behaviour is difficult to understand unless it is seen in its broader context, which is that any member of society has the right, or duty to protect a baby in distress. Under these circumstances subordinate and low-ranking individuals in society have the right to chastise anyone, regardless of rank, if they are seen to distress a baby.

The baby's cry

Aunt behaviour is inhibited when the baby is asleep, but is powerfully stimulated by its cry. A human or chimpanzee mother in possession of a crying baby will have to show extreme determination if she is not to have her baby taken away from her. A man in possession of a crying baby stands no chance.

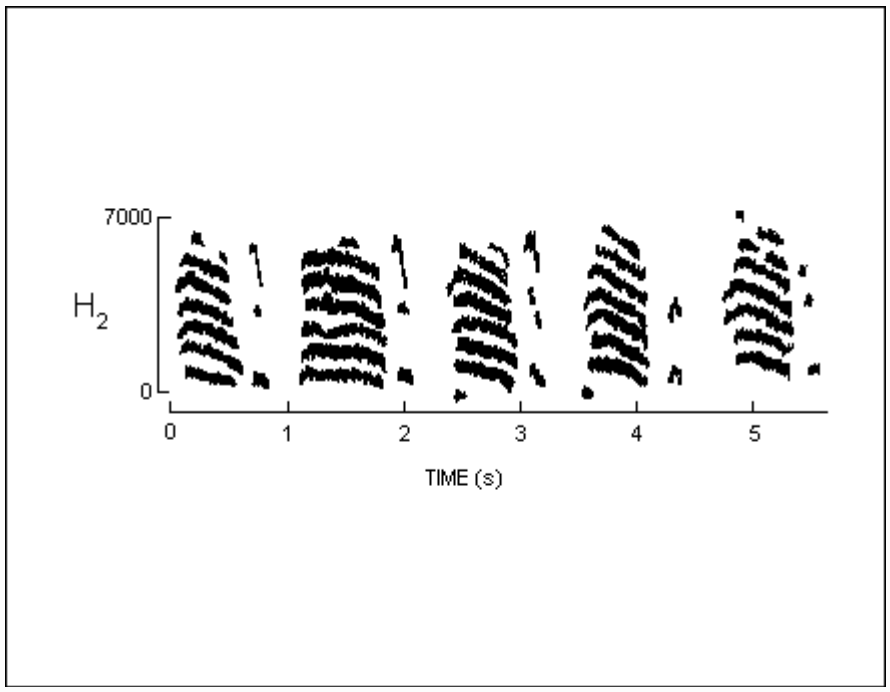
The cry of a baby rhesus monkey instantly alerts the mother, who runs to it and gathers it into her arms. If the mother does not come quickly, then even an adult male will come to rescue.

Three types of cries have been identified in the human infant.

The 'basic' cry or hunger cry.

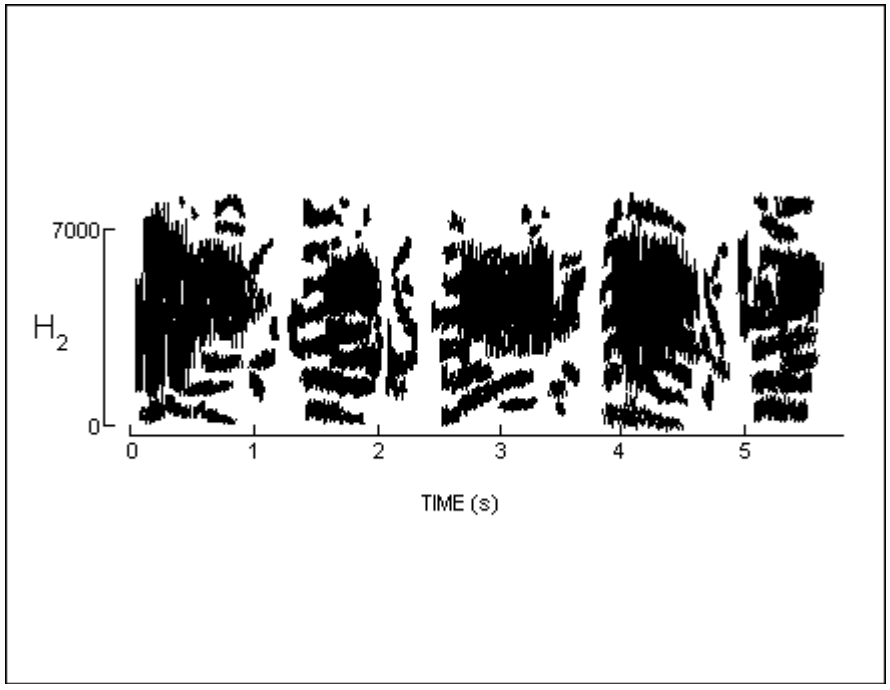
It is rhythmic, consisting on average of a cry lasting 0.6 s, a pause lasting 0,08 s, a high frequency

inspiratory whistle lasting about 0.03 s, followed by another pause (0,07 s) after which the cycle is repeated. This type of cry occurs from about half an hour after birth, and lasts till the end of the second month, after which it continues in a more variable form.



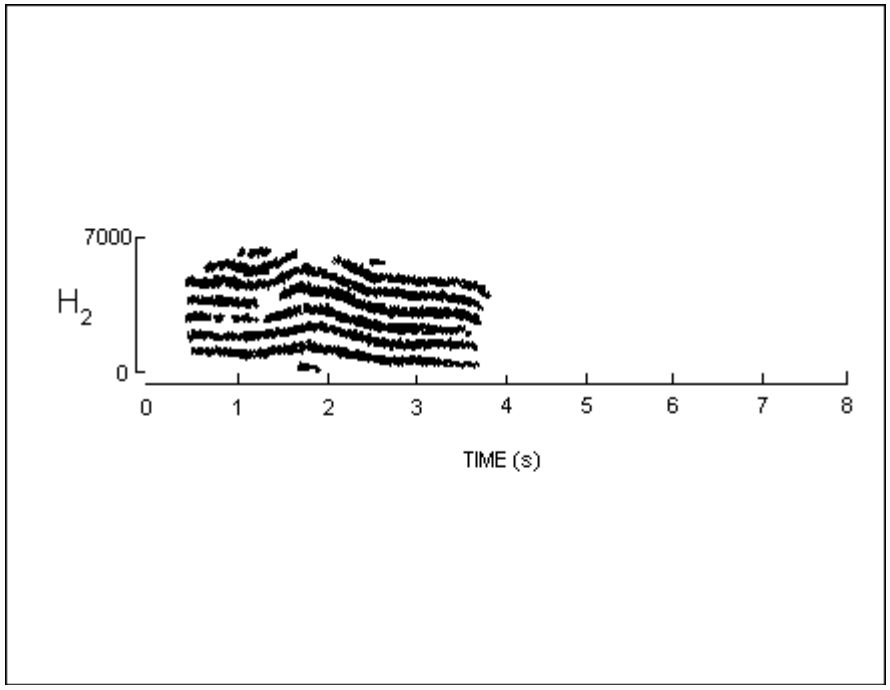
The mad or angry cry.

This cry differs from the basic cry not in its rhythm, but in its constitution. It has a more rasping quality, and is interpreted by adults as an expression of exasperation or anger.



The pain cry

The third type of cry has quite distinct characteristics. It has been recorded just after new born infants have been given a routine pin-prick, or have been circumcised. This is a prolonged cry lasting as long as 4 s, followed by a prolonged silence of as long as 7 s, during which the baby holds its breath (in exhalation). This is followed by inhalation and more crying, gradually turning into the basic type.



The function of their third type of cry is clearly to alert the mother to an emergency. Wolff conducted an experiment in homes by playing a tape recording of the pain cry when mothers were away from their infants in another part of the house. The response of the mothers was to immediately rush into the infant's room looking worried.

There is great variability in the extent to which individual babies cry, and the types of cry they use. There is even greater variability in the responses of the mothers to the crying of their babies.

It should hardly be necessary to state that animals, particularly the primates and humans, are not automatons. The cry of a baby does not elicit a stereotyped response from adults. There are individual differences and cultural differences. Among the traditional Khoi-San, babies were carried at all times close to the mother's body and most of the baby's needs were met before she started to cry. In other cultures, such as amongst the traditional North American Indians, babies were restrained in papooses (types of cradles boards) and left to hang from the walls of the dwellings. In Western societies, babies are put into cots where they are left away from their mothers for considerable periods of time.

Within our culture there are mothers who demand-feed their babies (i.e. whenever they utter the basic cry) while others try to subject their infants to a rigid feeding schedule, as a form of discipline. (Whether either form of behaviour ever remains "pure" or substantially different from the other would form the subject of an interesting investigation!)

This variability of behaviour is as useful to the species as the diversity in body form and physical function. It means that although a particular form of behaviour may not be ideal at that particular time, or in that particular place, and may even be detrimental, (just as certain genes may be detrimental to human life as it exists today) that form of behaviour or response is nevertheless available and has been tried out. Should there, therefore, be a need for it, due to changed circumstances, it can will be immediately be implemented. A species can only survive if it maintains diversity of form, function and behaviour amongst its individual members.

The average behaviour (Cf. The average form and function) is generally the most advantageous for the society at a particular time and in a particular place. The deviants from this behaviour, though important from the point of view of the survival of the species in a changing world, are likely to be the least happy, and worst adjusted to the circumstances as they exist.

The smile

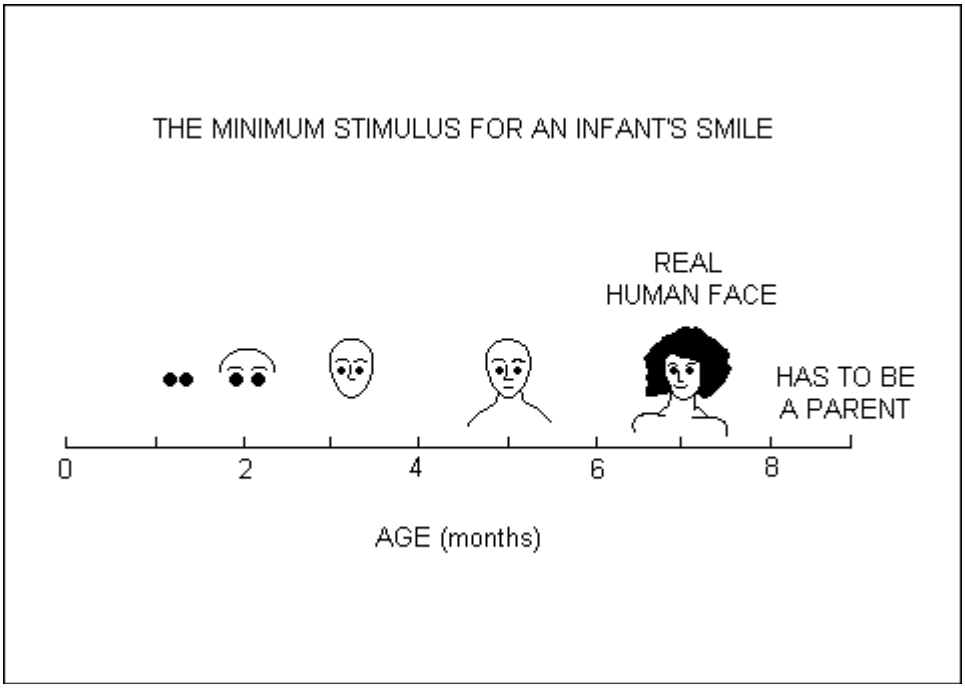
During the first year of post-natal life the baby rapidly extends her repertoire of signals and responses, and as she does so she elicits fewer and fewer "aunt responses" form strange adult females.

Smiling, like crying, is one of the infant's major aids in her struggle for attention, and thereby survival.

Clear-cut recognisable smiles first pass across an infant's face at about 5 weeks. They are elicited by the human voice and face, and develop into a strong social smile during the ensuing 6 months.

At first 2 black dots on a white card will elicit smiling, but 6 dots will elicit even more smiling than 2 (a case of supernormal stimulation which has been described before).

At about 2 months the dots have to be more like eyes and have to be accompanied by eyebrows and forehead features to elicit a smile. As time goes on more and more face-like details are needed to evoke smiling. By 8 months of age nothing short of a real human face will do. The smile is always bigger if it is accompanied by a human voice.



After about 7 - 8 months the smile is reserved for the mother's face and voice, and the child begins to display expressions of fear and will start crying if confronted by strangers.

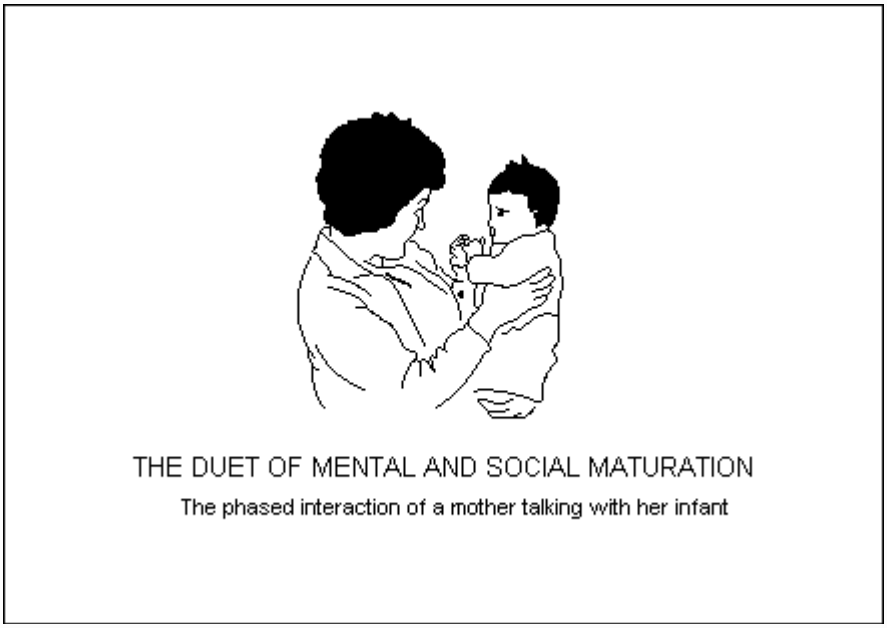
Blind children also smile, but here it is in response to only the human voice, and, eventually, in response to the mother's voice.

The response of the adult to the smile of the infant is to smile back, and to accompany it with a vocal greeting. The vocalisation takes the form of high pitched utterances, which may consist of words but can equally be a series of nonsense syllables. It is the pitch and rhythm of sounds which carries the message of tenderness and social acknowledgement.

The communication duet

Also important in the interaction between the infant and the adult is the sequence of the signals. The only way you can be sure that a given facial expression or vocalisation is intended for you is that it alternates with your signals in a meaningful and harmonious manner, like a duet. Everyone will have experienced the situation in a crowd when you believe that someone has recognised and smiled at you, from a distance, say. You smile back, but then quickly realise that the original smile was not directed at you, but another person behind you. This always causes you some embarrassment, because you had embarked on a communication duet, which was not reciprocated. Very few forms of human communication are unidirectional broadcasts of emotional or other information, as in a news broadcast on radio or TV.

Thus, from an early age mothers hold their infants on their laps, so that they are facing each other.



The mother smiles and vocalises and moves her head rhythmically towards and away from her baby. At first the infant regards this with rapt attention, with widening of the eyes and stilling of any body movements. Then, as her excitement increases body movements begin again and she may vocalise in return and eventually let a smile spread over her face. Throughout this sequence the mother's actions are carefully phased with those of the baby. As the baby shows signs of attention her behaviour becomes more restrained, but as the baby's excitement increases the mother starts vocalising more rapidly and the pitch of her voice rises. As the child is about to smile her movements are once again suddenly reduced as if allowing her time to reply. If the mother does not pause to allow the baby to reply, but subjects her infant to an unphased barrage of stimulation the baby becomes confused and may start to cry, or to turning away from the mother.

Conversely if the child does not reply (i.e. make phased responses) the mother becomes distressed, and if this happens all the time, she becomes withdrawn from her child. Eventually she may not dare touch her child in love, and become emotionally cold towards the child. This occurs in the condition called 'autism' in which the child seems to lack the ability to tolerate other human beings who represent mere objects to them (it seems).

Illustrations and website design by Ann Koeslag

Part 20
VERBAL COMMUNICATION
Children who are brought up, either intentionally, or accidentally, by deaf-mutes do not develop language, even if they are exposed to it via a television set or the radio. There were, in fact, a number of attempts by mediaeval monarchs to find out what the true original basic human language is, by isolating babies from birth with deaf-mute nurses for the first 10 years of their lives. These monarchs expected the children to come out of this experiment speaking some ancient language such as Hebrew or ancient Greek etc. Instead, the ones who survived the deprivation dwarfism came out speaking no language except the sign language of the deaf-mute nurses!
Under normal circumstances, however a child will acquire the language of the family into which she is born with remarkable skill, and within a remarkably short span of time, almost without direct instruction. Most children complete most of their basic language-acquisition by the age of 5 years. By then the child has dissected the language into its minimal units of sound and meaning, and knows most of the rules for combining these sounds into words and meaningful sentences. More important, the child has learned to use the language in a phased, interactive manner, with other

humans, called dialogue.

Registers and dialects

It should be emphasised, at this stage, that a person may think that she can speak only one language, e.g. English, whereas, in fact, she speaks a very wide variety of languages, all called "English" but each with a different vocabulary and grammar, appropriate for different situations in life. The so-called "correct" English which is painfully acquired in English lessons at school, is a language that is seldom if ever used in conversation. It is largely a written language, to be used in official letters, essays and in communicating with faceless strangers, as on the radio or on TV. A quite different language is used at home. A different one yet is used in the office at work. Yet another language is used in church, or at scouts, or amongst mountaineers, or surfers, or jail-birds etc. These variations in language are termed "Registers". Part of learning a new language comprises the acquisition of the different registers, and when they should be used. Occasionally a "register" might be derived from a completely different parent language. Thus in Sauris in the NE Italy, Italian is used in church and at school, Friulian is used by the men to communicate with others outside the family, and German is spoken at home, or when angry or being denigrating. In another example, the Holy Roman Emperor Charles V maintained that he spoke Spanish to God, Italian to women, French to men and German to his horse.

"Dialects" are independent languages, each with a full set of registers. They are generally distinguished from "Languages" by the fact that they are not taught at school. (The moment a dialect is taught at school it acquires the status of a "Language".) People who speak a dialect will, however, often use it as a register of the "official" language in the way that the people of Sauris in Italy use Italian, Friulian or German, and various registers of each of these, depending on whom they are addressing, and under what circumstances.

Apart from these many different registers, each layer of society speaks a different form of English. Thus the English spoken by the Cockney is not the same as the English spoken by the British aristocracy, nor is the English spoken in Bishop's Court (in Cape Town) the same as the English spoken in Rondebosch East. Whether one calls these variations "dialects" or "registers" depends on the your perspective. In practice both dialects and registers have a full sets of grammatical rules and vocabulary, as complex and intricate as the language taught at school. One could possibly maintain that a dialect will consist of many registers, whereas a register is not further subdivided into subregisters; but this is a moot point with very little practical usefulness.

"There ain't nobody here," is correct colloquial, conversational English, as only English speaking persons use the sentence. But it is incorrect English in the register taught at school. If someone used the school-taught register when an English speaking person would have used the phrase "There ain't nobody here," this would almost certainly cause offence, or raise an eyebrow about the speaker's emotional state. Alternatively the speaker would be identified as someone whose home language is not English.

Each register of, say, English is an authentic, separate language, with its own strict rules of grammar, vocabulary, and intonation. None is more correct than any other, except for different purposes. To use conversational English (in exactly the way that it is spoken) in writing is not only incorrect, but almost unintelligible. This is because it is not intended to carry a great deal of factual, encyclopaedic information. It is indulged in mainly to be social. Sentences are often incomplete, 'ungrammatical', ambiguous, garbled nonsense, or many even not contain recognisable words. The meaning in conversation is contained, to a large extent, in the intonation and accompanying facial expressions and gestures.

The child at 5 years of age speaks the type of conversational English that is accepted and meaningful in her circle of acquaintances and friends, and, as such, is perfectly grammatical and correct.

Acquiring the home register

The first scientific attempts at recording how children learn to speak, consisted of keeping diaries of the words used by children of different ages, as if language learning consists largely of copying

'words'.
The picture that has emerged from more sophisticated investigations is, however, that the child is an active language learner, continually analysing what is heard, and proceeding in a methodical, predictable way to put together the jigsaw puzzle of language. Different children learn language in similar ways. What will be described here is the acquisition of English, though almost identical information has been obtained about the learning of French, Russian, Finnish, Chinese and Zulu.
Children learn phonology, (sounds in the language), syntax (sentence construction), semantics (connotation of words) and pragmatics (adapting language to the occasion), by breaking each system into its smallest parts and then developing rules for combining the parts.
The most general rules are hypothesised first, and as time passes the rules are refined and exceptions are accommodated etc. Thus at the earliest stage of acquiring negatives a child might apply the general rule that a 'No' at the beginning of a sentence will negate the statement of that sentence. All negative sentences will then be formed according that rule.
But the child does not stop there, she is continually revising and refining the rules and establishing sub-rules, to enable her to create a full array of complex adult sentences. This process of refinement and the acquisition of new English registers probably never really stops, nor need it ever stop if the person is socially active.
Thus a child approaches the problem of language learning in an economical way, concentrating on broad issues before dealing with specifics.

Baby talk:

Most infants, even if they are deaf, coo and babble during the first 6 months of life. During this time they are learning to interact with a caregiver adult, usually the mother, with facial expressions and vocalisations. It is these phased interactions that are essential for the acquisition of language, since the child will not simply copy the sounds she hears around her like a parrot, but learns to speak during the process of 'duet-singing' with her caregiver, in which sounds and expressions are exchanged to the mutual delight of the participants.
The language the child therefore learns to speak develops between mother and child. Both contribute to the vocabulary, which, therefore, differs in detail from 1st to the 2nd and the 3rd child etc. There is no question of the mother "teaching" the child to talk. Speech in the early stages is very much an extension of non-verbal communication and develops as a way in which mother and child get on together.
At first the caregiver will use long sentences as well as nonsense sounds and words during the interchanges with her infant, but as soon as the child shows signs of wanting to use words, or starts to make sounds that are construed as words, she gets exposed to a special kind of language called 'baby talk'. The characteristics of this language seem to be universal, and it can be recognised as being 'baby talk' whether the caregiver normally speaks English, Zulu, Arabic or Swedish. First of all, the speaker uses a high pitched voice, with exaggerated intonations, and very short simply sentences. The words are frequently made by duplicating syllables such as 'wawa' for water, or 'choochoo' for train, or by reducing the number of syllables from 'stomach' to 'tummy'. The most characteristic feature is however the short very simple sentences.
The exact purpose of baby talk is not known, since there is no evidence that simplified words aid pronunciation. However the simple sentences probably do help the child to recognise the elementary rules on which it can build its own attempts at speech. The high pitched voice indicates that speech is intended to be affectionate.
Thus a child is not exposed to the language of adults at all. The language it is exposed to by the caregiver can best be described as a language about 6 months in advance of her own.
The following is an example the language used by a caretaker with an 18 month-old child:
That's a lion.
And the lion's name is Leo.
Leo lives in a big house.

Leo goes for a walk every morning.
And he always takes his cane along.
At first the child uses single words, usually consisting of concrete nouns and verbs. Adjectives are acquired later. By the time the child is using 2 word sentences it already has a vocabulary of a few hundred words. The next stage is short sentences, which has been called 'telegraphic speech', in which children deal with the grammar problem by sticking rigidly to a fixed word order to denote which is the subject, the verb and the object. They do not use suffixes as adults do to give them more flexibility with word order. Thus an adult can say 'The dog followed Johnny", or 'Johnny was followed by the dog'. The child uses only the more common first form in which the subject comes in before the verb, and the object after it. All their sentences are constructed in this way.
The child deals with plurals in a most sensible manner, by over-applying the general rule that an 's' at the end of a noun makes it plural. Thus she will talk of dogs and cats, but also of foots and mans. Occasionally a child will use the word 'men' before she discovers the general rule that an 's' at the end of a word makes it plural. She will then actually change to the use of the word 'mans'. This often distresses parents, as it seems to indicate regression. It is not regression at all. When the child used 'men' at first it was repeating an individual memorised item without really knowing that it denoted the plural, or that there were other plurals.
As other rules are discovered these may be over-applied, until the various rules are all made to slip into their correct adult proportions.
Children do not generate general rules only about grammar, but also about word meanings (or semantics). Thus a child may refer to a dog as a 'bow-wow'. But soon extends the use of that word to other 4-footed animals. A 'choo-choo' comes to refer to anything mechanical that moves etc. It is only as a child progresses that the meaning of words is narrowed down until at last it more or less corresponds to the adult use of the word.
Throughout this process the caregiver also talks a language in which general rules outnumber the exceptions to the rule. The simplified child-talk remains very distinctive in its rhythm and pitch, whether it is Chinese, Swahili or Spanish. You can always recognise a children's programme on the radio by the way in which the presenter speaks and uses her language. This child-talk is always a little ahead of what the child herself is speaking at the time, but which she nevertheless understands perfectly well. In fact, it is interesting that children will recognise mistakes in the adult's speech before they themselves are able to avoid that mistake. There is a classic example of this recorded by Brown. The child kept referring to 'fis', but when Brown repeated 'fis?' the child indignantly said 'No! fis'. After several such exchanges Brown tried 'fish', and the child, finally satisfied, said 'Yes, fis'. Here the child was still generalising about the 's' and 'sh' sounds at the end of words, but could already distinguish the difference when an adult made these sounds.
Since children do not speak ungrammatically, but apply over-generalised rules, it is not surprising that children are fairly impervious to correction of their language by adults, and, indeed, to any attempts at "teaching" them language. Consider the boy who lamented to his mother 'Nobody don't like me'. His mother tried to correct him by replying 'nobody likes me'. The child repeated his original version and the mother her modified one, eight times over. At last the mother became exasperated and shouted 'Now listen carefully: nobody likes me'. To which the child responded 'oh, Nobody don't likes me'. The child did not understand what the adult was correcting, or it may have been that the information that the adult tried to impart may have been at odds with the rules the child was postulating for producing language.
It seems to be virtually impossible to speed up the language learning process. Since children do not learn by imitation, frequent correction of their mistakes by adults has an inhibitory effect on their learning process, for two reasons. First of all, these corrections confuse the child, and secondly they interrupt the interaction between the child and her caregiver, which is, after all, the function of language. Secondly the child is already putting maximum effort into acquiring language. Most adults, in fact, do not try to correct the language of their children, accepting their type of English as readily as they accept the many other registers of English which they encounter in everyday life, without even realising that the rules of 'correct' English are different in different circumstances.

Development of Social Speech

By the age of 5 or 6 years the child has recognised and is using all the rules by which adults construct their language. The actual rules which the child follows are partly those of her parents, but at the age of 5 she is also using rules learnt from her peers - in other words those of the neighbourhood. However apart from learning the phonology, syntax and vocabulary, a child also has to learn to adjust her language to take the characteristics of the audience into account. As adults we do this unthinkingly, as illustrated by an experiment of Douglas Kingsbury when he was an undergraduate at Harvard.

He casually approached randomly selected strangers on the street and asked them the way to Central Square (in Cambridge, USA). When he asked the question 'Can you tell me how to get to Central Square', in a nondescript local accent, the typical reply as brief and direct, containing no more, or less, information than the situation seemed to require (e.g. 'First stop on the subway'). However, when Kingsbury prefaced his question with 'I'm from out of town." The same busy Cantabrians gave him involved and explicit instructions, describing landmarks he would encounter en route, and telling him how he could be sure he was in Central Square when he reached it. Interestingly Kingsbury found he could achieve the same effect if he signalled his ignorance of local geography by adopting a rural Missouri accent which is exotic enough in Cambridge to indicate quite clearly that "I am from out of town".

What those Cambridge pedestrians were demonstrating was their implicit knowledge of how to use language communicatively. They did not say the same thing even when they were talking about the same thing: how to get from point A to point B. They tailored what they said, and how they said it, to suit what they understood to be the knowledge and perspective of their listener.

When adults are confronted with the task of describing an unfamiliar object to a stranger, they find this trivially easy. Their speech is detailed, and contains a lot of redundant reiterations, and re-phrasing of the same thing, so that there can be no mistaking what is meant.

This was shown in an experiment by Krauss, in which 2 adults were separated from each other by an opaque barrier. The person who was to be the speaker had in front of him a page showing 6 abstract designs or doodles, numbered in order 1 to 6.

The listener had in front of him the same designs, arranged differently on the page, and not numbered.

The task called for the speaker to describe each design and give its number so that the listener could identify the appropriate doodles and number them accordingly.

Even though the objects had no familiar names, and did not evoke simple unequivocal descriptions, adults found the task trivially easy. No pairs of adults, whether they were university students or army recruits, made any mistakes. The speakers' descriptions were detailed and clear enough for nursery school children to understand which figures were being referred to!

But here is the interesting part: when the same pairs of adults were asked to repeat the test, even though they had not been allowed to communicate with one another after their first anonymous encounter, they completed the task much more rapidly, with the speaker using on average only about 4 words per item instead of 9 per item as on the first occasion. After doing the test 4 times the speaker was using one word per item, and his partner was still getting them all correctly numbered. The original long descriptive phrase remained the effective reference. Subsequent messages were mere reminders to the listener of that more detailed description. Thus item 6 was described by one speaker as "An upside-down cup. It's got 2 triangles, one on top of the other", in the first trial. On a subsequent trial that was shortened to "An upside-down cup", and it finally became "The cup".

	INITIAL (REFERENCE) DESCRIPTION	SHORTER VERSION	SHORTEST VERSION
	Looks like a motor from a motor boat. It has a thing hanging down with 2 teeth.	Motorboat with teeth.	Motorboat.
	It looks like 2 worms or snakes looking at each other. The bottom part looks like the rocker from a rocking chair.	Two worms looking at each other.	Two worms.
	It's a zigzag with lines going in all different directions.	The zigzag with lines.	Zigzag.
	It's like a spaceman's helmet. Its got 2 things going up the sides.	The spaceman's helmet.	Helmet
	This looks something like a horse's head.	The horse's head.	Horse.
	It's an upside down cup. Its got 2 triangles, one on top of the other.	An upside down cup.	Cup.

Even the nursery school children could follow the shortened versions if they had previously been given the initial descriptions. But without those initial descriptions no one could know what was being referred to when the speaker talked about 'The motorboat' (item 1), 'The two worms' (item 2), 'The zigzag' (item 3) 'The helmet' (item 4), or the 'horse' (item 5). In other words, these adults had developed their own specialised jargon, to cut short a lot of unnecessary and repetitive descriptions. Jargon therefore develops very rapidly amongst humans who have experiences in common, and makes conversations between group members virtually unintelligible to outsiders. There are all sorts of short cuts in logic, meaning, and descriptions. In addition they use familiar words in unfamiliar contexts or give new meanings to established English words or phrases. Furthermore, completely new words - neologisms - are invented as substitutes for more familiar words or meanings, or for completely new meanings or concepts for which standard English has no equivalent.
In other words, a lot of conversation consists merely of strings of 'reminders' to the listener, and, unless you are in the know as to what it is you are being reminded of, you may as well be listening to a foreign language.
As has been mentioned, adults very efficiently gauge what experiences they have in common with their listeners, and adjust their language accordingly, without thinking about it. Children, at the age of 5 years, when they can speak their home language correctly and fluently, still have to learn how to do this however.

When children are asked to describe the abstract designs we mentioned earlier, they used the short idiosyncratic messages from the outset, without first establishing their reference descriptions the way adults do. As a consequence nobody but the speaker knows what is being said. Some of these short descriptions seemed so way-out that the investigators wondered whether the children were just saying anything, but this appeared not to be so, since the speaker usually continued to use the same short message for the same object in subsequent runs, and correctly identified each object if the experimenter referred to them in the words used by the child even 3 weeks after the test. Clearly the speaker's own descriptions were meaningful to her, but not to any one else, because these children had not yet learned to use language to develop a socially shared and mutually comprehensible code.

This comes out in every day life, in as far as children do not vary their descriptions and conversation to suit their audiences. A child will relive the exciting experiences of an afternoon at, say, the zoo in exactly the same words whether she is reminding her parents (who accompanied her to the zoo) of the fun she had, or she is telling her nursery school teacher about it. The parents will of course know exactly what is meant, but the nursery school teacher will be utterly confused, and if she wants to know what it is all about, will have to ask for a 'translation' from the parents.

Here are two examples of children communicating with their (common) grandmother who lives far away, and has no knowledge of the children's everyday lives. The one child is 9, and the other 12 years old. Note that they use correct English (the spelling has been corrected, but not the word content), but comprehensibility differs markedly between the two letters. An adult writing about the same events would have written a very different letter.

9 -year-old writing to his grandmother:

I like the TV games. We play with them a lot. Thank you for them. I have technical motor and a new technical Lego set.

We went on a ship to Seal Island. I don't sit next to Natalie Galagher. The A-Team is finished, boohoo. Sigfried is not coming in so we keep him inside.

Lots of love, Anthony

12-year old writing to his grandmother:

We have just got 2 new TV games: they are called Space Raiders and Space Vultures. My highest score on Space vultures is 2775.

I was happy with my report this term. I am also happy with my teacher.

We recently had an accident with our boat but we managed to fix it. For the first time AI went out in our boat and found I was too light, because I usually go out with my father, which means when the wind comes up we are not blown over.

Lots of love, Peter

How long does it take before children reach the adult levels of competence in this task? Using Krauss's test figures, Hugh O'Brien repeated the test on children from kindergarten to the equivalent of Grade 10 in the USA. He found that even at the age of 10 children are still very poor at describing new information to others, and that at the age of 15 years they are still not up to the adult standard.

To summarise: Speech consists of, and is used mainly as a way of reminding the listener of common experiences or ideas. In our constant babblings, all day long, we impart very little new information to our listeners. The child learns to join in with these "reminders" at home, and speaks the "jargon", therefore, of the household. As its world expands it gradually has to extend its socialising to friends in the neighbourhood, and to adjust its language in order to be able to share in the reminding process with them. It is only fairly late in puberty that a person eventually learns to speak, and communicate with complete strangers in a meaningful way. At that stage she has the adult grasp of the language.

Illustrations and website design by Ann Koeslag

The Human Lifecycle
Part 21

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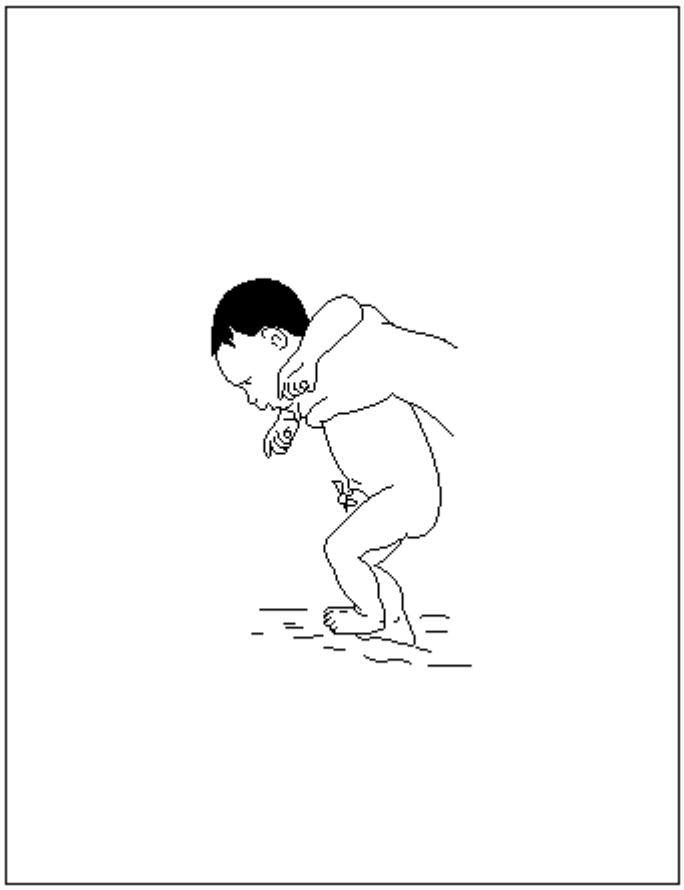
SOME ASPECTS OF BEHAVIOURAL AND INTELLECTUAL DEVELOPMENT

Intuitively one imagines that intellectual development during childhood is always progressive, and that the average 9 year-old child can do all that an average 8 year-old can do plus a little more. And the 8 year-old can do all a 7 year-old can do and a little more etc. Recent studies have shown this not to be so. Intellectual development does not seem to be cumulative the way anatomical development seems to be. The child progresses and then seems to regress.

Walking:

New born infants, if they are properly supported, will march along a flat surface,



But at the age of 8 weeks this ability has disappeared and the child will not be seen to make any walking movements again till the end of the first year.

Eye-hand co-ordination:

On a somewhat more complex level, during the first few weeks of life neonates can reach out to touch visible objects and will occasionally even grasp them. That eye-hand co-ordination also disappears at the age of about 4 weeks and will not be seen again until about the age of 4 months.

Ear-hand co-ordination:

Similarly, young neonates have appreciable ear-hand co-ordination. They are quite willing and able to reach out for objects they can hear but cannot see. This too disappears when the child is about 5 or 6 months old, and reappears much later.

Imitation:

New-born babies have an extraordinary capacity to imitate the behaviour of adults. For example, they are quite able to imitate an adult sticking the tongue out, opening the mouth or widening the eyes. This is a most extraordinary ability as it means that the child can identify parts of the adult body and find these organs on its own body, and then carry out the same actions with them, without being able to see herself. She can only feel herself doing it! However this ability soon fades and only returns towards the end of the first year.

This apparent loss of abilities is not limited to the period of infancy. The pattern of loss and reacquisition of capacities and skills persists all the way through childhood. For example:

Conservation of mass:

An adult knows perfectly well that the weight of a lump of plasticine does not change with changes in it shape. This is a fact that a child must discover, not once, but 3 times over in the course of her development.

If a one-year-old child is presented with a ball of plasticines she quickly learns how much it weighs, and she can pick it up without misjudging the force necessary to do so. If that ball of plasticine is then rolled into a sausage shape in front of the child, she typically misjudges the weight of that sausage, and uses too much force to lift it, with the consequence that the arm flies up over her head. She makes the opposite mistake if she is first presented with the sausage-shaped plasticine, which is then rolled into a ball, because the longer shape looks heavier than the rounded shape.

If one repeats the same experiment when the child is 18 months old she will not make a mistake about the weight of the sausage. She has learned that changes in shape do not affect the weight of an object. But if you ask that child to do this again 2 years later, after the age of 3œ years, then she will once again think that the sausage is heavier than the ball! At the age of 7 or 8 years the child will once again exhibit both behaviourally and verbally that it understands the law of conservation of mass, but at 12 years she will once again give the wrong verbal response just as the 4 year old does! Not until the age of 13 - 14 years does the child arrive at a stable concept of conservation of mass.

The reasons for these repetitive processes in development are not clear. They are not due to a process of forgetting due to lack of practice in the use of newly acquired skill. If children are given a lot of practice at using a skill they have just acquired, it may in fact be lost sooner than if no special practice is given. Furthermore such practice may, on occasions, delay the reappearance of the skill, though in some cases it may accelerate the reappearance - that varies with the different skills. For instance:

Walking versus ear-hand co-ordination:

> A lot of practice at walking during neonatal period seems to accelerate the appearance of walking at one year of age. On the other hand, practise at ear-hand co-ordination during the early phase accelerates its disappearance, and retards its reappearance in the second phase.

The only conclusion that can be drawn from this is that the repetitive processes are not due to forgetting, but suggest that there is, nevertheless, some, as yet unknown, link between learning it the first time and the second. It seems as if the acquisition of more complex skills interfere with the primitive skill or reflex.

A good example is provided by the development of eye-hand co-ordination. During the first few weeks of life a neonate will reach out and grasp any object that moves, is bright or makes a noise, and is within her reach. She does this quite automatically, or reflexly, rather in the same way that she imitates the facial grimaces of her caregiver. She does not need to see her hand to carry out either task - she just 'feels' her body into the right shape to carry out the task. Thus, the neonate is not in the least inhibited from grasping an object in her reach if the lights are put out before she can make a grab for it. She has seen where it is and then puts her hand out in the correct location of the object without any guidance from her eyes. In fact, it would seem that she probably does not even recognise her own hand as belonging to herself, as we shall see shortly.

Furthermore if a neonate is fitted with prismatic spectacles which displace the image of the object say to the left of where it really is the neonate will grasp where she sees the object, and therefore put out her hand too far to the left. Even though she can see her hand going off too far to the left the neonate of a week or two in age will not correct the movement of her hand, and continue to grasp in the wrong location.

If these experiments are repeated on a 6 or 7 month old infant, who is reaching out for objects once again after a period when she seemed unable to perform this task, we notice that putting out the light after she has seen the object causes her great problems. These infants reach out and then have to fumble about to find it. This would indicate the that they are now relying heavily on visually guiding their hand to the object, which is confirmed by the prism experiments. When such a child is fitted with prismatic lenses she will put her hand out in the wrong direction initially, but quickly change the direction of her grasp as her hand comes into view and is seen to be going off to one side of the object that has caught their attention. From there on the hand is visually guided without further problem to the object.

When the young neonate is given a lot of practise at this reaching-out task, the disappearance of the skill is accelerated. The reason is probably that the sight of the hand coming up into view every time she reaches out now begins to occupy her interest. During the period between about 4 weeks and 6 months when infants will not reach out to grasp objects in their reach they are probably completely absorbed by these 'objects' (i.e. their arms) in their view which they make perform such interesting movements just by thinking about them! In other words they are grasping out "into" their own limbs at this stage, and only at 6 months does this become such "old hat" that they turn this new skill of visually manipulating their limbs to the task of grasping objects from the environment again.

The same process is probably the cause of repetitive processes in more intellectual tasks. The child learns the rules which seem to govern the behaviour of a certain specific set of physical phenomena, but does not realise that these rules apply equally well to a broader set of circumstances which she comes into contact with a later age. Thus when you test her at the earlier age she seems to have grasped that objects don't disappear when she can't see them. When she is re-examined at a later

age, her wider experience of the world may have made her realise that there are apparent exceptions to this rule and she may well have revised her concept of what happens to certain objects that cannot be seen, or she may misapply the earlier rule to situations which are essentially different from her earlier experiences.

We can easily appreciate how conflicts and contradictions can arise as experience widens, if we consider the "law of conservation of mass":

We have already seen that at the age of 14 years most people realise for the final occasion that changes in the shape of an object do not change its weight and will base their actions on this assumption. However very many adults do not realise that this is a universal rule of the conservation of mass, and that it applies even to what happens when you burn materials. If questioned about this, an experienced arsonist will probably maintain that fire gets rid of material, and would be considered to have regressed since he was 14 years of age!

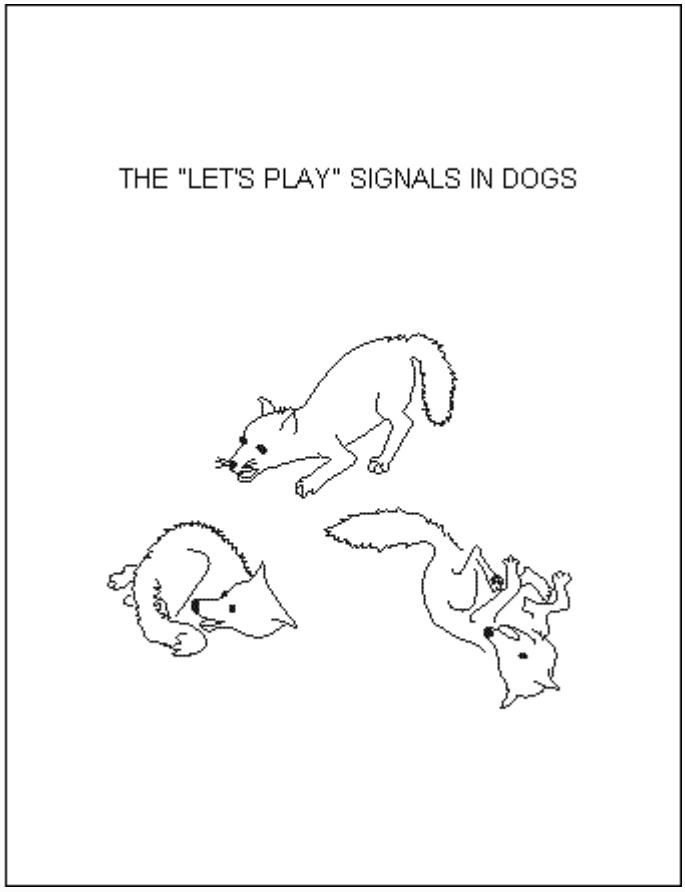
PLAY

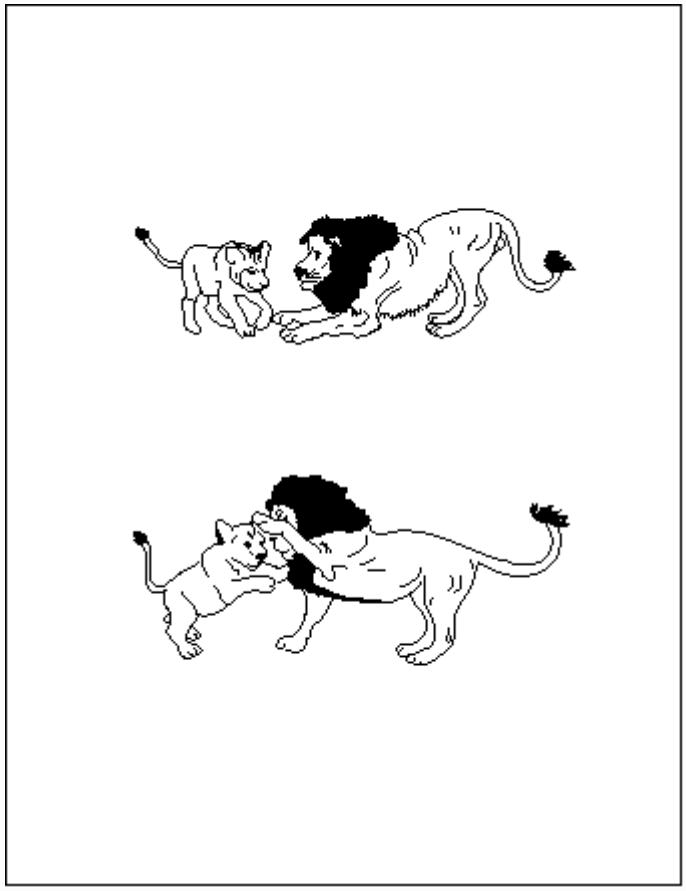
Biologists have become aware that play occurs with great frequency in the early development of a wide variety of mammals, particularly those having long periods of parental dependency and complex social behaviours similar to those possessed by the higher primates.

Play was, for a long time, ignored or even avoided by biologists, since it seemed to serve no immediate adaptive function and achieved nothing to enhance the survival of the young animal. At best is was considered to be an immature form of imitation of adult behaviour.

The very fact however that play behaviour is uncoupled from obvious stimuli or consequences gives it some of its identifying character. It is often repetitious and seems to lead nowhere. In fact if an actual sequence is studied, it resembles adult adaptive behaviour except that the elements are scrambled. For instance, a young mammal at play may begin with a pounce on some object or other animal and then run about chasing it. In addition the behaviour itself is exaggerated, first by the extent of the movements, second by repetition, and third by prolongation of certain phases of movement.

The quantitative modifications that characterise play are very easy to recognise and allow it to be distinguished from 'serious' (goal-directed) behaviour. This is necessary so that the sexual or aggressive nature of some play behaviours are not misunderstood. Apparently, as an additional safeguard, play signals have evolved: facial expressions or body movements that make it clear that what is about to follow is 'just a game'.





These latter features make it possible for play behaviours to become more and more similar to adult

goal-directed behaviours in a gradual shading-off process, which extends into adulthood and even into old age in many animals. Under the protection of play signals, movements become more and more economical, sequences become more purposefully ordered and extraneous frills eliminated. But, if properly signalled, they are still responded to playfully by other animals.

Thus, although play behaviour resembles many other behaviours, it has distinctive features that allow it to be differentiated from serious behaviour. But why does it occur?

When we were discussing the acquisition of speech we saw that a child does not learn to speak merely by copying, parrot fashion, the sounds she hears around her. For speech to develop the child has to try out sounds, and has to construct theories about the effect of sounds on her caregiver. She learns to speak only by interacting with the caregiver, which requires more than just imitative ability.

The same applies to the development of intellectual or cognitive skills. An experiment was carried out on pairs of young kittens, who were brought up in the dark, except for a 3-hour period each day during which one of each pair of kittens was allowed to move freely in a box. She was harnessed however by a system of levers to her partner in a similar box, in such a way that the second kitten was passively moved about her box in exactly the same way as the first kitten. At the end of the 3-hour exploratory session in the light, both kittens were returned to their mother in the dark. After 10 days of this experimentation, the kittens were tested. The active member of the pair showed normal behaviour on visual tasks - it blinked at the approach of a threatening object to the face, and put out its paw to avoid a collision. It also avoided the deep side of a visual cliff illusion. The passive member failed to show any of these behaviours. So here again skills are developed only if the young animal can try out the environment and put it to the test in the ways at his disposal.

Play seems to serve the same function as far as social interactions are concerned. It is only by trying out various forms of behaviour that one learns how others respond to it, and what emotional effect their responses have on you. No amount of plain imitation can achieve that. Each component of behaviour has to be tried out, repeated many times and linked in many combinations and permutations with other bits of behaviour to find out what they mean and how they can be used in society to convey what you mean. Just like speech. Complete sequences of behaviour in adult life will thus be unique, just like sentences and paragraphs of speech are nearly always unique and not simply plagiarisms of the actions or speech of others.

What happens if animals are prevented from playing? This is a rather difficult thing to do in the primates who spend a lot of their childhood playing, whether it is with their peers or with their mothers and other adults. A chimpanzee raised away from other members of its species, will still often play with its human caregivers. However the results of experiments with the higher primates, seem to be in keeping with those in other mammals such as in the rat where play is almost confined to interaction with peers.

When young rats are brought up in age-peer groups which are all of the same sex or are composed of both sexes, behavioural development is essentially normal, even though there are no adult animals to copy. Adult male rats brought up this way will show normal mating behaviour if presented with a receptive female, even if they had had only male company during childhood.

Rats which were prevented from playing with other rats, even if this was simply by means of a wire mesh, which allowed the young rats to see each other, smell each other and to hear each other, did not develop normally. As adults these male rats became hyper-excited when presented with a receptive female, and tried mounting her shoulder, or her head and made clasping motions to her side. Even if such males accidentally mounted the female from behind, the clasping, mounting and thrusting movements were combined into an ineffective sequence which precluded intromission and

ejaculation.

Studies on primates suggest that peer-group play is probably even more essential for the development of normal primate behaviour than it is in the rat. Again groups of isolated young chimpanzees will display normal heterosexual behaviour when they grow up, even if they have not had any examples to follow from other adults. Chimpanzees brought up with only their mothers for company show many deficiencies in their behaviour, and those reared entirely in the company of humans will interact happily with humans as pets and even as friends, but are hopelessly lost in adult chimpanzee society. They certainly have no clue about mating or maternal behaviour. This behaviour in the primates is therefore not 'instinctive' in the sense that it is inherited and independent of childhood experiences.

Nobody can say exactly what is learnt during play in human children, what is strictly instinctive about play, and what is plain imitation of adult attitudes and behaviour. We are probably not all that far removed from the chimpanzees' situation as far as the mechanisms by which we learn to behave as adults. We probably also learn our gender role during play with other children, but it is always in the complex setting of an adult world, which endows us with boys' and girls' names and dress, and encourages certain types of play and certain types of expressions of emotion depending on whether we are boys or girls. But peer group play is still probably the most powerful force in determining how we will eventually behave as adults, as there have been innumerable examples of children who were brought up, outwardly anyway, as members of the opposite sex by their parents. This was quite common during the 19th century, when boys were often put in dresses and had ribbons put in their hair etc. Yet most of these boys grew up into perfectly normal men, while others who seemed to have had their gender role emphasised from the beginning, in isolated cases, showed signs of wanting to belong to the opposite sex when they grew up. There have been celebrated instances of both situations all through history, which simply shows what a wide variety of diverse behaviours humans are capable of - a factor which has probably accounted for much of the species' success in this world.

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