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The Small Book of Big Thoughts

THE HUMAN BODY

Discover yourself

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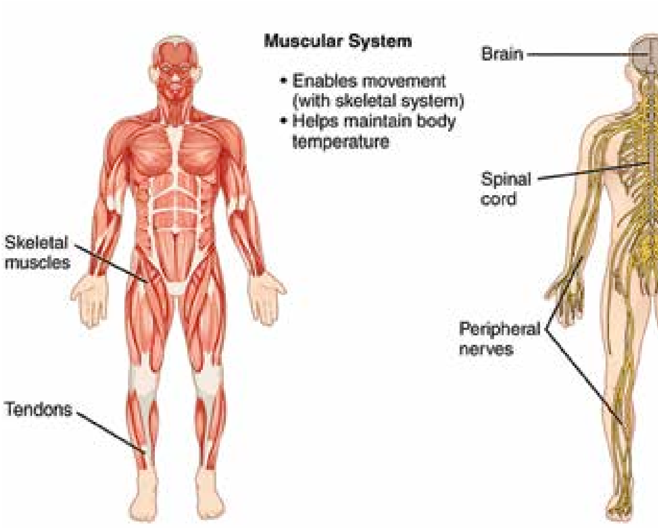
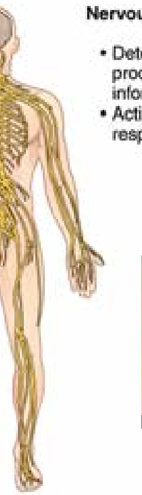
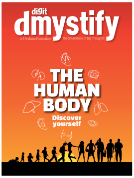
September 2016

The Human Body
Ever-changing from the moment of conception until final death



INSIDE





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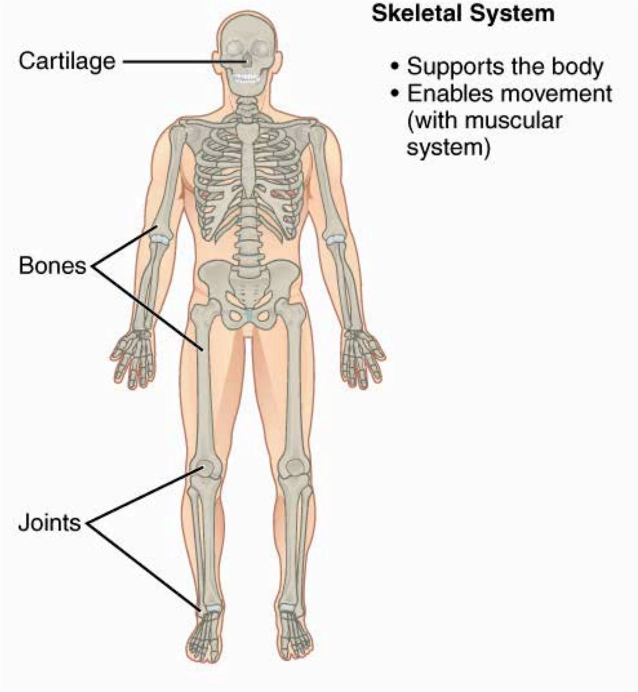

Skeletal System
• Supports the body
• Enables movement (with muscular system)
Cartilage
Bones
Joints

This is us

We've covered a lot of topics now, and even covered human evolution in this series under dmystify Evolution. However, it's now time to discover your body. Settle down now, there will be no sniggering and note passing, and yes, we will have a few pictures of the naked human form, and no, it's not funny. This is just science, and science is no place for the immature. Thus, if you're easily butthurt or scandalised by such images, please stop now. Do not read any further, just give this book to someone else who might appreciate it.

Still here? Good, let's get on with the science of us shall we? ■

Corrigendum

In our previous dmystify, *The Quantum World*, on Page 33, about Rutherford's Gold Foil experiment, we erroneously said "Obviously, thinking of the gold atoms as a plum cake, **they expect** alpha particles to rebound off the gold foil and go all over the place." This is in fact the opposite of what we intended to say. The line should have read: "Obviously, thinking of the gold atoms as a plum cake, **they didn't expect** alpha particles to rebound off the gold foil and go all over the place." Our sincere apologies for this blatant error. The image on page 34 of that book has the correct explanation for the experiment.

History

As usual, we need to start at the start, especially when it comes to us

Since even prehistoric times, mankind has had knowledge about the human body. Ever since mankind started spreading and clumping into groups, it's been at war with itself and its evolutionary cousins for dominance over the Earth. Scientific estimates put the total number of humans to have ever lived (and died) on this planet to be a little over 100 billion since Homo Sapiens first evolved. Who knows how many billions of those died violently, at the hands of other humans. Given that we're still struggling to put an end to violence, and the past was certainly more violent than the present, if we continue along that line of reasoning, one would have to assume that certainly tens of billions of humans died violently. It is violence that first got us interested in the human body.

Violent beginnings

How do you injure someone, how hard do you need to hit, where do you hit them if you're fighting, what's the most efficient way to kill? All of these are really just anatomy questions when you think about it. Pretty much all carnivorous mammals also know this, and fight each other for the rights to mate, or to command territory. Humans were the first to build tools, and also weapons for this very purpose. Perhaps graduating from a humble stick (which would increase reach and striking distance) to spears and axes, and other weapons. Someone once said that you could consider the sword to be a much bigger weapon of mass destruction than nuclear weapons, merely based on the amount of humans killed by each one.

Another grisly way of studying anatomy was during ritual sacrifice. What no doubt started as animal sacrifice would have soon escalated into human sacrifice, and it would have given some people the opportunity to be up close and personal with the innards of human beings. However, sacrifice may or may not have resulted in an indepth study of anatomy.

The undisputed violent precursor to the study of anatomy would have to be torture. Why? Sacrifice would usually be a simple killing affair, by slitting of throats and or decapitation of heads. Similarly, for war, fighters would be trained in attacking and killing swiftly, because you want each of your soldiers to kill more than one of the enemy's soldiers, and thus speed and efficiency of killing is of the utmost importance. Torture on the other hand, requires the eventual death to be as slow as possible, and the suffering to be as long drawn out as possible. This obviously would need indepth study of human anatomy to know what is vital, what isn't, what hurts more, and for longer, but doesn't kill. How do you think people got so good at torture if it wasn't for practice and perfecting the basic understanding of anatomy?

Healing

Because of all the wars over territory, there is no doubt that there would have been many injured humans lying around as an aftermath. Depending on who won the war, and how many were left standing, it is obvious that one would rush to find friends and loved ones amongst the living who might be injured. It is here that some humans no doubt discovered the need to understand the anatomy to be able to help mend things. Who knows how many countless trials for various natural medicines and herbs happened in the past before the initial medicine men were first successful in saving a human life. Coupled with the knowledge they had from all of the violent methods mentioned above, it's quite easy to see how the first doctors figured out that stopping blood loss could save a life. Again, with much trial and error, one would no doubt get better and better at saving lives. This was

Ancient torture technique of enclosing a man in a hollow bronze bull, lighting a fire under it. Was called the bellowing bull because the screams of the burning man sounded like a bull bellowing!

science at work, even before the notion of science even existed. No doubt that countless gods would be given the credit, but it was the innate tendency of pattern recognition that would have started the study of the human body.

Art

There has always been an appreciation of the human form by other humans. Selfish genes have instilled in us the desire to seek out the best possible mates, and this gives us the inherent ability to tell a good body from a bad one. It's not just sexual, or a case of lusting after a good looking member of the opposite sex (or same sex, we don't judge). It's more than that, because we are able to tell good physique from bad for members of the human race of the same gender (or the gender that we're not attracted to). For example, a normal man is able to look at a body builder and realise a physically fit specimen without any attraction whatsoever, and still have appreciation.

This appreciation would have been the inspiration for the first art... and we don't just mean drawings, but also songs, poetry, etc. The understanding of the physical form would be required to be able to establish why someone was more attractive than someone else, and this is why we think early art would have inspired even those not involved with violence to study the human body in more detail.

Early Egyptians

To be clear, as we've mentioned above, the study of the human body was no doubt something that started hundreds of thousands of years ago, but because of the lack of evidence, we can only point out what probably happened. You and we may agree to the logic of all that we wrote before this, and be pretty sure (to a very high degree of probability) that things did indeed happen that way, however we have no real hard evidence of this. It is with the Egyptians that the hard evidence starts surfacing.

As early as between 1600 and 1500 BCE, Egyptians were noting down medical documents. One such document is called the Edwin Smith Papyrus (named after the dealer who bought it in 1862). This Egyptian papyrus has been dated to around 1600 BCE, and contains details of various injuries to various parts of the bodies, and details of what was done to treat them. Given that this is ancient, there are of course also details of which magic spells were cast to try and save the patient. If you ignore the magic spells, however, this is pretty much the oldest hospital record we have as a species. Many historians believe that this was in fact a military hospital or surgery document written by, and for the benefit of, "doctors" who were treating injured warriors.

The Egyptians also understood that the heart was the most important organ for blood, and that all blood vessels led to the heart, and they had also recognised all of the vital organs – lungs, liver, kidneys, spleen, uterus, bladder, etc. Even with the process of mummification, all of these were removed, but kept safe for the afterlife.

Greeks

A thousand years later, it was the Greeks who would enhance the study of anatomy. Going much more into details than others before them, the Greeks were able to understand that you didn't need to hack up humans (living or dead) to be able to understand anatomy, but could in fact hack up animals and study them in detail instead. Plus, there was a bonus of being able to feast on them after (OK, we jest!).

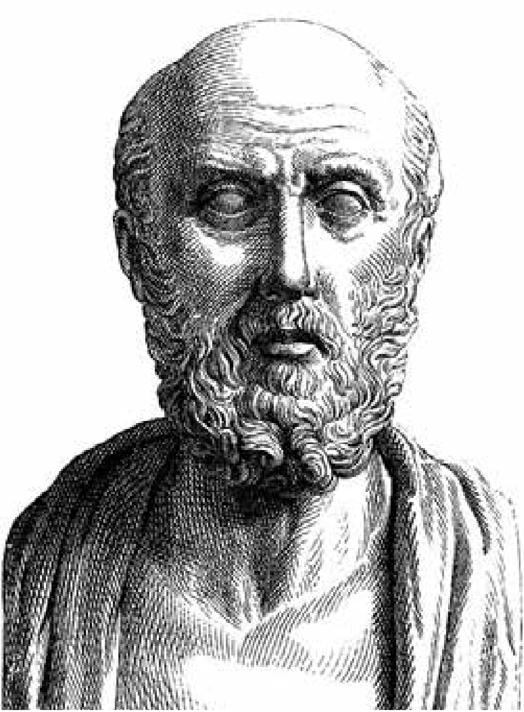
Using animals, the Greeks were especially able to study the eye. They were able to identify the optic nerves (something quite incredible considering this was about 500 BCE! Apart from this, the Greeks were also responsible for spreading the misinformation that the soul lies within the heart. This is understandable, of course, because seeing that all blood goes to and from the heart, and believing that the blood itself was what carried your life (losing a little makes you weak, losing too much kills you, etc.), it was easy for them to reach that conclusion, given their beliefs.

A Hippocratic Corpus manuscript from the 14th century

Hippocrates

Yes, one Greek guy gets a headline to himself, and with good reason. Hippocrates is considered by many to be the father of modern medicine. He lived between 460 and 370 BCE, and was the man responsible for showing that medicine was indeed a different subject altogether. It was previously considered to be a subset of philosophy and the rituals of magic and gods. Hippocrates was the first person in known history to have put forth the idea that diseases were in fact natural phenomenon, and that the Gods were not at all involved in causing them. It is under his guidance and by his followers that the Hippocratic Corpus was written – the Corpus is the most detailed medical textbook of ancient times.

It contains scores of ancient Greek medical papers, which include textbooks, lectures, notes and case studies. Although it is named after HIppocrates, none of the papers are written by Hippocrates himself. In fact, about 20 different authors have contributed the 60-odd texts in the Corpus, and while some are from Hippocrates time, many are from centuries after him. Since none of the work is actually his, and because of the centuries of time difference, many believe that the Corpus is in fact a copy of a collection of medical texts from an ancient library such as famous Alexandrian library.



Hippocrates – the father of modern medicine

Hippocrates may not have written those papers, but he certainly inspired all of those authors. The one thing we can directly credit to him, however, is the Hippocratic Oath, which basically boils down to "Do no harm" whilst pursuing the field of medicine. Even today, many medical colleges across the world have their students take the Hippocratic Oath before awarding their degrees, as it is considered a sacred duty of all doctors to help, and never harm.

Indian

There is no doubt that the ancient Indians also knew about medicine, and also practiced it. However, the lack of actual evidence in terms of books or papers (things which can be dated) means that there is a lot of confusion because of India's ancient oral traditions of learning. Knowledge existing for hundreds, if not thousands, of years before the first preserved text is discovered is definitely a global phenomenon – it's obvious that the Egyptians knew well before 1600 BCE about the anatomy of human body and how to treat injuries, but we only date it to 1600 BCE because of the Edwin Smith Papyrus.

The most ancient text known thus far from India is the Sushruta Samhita (Sushruta's Compendium). Although it is hard to place a date on the compendium, given that no old papyrus or paper has

A statue of "Maharishi Shusrata" at haridwar survived from then, it is by association that historians try and piece together the origins and thus the dates. Thus, some historians claim that the Shatapatha Brahmana (an ancient collection of prose that describes Vedic rituals in great detail) already knew about the contents of Sushruta's Compendium, and thus, since the Shatapatha Brahmana dates to between 1000 and 600 BCE. Other historians, working only with the contents of the text itself, date the text to about 600 CE, which gives us an error margin of about 1600 years! This is discounting our own claims of Maharishi Sushruta having lived in 1500 BCE, which would make the margin 2100 years!

If we accept the most recent non-Indian estimate, so that we can't be called biased as we are Indians ourselves, that's still about 600 CE, and it makes the Sushruta Samhita a very important document indeed. Inside it are details of studies of how many bones there are in the body – they claim 300, and modern medicine count it as 206, but they may have been including cartilage also. The most important contents of the Compendium are the texts on surgery, which include details on how to reattach a nose (or what we'd call plastic surgery today).

Another important aspect is the teaching about how students of surgical techniques should practice their skills – and the suggestions vary from practicing on fruit to dead animals. It also stresses the importance of prevention over cure.

Fast forward

After the ancients, especially the Greeks and Hippocrates, the western world began the practice of medicine as a distinct subject, and this led to a lot of fast paced developments in the more modern world.

Claudius Galenus (popularly known as Galen) was a Greek Physician within the Roman empire who lived between 129 and 200 AD. He worked as physician to the famous Gladiators of Rome, and his proximity to all the horrific injuries the Gladiators suffered gave him a better understanding of anatomy. He also dissected and vivisected many animals to try and understand the functioning of bodies, and applying that knowledge to humans. Just in case you don't know the difference, dissection is the cutting up of dead animal carcasses, while vivisection is surgery on living animals.

One of his major accomplishments was to rid the western world of the misconception that the arteries carried air to the major organs. Because he did a lot of vivisections, he was able to see that arteries in living things always contained blood, and not air. However, he made a mistake in understanding how the blood flowed in the body, and he assumed that it flowed back and forth through the same blood vessels (blood actually circulates to and from the heart going out via arteries and returning via veins). This flawed assumption of his remained for hundreds of years later. Essentially he busted one long-standing myth and created another!

Many others also came along in the years that followed, including Leonardo Da Vinci. He went indepth into the study of human anatomy, and even dissected many human bodies before Pope Leo X stopped him for religious reasons.

It wasn't until the 17th and 18th centuries when medicine really took off, thanks in large part to the invention of the printing press. It was the ability to share printed text that was a shot in the arm for all sciences, and biology was no exception. Finally, the world was able to share ideas by mass printing text and sending it off to all corners of the world. This meant that the knowledge gained by one doctor somewhere could be built upon by another halfway across the globe. Finally, the study of the human body had come of age, and we can now fast forward into the present, now that this very brief history lesson is done. ■

The cycle

The journey of each human from simple chemicals to old age, and then back to chemicals

As far as science is concerned, life is merely a chemical reaction that's happening all over the planet, and we individuals just happen to be one of those many reactions. It's not a very romantic idea, but science doesn't have to be romantic.

However, it's not as simple a story as that either, and there's some pretty complex biology and chemistry involved in making a human. Here, we're going to attempt to run you through the span of a human life in a mere chapter.

Where to start?

Immediately we run into a conundrum. When exactly does a human life start? While religions claim to be able to answer that question with certainty, science doesn't have all the answers just yet. Thankfully, that means scientists are still researching and learning more about this very question, however, we are going to start at the start, when different pairs of chromosomes meet. We aren't trying to answer any moral questions here, so don't assume any stance ours when it comes to complex situations and questions such as whether abortion is moral. That's a philosophical discussion that has no place in a dmystify, where all we care about is the science.

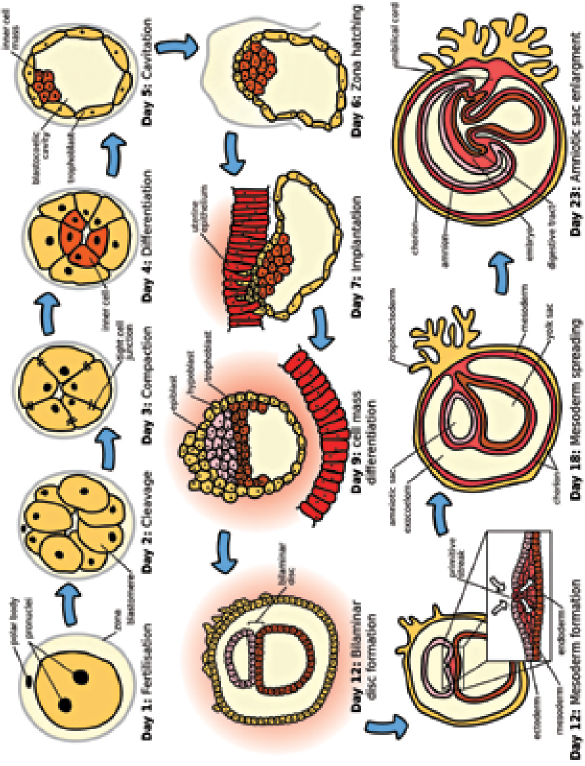
And now we come back to our main feature. Sex happens between a male and female, sperm travels up the vagina and past the cervix to meet the egg in fallopian tubes, and that's how a human gets 23 chromosomes from her mother and 23 from her father to make the 23 pairs of chromosomes that will define everything she becomes. (We choose to use females for all our examples, but this is also how it works for males). And that's how a human get's started.

Cell division

Once the egg is fertilised, it starts rapid cell division, and quickly becomes a blastocyst – in about 5 days after the egg is fertilised. This then implants itself into the mother's uterus, where it really starts to grow rapidly. This is a period when it is is termed an embryo, and continues to cell divide and take energy and nourishment from the uterine wall to grow and divide rapidly. It is during the first 10 weeks of gestation that the embryo cell divides according to the DNA blueprint it has inbuilt into itself to create the various clumps of cells that will later become all the different organs.

Note: While we're talking about pregnancy, you should know that there is a difference between gestational age and age of an embryo after fertilisation. Doctors only usually get involved in the process once pregnancy has already occurred – even if people are undergoing fertilisation and/or hormone therapy, the doctor only comes to know that the pregnancy has commenced a good two weeks after actual fertilisation of the egg occurred. Since the only dates that can really be confirmed with most pregnant women is the date of their last menstrual cycle, doctors calculate pregnancy in gestational age, which is nothing but the amount of time that has elapsed from the mother's last menstrual cycle. This is why the pregnancy cycle of humans is considered to be 40 weeks, which actually means 40 weeks after the last menstrual cycle, or about 38 weeks after fertilisation. In this book we will be using gestational age by default, as that is what doctors use, and what most of you will encounter someday (if not already).

At 10 weeks of gestational age the embryo is upgraded to a foetus in medical terminology. This is because the risk of miscarriage, for whatever reason, is the highest in the first 10 gestational weeks. In case there is some problem with the embryo's develop-


Day 1: Fertilisation
Day 2: Cleavage
Day 3: Compaction
Day 4: Differentiation
Day 5: Cavitation
Day 6: Zona hatching
Day 7: Implantation
Day 9: Cell mass differentiation
Day 12: Bilaminar disc formation
Day 12: Mesoderm formation
Day 18: Mesoderm spreading
Day 23: Amniotic sac enlargement

ment, or some uncorrectable errors in the replication process of the cells, or just improper implantation into the uterus, or because of one of a hundred other reasons and factors, embryos are much more likely to be miscarried (basically rejected) by the woman's body. The risk never really falls to zero, but it reduces drastically when a pregnancy completes 10 gestational weeks.

Foetus (aka fetus)

After the first 10 weeks, the new foetus is about 1.2 inches tall. It looks more like the creature from the Alien series than it does a human at this stage, but then again a lot of mammals look exactly the same at this age. This is, in fact, considered to be another proof of evolution, because unless you're a doctor, you'd be hard pressed to tell a new human foetus apart from a dog's, or pig's, etc. Human foetuses even have tails!

Although the little heart starts to beat in the embryonic stage itself, at about 5 weeks of gestational age, it isn't until the foetus stage that ultrasound devices can pick up the heartbeat. During this time the foetus is seen to move around and seeing that can cause much joy to the parents. It starts looking more and more like a baby (and less like an Alien) very quickly, and by about 3 months of gestational age, the sex organs make an appearance. Of course thanks to the idiocy of some, and the horrendous female abortions and infanticide that they commit, Indians are not allowed to know the sex of our unborn child, even though pretty much any skilled ultrasound technician knows soon after 3 months of gestation. This is for the greater good, however.

The brain of a foetus is a complex thing. Of course we are still getting to know the human brain, so it's a bit of a grey area (pun intended). We do know that the first electrical activity inside what eventually becomes the head can usually be measured by about six weeks gestational age. All through the pregnancy the brain develops, however, and it is only after the 28th week that brain development really speeds up and synapses are firing all over the place signifying what we can relate to as brain activity. This rapid brain development continues quite a few months past a baby's birth as well – she will gain a lot of grey matter rapidly for three to four months after birth.

Birth

A baby is brought into the world via natural delivery or caesarean section. It's a myth that Julius Caesar was born by C-section and thus the procedure was named after him. It is in fact, almost the other way around. Historians believe that an ancestor of the famous emperor Julius Caesar was born by this method, and that's where the name Caesar came from, and was carried on by descendants all the way to the famous Julius Caesar.

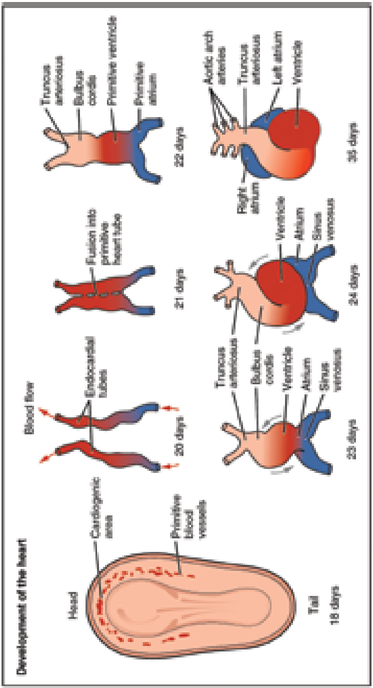
We know this because the romans already had a word for children who were cut from their mother's womb – caesones. Not that they were conducting successful surgeries, because this was usually done when the mother had already died, or was almost dead during childbirth, as a way of trying to save the foetus. If the mother wasn't already dead, this procedure would no doubt kill her.

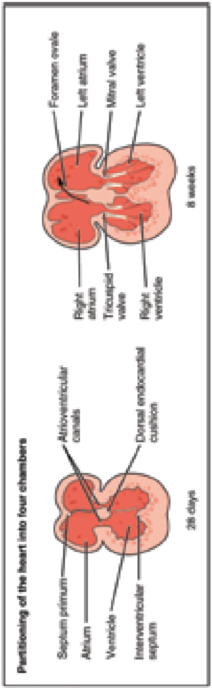
Birth is a very traumatic event for a foetus. So far it has been sheltered, kept warm and cocooned in a very comfortable sac of fluid, and then suddenly it is thrown into a world where not only its body is shocked by the temperature difference, but also it suddenly has to breathe air, and expel the liquid from its lungs, or risk drowning from the fluid in its lungs. The adrenal gland kicks into action, stresses the little baby, and kickstarts the breathing process. This is why the baby cries.

Life for all of us, starts with the struggle to breath in a very stressful situation. Thankfully we remember nothing because our brains are not formed well enough to, or else psychiatry would be the world's largest profession!

Survival techniques

The umbilical cord is cut, and it's a very risky time for the baby. The baby's body has to be shocked into starting up by adrenaline, and all of her organs need to start being self sustaining immediately


Development of the heart
Head
Cardiogenic area
Primitive blood vessels
Tail
18 days
Blood flow
Endocardial tubes
20 days
Fusion into primitive heart tube
21 days
Truncus arteriosus
Bulbus cordis
Primitive ventricle
Primitive atrium
22 days
Truncus arteriosus
Bulbus cordis
Ventricle
Atrium
Sinus venosus
23 days
Ventricle
Atrium
Sinus venosus
24 days
Aortic arch arteries
Truncus arteriosus
Left atrium
Ventricle
Right atrium
35 days


Partitioning of the heart into four chambers
Septum primum
Atrium
Ventricle
Interventricular septum
Atrioventricular canals
Dorsal endocardial cushion
28 days
Foramen ovale
Left atrium
Mitral valve
Left ventricle
Right atrium
Tricuspid valve
Right ventricle
8 weeks

after birth. Her lungs need to work, heart needs to beat, circulation needs to get going and oxygen needs to get all around the body from the lungs. This is in stark contrast to her mother's lungs doing the breathing for her when she was a foetus. In fact, all babies are born with holes in their aorta (major artery) and heart, because thus far blood was not pumped into the lungs, as they weren't functioning. Now that the lungs work, these holes need to close up, or else emergency surgery might be required to save the baby's life! This happens as early as an hour after birth.

The next immediate challenge is for the baby to survive the cold. Although we think we keep our babies warm, the fact is that the outside temperature is just always going to be way colder than inside the mother's womb. The baby's brain is not developed yet, and cannot send the correct signals to her body to regulate her body temperature the way we later in life. The hypothalamus is where this "processing" of signals from nerves happens, to tell us when we are cold or warm, and her hypothalamus just cannot do that yet. Thankfully, babies come more pre-prepared than an IIT topper before their JEE – pardon the engineering college simile.

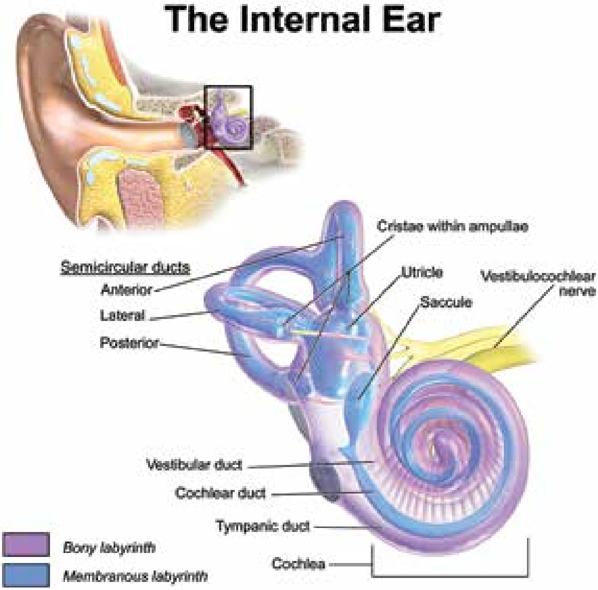
Babies are armed with a special layer of fat (called brown fat) that acts as an insulator and helps regulate their body temperature while their brain develops. Again, similarities to this are found in the animals world, where animals such as bears put on a lot of brown fat before going into hibernation. The burning of this fat is why babies inevitably tend to lose weight in the first few weeks after being born, and then slowly start to put the weight back on again later as they grow.

Babies are instinctive creatures, and are more like robots than humans in their first few months. They have no control over their actions, and even suckling to drink milk, or crying, are just automated and instinctive actions – the amount of thinking that goes into doing those things is akin to us breathing.

Even after birth, the baby's mother fights infections for her. Being exposed to the same viruses and bacteria and chemicals in the air as the baby, the mother creates the correct antibodies and passes it on to her baby via her milk. This is why mother's milk is so important to babies.

Childhood

Fast forwarding to only the major events,we stop off first at the ears. A baby may not be able to see, or her brain might not be able to comprehend much, but her hearing is the best it is ever going to be. This is because of the way the ear is made, and the tiny hair-like appendages inside the cochlea that we are born with. These hairs pick up vibrations, and as we age and when we hear loud sounds, these hairs get damaged. Thus, only as a baby is our hearing perfect.



The human ear is a wonder of nature. Not only does it allow us to hear, it also helps us balance and be able to walk and run on just our legs, with no support from our hands needed

By 6 months of age, we undergo a growth spurt, putting on more than 20 percent of our body weight every month, and by 8 months we can see perfectly. A baby's first teeth start appearing at about the same time.

By about a year our skeletons develop, and the gap between our skull bones (called the fontanel) starts to finally close off. We also develop our vestibular system – the three loops in our inner ear that help us balance – to help us finally stand up and walk.

Language is our next challenge, and a toddler has to learn the words you say to her before she learns how to repeat them and talk. The ability to understand and communicate using language is what essentially makes us humans.

Puberty

Though there is no set age for the onset of puberty, because everyone is different genetically, and also has different lifestyles and development clocks, we all hit it at some point or another. This is nothing but the changing of the human body from a child into an adult. Many an irritated parent will tell you this is an age when a human stops being a child that asks questions because it wants to learn, and instead becomes a child that thinks it knows everything!

The main reason for puberty is to prepare the body for adulthood and reproduction. Although the effects are not identical for

Teenagers are from outer space. And it must be true, because there's even a movie about it!

all, there are some common changes that will happen broadly to humans. In females this results in the growth of breasts and the uterus, in preparation for pregnancy, and also changes in the physical figure from a girl to a woman. In males, puberty results in a longer growth spurt than in women, and men (usually) grow taller than women, develop more coarse hair on their bodies and are filled with testosterone. All of this starts in the brain when the hypothalamus releases a protein called kisspeptin into the brain.

Adulthood

We are at our strongest in our mid 20s, and many of us will never feel as good ever again. As we grow older from our teens, our bodies get fitter and stronger and our cells are able to replicate perfectly and live longer. All of this contributes to our pinnacle of fitness in our 20s, which then can continue into our 30s as well depending on the lifestyle choices we make. Although it is easy for people who are health conscious to feel fit and healthy for well into their old age as well, the fact is that our bodies start degrading once we are past our individual primes. The difference can be very minor and almost pass unnoticed, or if you lead a sedentary lifestyle, you will start feeling the difference rapidly – noticing how you just cannot do the things anymore that you could a few years ago.

Ah! The joys of becoming an adult and entering the "real" world!

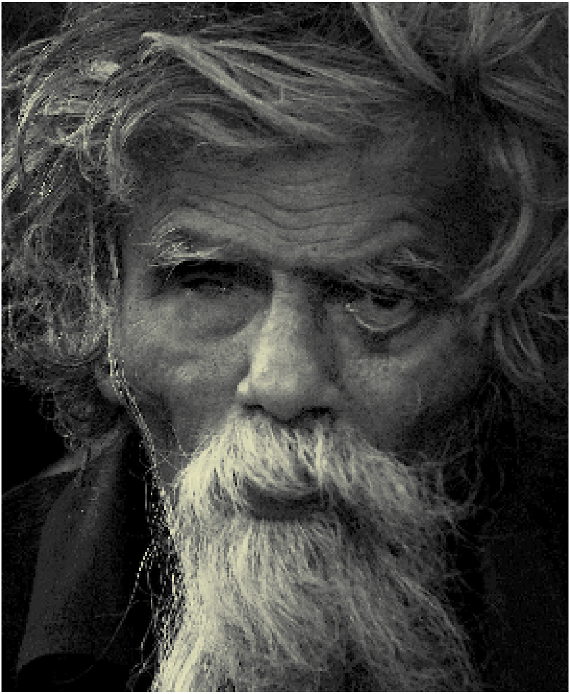
Ageing and death

Ageing is when our appearance starts to change, and the repair systems tend to break down. Wrinkles start to appear, males may bald, and females might have their hair turn grey. Our skin starts looking old because of the degradation of the collagen in our skin. For many, eyesight also deteriorates. It becomes very easy to put on weight as our bodies burn less, and our hormone levels change. We lose muscle mass, which again results in us burning less calories, and most of what we eat turns into fat.

Women also have to go through menopause at around 50, which is a huge change in their bodies. They lose bone and muscle mass rapidly, and become weaker (also shorter).

After 60 or 70 we are at high risk for broken bones because of osteoporosis. This is because all though our lives, our bodies are set to make new bones by stripping away bone and making new bone cells. During old age, however, the stripping away works fine, but the creation of new bone cells slows down, which causes our bones to become more brittle.

The reason why we eventually die, and why we age to begin with is a defect in the copying process of our cells. This could be because of oxygen poisoning as well, as a lot of us gets oxidised. The mitochondria inside us act as catalysts to use oxygen to convert food to energy – via oxidation. All of this oxygenation causes



Stop worrying. No one gets out of life alive.

the mitochondria itself to change slowly, which means we are essentially making copies of ourselves using a lossy copier. Imagine photocopying a copy, and then photocopying that, etc., until you are just left with an unreadable copy.

Eventually, we all have to die, and we will, and it is merely the shutting down of one biological system that has run for way too long. The heart is usually the first to go as it degrades with age. The brain dies slower from oxygen starvation, and hearing, we think, is the last sense to go – which explains why even people who have "died", and then revived using artificial means such as electric shocks, sometimes remember events that happened when they were dead, or get a feeling of witnessing the events in the room from outside their own body (out of body experiences).

Skin cells are the last to stop cell division (more than a day after the heart stopped beating!), but because of what we know about "consciousness" and the importance of the brain to a human, we consider a human to be dead when the brain is dead beyond doubt – heart has not pumped and oxygenated blood has not reached the brain for about 10 minutes. Technically, the brain cells can live longer than 10 minutes (even hours) but they suffer so much damage that even restarting oxygenated blood circulation will not prevent them from dying anyway. Thus, clinically, death is a grey area between the time when oxygen stops flowing to the brain and when the brain cells actually die from lack of oxygen – doctors choose to call it quits at the point of no return though, which is about 3 minutes after no oxygenated blood has reached the brain either through natural heartbeat or even through CPR – but this varies for each case, because body temperature, ambient temperature, drugs given by the doctor, etc., can all increase this time limit.

In the end though, all we can say is enjoy your life, because no one gets out of it alive. ■

Organs

Now it's time to get indepth with a few important organs

As we have mentioned before, the human brain is by far the most important organ we have. We know that pretty much all that we are comes from there, and this is why we did a whole dmystify on that subject already. It's why we will be skipping past that in totality in this book, and if you haven't read that already, we suggest that you do.

Circulatory system

Also called the cardio-vascular system, this is the system that keeps all of your organs, and thus you, alive. It consists of the heart and all of our arteries and veins. Many mistakenly believe that the only aim of the circulatory system is to transport oxygen from the lungs and carbon dioxide back to the lungs. In fact, it's the circulatory system that is responsible for carrying pretty much everything across the body. It also transports electrolytes and amino acids, hormones and also lymph. While the blood circulatory system is fast moving, the lymph system is slower and responsible for returning excess plasma back to the blood circulatory system.

Made up of arteries that carry blood away from the heart (usually oxygenated blood, except inside the pulmonary artery that carries blood to the lungs), and veins, which carry blood to the heart (usually deoxygenated blood with more carbon dioxide, except in the pulmonary vein which carries oxygenated blood from the lungs to the heart).

The average human adult has about 5 litres of blood (4.5 to 5.7 litres), and this blood constantly in motion thanks to the pumping of the heart. Blood starts off by exiting the left ventricle of the heart, is pumped through the aorta (our biggest artery), and is then distributed to many branches of arteries that get narrower the further away from the heart (in terms of distance travelled in a path, not actual straight line distance from the heart).

Arteries branch into arterioles, and then eventually into capillaries, which are really narrow arteries. Capillaries then merge into venules, as the blood starts the long journey back to the heart, and then these venules merge into much broader veins, and finally end up in two large veins – the superior vena cava (blood from areas of the body above the heart, such as the brain) and inferior vena cava (blood from parts of the body below the heart such as the legs and reproductive systems). These two major veins then empty into the right atrium of the heart. Blood is pumped to the lungs, received back and then the whole process repeats.

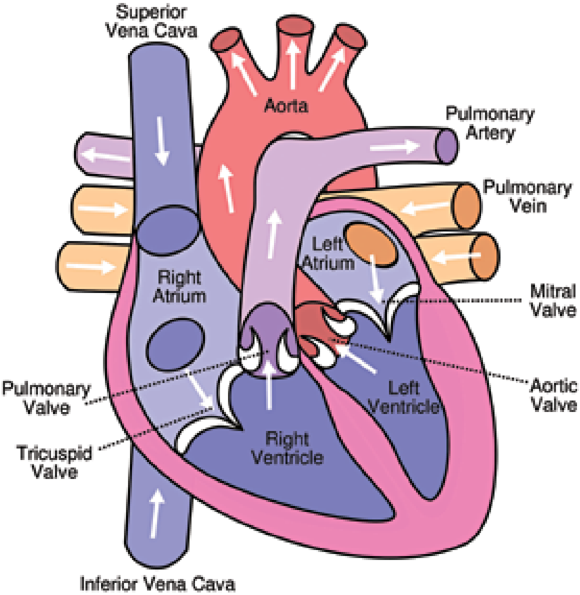
Our hepatic portal vein is the only exception that carries blood from capillaries to an organ other than the heart. In this case, nutrient rich blood from the stomach is collected from capillaries in the hepatic portal vein, then again distributed into capillaries that spread across the liver.

Heart

Our tireless engine that powers us, the heart, as we discussed earlier is something that starts pumping early on when we're still just nothing more than a lump of cells, and doesn't stop until the day we die – which can be a century or more later!

Responsible for pumping blood throughout our bodies, our hearts are literally the powerhouses that allow us humans to have such varied lives and power our larger brains. Of course we could write a couple of dmystifys on just the heart alone, but such depth would be beyond the scope of this book.

All mammals and birds have similarly designed hearts which consist of four chambers – left and right atria above, and left and right ventricles below. It's usually looked as in terms of left and right – the left atria and ventricle are the left side of the heart and



The human heart beats about 2.5 billion times in the average adult's lifetime, that's about 1 lakh (100,000) times a day, or 3.5 crore (35 million) times a year!

the right atria and ventricle are the right side. Pretty much made up of high quality muscle cells, the human heart is also enclosed in a protective fluid filled sac called the pericardium, and the heart itself is made up of three layers.

The heart works pretty much exactly like a pump, and even has valves that prevent backflow of blood, and thus keep the direction of blood flow consistent. Like any pump, electric signals are required to tell the heart when to pump, how hard and how often, and these signals are sent out by a group of cells called the sinoatrial node. The electrical impulse is carried through the heart via a conduction system, which then causes the heart muscles to contract, and thus pump blood out.

Heart disease is the leading killer of humans, with estimates in excess of 30% of all untimely deaths caused by problems with the heart of the circulatory system. If you account for a simple "death caused by heart stopping beating" which would include all natural deaths even from old age, that number would be way higher.

Adults have hearts that weight between 250 to 350 grams, and it is typically the size of your closed fist. At rest the heart pumps about 72 times a minute for the average human, though this can be much slower for well trained athletes. Exercise causes the heart rate to increase while it is happening, but regular exercise causes the heart rate to lower, which is considered healthy. Like other muscles, exercising can cause the heart to grow a little larger for athletes, which makes the heart stronger. Maintaining a good diet, getting plenty of exercise and not indulging in any bad habits such as smoking and drinking can help keep your heart healthy and give you a higher quality of life.

During early exploration of medicine, because the heart was so central and everything was connected to it, it gained a lot of prominence in religion and romance. Through life we have taken this for granted, and people often say "I mean it from the heart", "let god into your heart", etc., which medical students will probably laugh at.

The respiratory system

As we've mentioned before, to some, life can be considered to be merely a slow and ongoing oxidation reaction of carbon. If this is the case, then our lungs are the inlet valves for the oxygen as well the outlet valves for the resultant carbon dioxide.

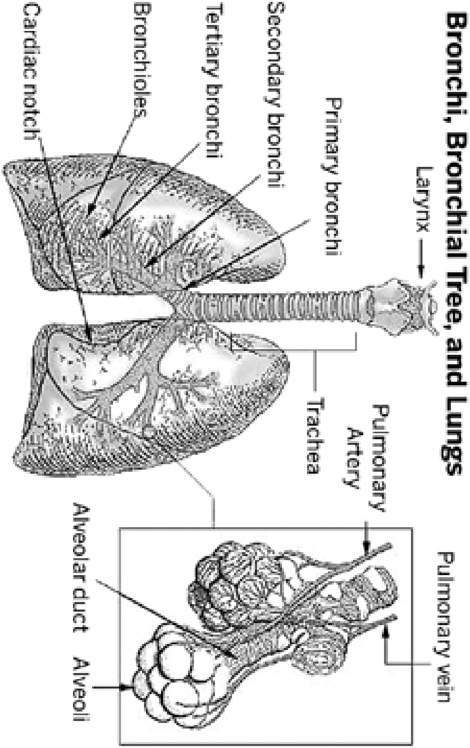
Humans have two lungs, placed on either side of the chest cavity. Many don't know that the left lung is smaller for all individuals, because of the slightly extra space that the heart occupies in the left part of the chest cavity.

Most people think that the lungs only extract oxygen from air and add it to the bloodstream, and then extract carbon dioxide from the bloodstream and pass it back into the atmosphere. While this is their primary function, the lungs also provide the air that is used by the vocal organs that enable us to talk, or sing.

The lungs are an incredible organ, which utilise a very small space to create the very large surface area for the purpose of adding / extracting gases to or from the bloodstream.

Let's try and illustrate how they work: imagine the function of extraction of oxygen from the air to be something like using a towel to dry yourself when you get out of a pool. You could theoretically use a tightly folded towel to dry yourself, but it's just more efficient if you unwrap the towel and increase the surface area of contact with your body. Imagine the extraction of carbon dioxide to be similar to how you would dry this now wet towel. You could leave the wet towel folded up, and hope that it would dry itself out, but we all know that spreading the towel thin is the best way to get it to dry fast, again, because we increased the surface area of the towel in contact with the air.

Since the lungs are internal, and can't really be spread out, they instead spread the air itself and increase the surface area internally by channelling the air down tiny airways. If you took these airways inside the average adult human lung, and spread it out in a straight line, you would get a really thin column of air that would be about 2400 km long! How much is it in terms of area? About 75 sq metres, which is about the size of a badminton court.


Bronchi, Bronchial Tree, and Lungs
Larynx
Primary bronchi
Secondary bronchi
Tertiary bronchi
Bronchioles
Cardiac notch
Pulmonary Artery
Trachea
Pulmonary vein
Alveolar duct
Alveoli

This may not sound like much, but think about the small amount of air that you breathe in being spread evenly and thinly across that amount of area, and you will understand why the lung is so effective at doing it's job.

How do they do this job? The lungs have about 400 million alveoli, which are just little cavities at the end of all those kilometres of airways. Here, inside the alveoli, the blood from veins and the air are brought into close contact to aid in the oxygenation of the blood and the removal of carbon dioxide.

Air enters the lungs through our windpipe (the trachea), is transported to our lungs, where gas exchange happens, and then the air is forced out again. The lungs are fragile, and thus need protection from air pollutants such as dust and debris, which can block off the microscopic airways, or clog up the alveoli. This protection is usually in the form of our nose hairs for large particles, and mucous for smaller particles. We also have other defenses, such as sneezing or coughing which help clear our respiratory system of excess mucous or foreign particles. Lung disease whether major or minor such as the common cold or pneumonia can result in everything from a feeling of weakness to even death, because of how vital our lungs are for us.

We are able to talk and sing because of air being forced out of our lungs then vibrates against our larynx (vocal chords, or voice box) to produce all of the various sounds we make.

Digestive system

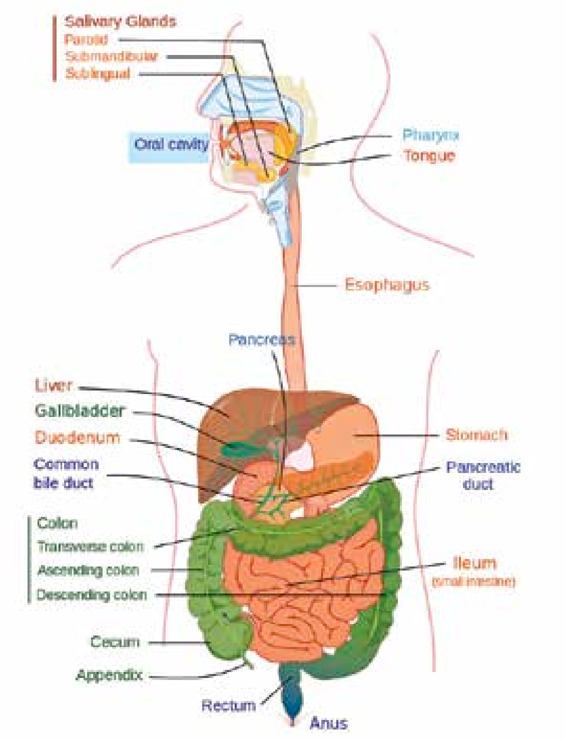
Now here comes the fun part for food-lovers like us. The digestive system is what's responsible for extracting energy from the stuff we eat and drink, and basically extracting the fuel that the human body needs in order to be able to function.

There are many important organs that make up this system, so we're going to tick them off one by one.

Mouth: This is the start of the digestive system, and is the place where everything we eat and drink enters our bodies. The major features of the mouth are a set of teeth, a tongue and saliva glands. The mouth is usually always moist, and when we eat, our saliva glands release a lot of saliva in order to help soften and begin digesting the food we put into our mouths. The teeth, as we all know, are designed to break down our food into pulp, and mix it with saliva. By chewing, we increase the surface area of the food and aid in the digestion of it. The tongue has the job of tasting and determining whether the food we have put into our mouths is something that should be eaten or not. With the help of the nose, we are able to smell a food, then taste it with the tongue to determine if it is fit for consumption – which is our defense mechanism against eating things that might make us fall sick.

Esophagus: Food from the mouth is then transported into the back of the mouth, and then swallowed. The action of swallowing causes the epiglottis (a flap of cartilage) to block off the entrance to the larynx, so that food or drink goes down the esophagus, where it is supposed to. If some enters the windpipe, a gag reflex occurs, which can be quite painful. Once food is in the esophagus, it is transported down to the stomach. The esophagus is closed off at both ends by upper and lower sphincters. Swallowing causes the upper esophageal sphincter to open and allow food in. This prevents food from coming back up, and it's why you can swallow even when upside down. Sometimes, however, when you throw up, food is forced out despite the upper esophageal sphincter trying to stop it, which is why throwing up can sometimes hurt like hell!

Stomach: The stomach is shaped somewhat like the letter J and is where all of the food you swallow is deposited. It lies in the left upper part of your abdominal cavity, and you should know that after a large meal, when you rub your hand across your belly button in satisfaction, you are essentially patting and rubbing your "intestines" and not your "stomach". There is a LOT of complex chemistry that happens in the stomach, but we will simplify it down to "digestion". When chewed-up food enters the stomach, the stomach releases hydrochloric acid to kill off unwanted bacteria, and also to help provide the right pH environment for enzymes to be able to start breaking down protein. Food is mixed, or "churned" inside the stomach as the muscles around it contract and expand,



The human digestive system

and this helps it break the food down even further into a partially digested goo that is called chyme. All of this is in preparation for the actual extraction of nutrients later on. A normal adult human stomach can hold about a litre of food. The size of the stomach changes based on how much food you regularly eat, and this is why dieticians advocate eating smaller meals more often than just two large meals a day in order to lose weight. Food stays in the stomach between 45 minutes to 3 hours depending on the quantity and type of food you eat.

Small intestine: Once the stomach is convinced that the chyme is fine enough, it passes into the small intestine via the pyloric sphincter and the duodenum (the entrance to the small intestine). About an hour after you finish eating, food starts being sent through the stomach to the small intestine. Usually, after about two hours, the stomach is emptied of its contents. The chyme that comes into the intestine is very acidic in its pH levels, and needs to be made more alkaline in order for the enzymes of the small intestine to do their work. It's in the duodenum that bile from the gall bladder, secretions from the pancreas and also the duodenum itself are mixed into the chyme to change the pH of the chyme. The walls of the intestine itself absorb the nutrients from the chyme as it passes along through the three sections of the small intestine – duodenum, jejunum and ileum. Fat digestion mainly happens in the small intestine – fats are broken down into emulsified form called chylomicrons. The small intestine is covered in cells called enterocytes, which do most of the digestion. Enterocytes have finger like projections called villi, which in turn have even more projections called microvilli. Think of the inside of the small intestine looking like a brush whose bristles have even more smaller bristles. The chyme is forced through all these bristles, which essentially means that it is exposed to a much higher surface area of enterocytes. Nutrients are diffused into these villi, which in turn diffuse them into the bloodstream. The chylomicrons are able to pass through the villi and into the lymph capillaries, and form a milky fluid called chyle inside them. The lymph system transports chyle to the rest of the body. This is why the more fatty food you eat, the fatter you get, and not just in one part of the body, but all over – thanks to the lymph system.

Large intestine: By the time the chyme reaches the large intestine it is mostly stripped of nutrients. The ileocecal valve (or sphincter) is found at the end of the ileum (this is also where the appendix is) and slows the chyme down right at the end to try and absorb even more nutrients before opening to deposit it in the cecum. The cecum is a small pouch that marks the end of the small intestine and the beginning of the large. From here on, the digested food is no longer called chyme and is termed faeces. The major purpose of the large intestine is to allow the various bacteria of the digestive system to break down the faeces even further. The large intestine contracts in a specific rhythm (called peristalsis) in order to push the faeces further down the intestinal tract. Water is extracted here, and the faecal matter becomes much more solid as compared to chyme. The faeces is pushed along slowly, and in anywhere from 12 to 50 hours is finally thrown out of the body via the anus in the act of defaecation.

Spleen: Though it doesn't come into contact with the food we consume, the spleen is the graveyard for dead blood cells. Our bodies attempt to not waste anything, and even these dead blood cells are 'digested' by our bodies. The spleen breaks down the dead cells into a bilirubin, which is sent off to the liver to be included in the bile. The iron that is extracted from the dead red blood cells is transported to the bone marrow in order to make more red blood cells. It also acts as a storage area of red blood cells, and can contain as much as 250 ml of these cells. In the event of a crisis, when massive blood loss is detected, the spleen releases these into the bloodstream as an emergency method of trying to stay alive.

Liver: The largest internal organ (second largest overall organ after the skin), the liver also plays a part in digestion by producing bile. It also plays an important role in decomposing dead blood cells, removing toxins from the bloodstream, and other functions too varied to list here – at last count there were over 500 functions of the human liver! A healthy adult liver weighs between 1.4 to 1.7 kg. It also processes proteins into albumen and transfers it into the bloodstream.

Skin

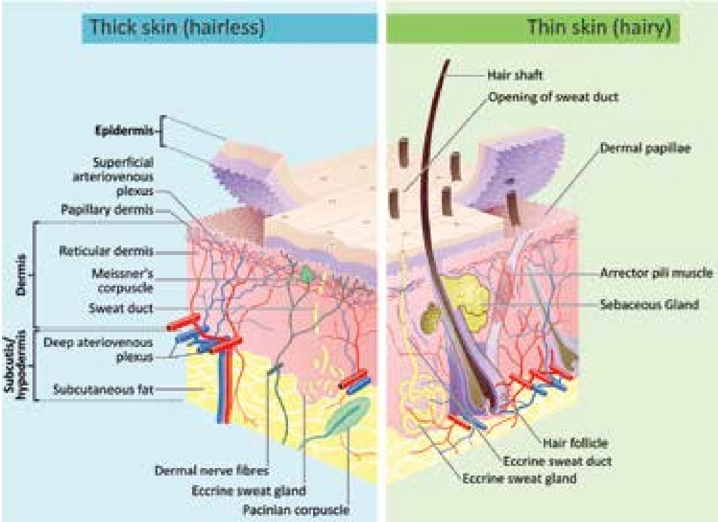
The largest organ of our bodies, the skin is what protects us from the big bad world. We are now used to being considered naked when we are only in our skin, but that's only a recent change in human psychology and biology, because for a 100,000 years or more naked is exactly how we lived. The skin protects our internal organs from the elements by waterproofing us, and also sealing out all sorts of pathogens. It is also responsible for producing vitamin D when exposed to sunlight, for giving us the sensation of touch, and of course, insulating us and helping us maintain a regular body temperature.

Skin is what we see when we look at another human, and is presented as many different colours depending on the ancestry of the human in question. Although merely a function of how much melanin is in the skin, because of the geographical differences in where a person's ancestors lived, skin colour has wrongly been used to differentiate people as different "races". People who live closer to the equator have darker skin because they are exposed to more sunlight, and more melanin is needed in the skin to block out harmful UV radiation. The converse is that people who live closer to the poles have lost pigmentation in order to be able to absorb more sunlight in areas that receive a lot less sunlight than at the equator. What is merely microevolution at work – the adaptation of skin to changing conditions – has sadly become a way to divide the human race into these non-existent sub-races.

In India, where we receive quite a lot of sunlight over the course of a year, it should be far more desirable to be dark-skinned, because that would mean being more equipped to handle life in India and also reduce the risk of cancer. However, cultural misinformation means that the opposite is in fact desired by most, as you will no doubt find out when you look at matrimonial advertising!

Skin consists of two major layers – the epidermis and the dermis – which do very different jobs for the human body.

The epidermis is the outermost layer of skin that comes into contact with the environment. It helps keep our bodies waterproof, and also keeps infections at bay. Contrary to popular belief, it isn't only the lungs that "breathe" for us, because the epidermis has virtually no blood supply anywhere on the body. The epidermis "breathes" by diffusing oxygen out of the air that it comes into contact with. It is nourished in the same way, but from within – by diffusion of nutrients from the outer layers of the dermis to the



Differences in hairy and hairless skin

epidermis. Skin cells move from the deepest layer of the epidermis, where they are formed, to the outer layers, where they die. Thus, the outermost layer of epidermal skin on our bodies is actually just a bunch of layers of dead skin cells. As the skin cells move outwards, they get filled with keratin, and the process of skin cells moving out and dying off is called keratinization. It takes a few weeks for us to shed our layers of skin (one full layer of epidermis is shed in two to three weeks). This skin flakes off as microscopic dust, and is the reason why you can live in a totally sealed off room and still dust will appear to settle on everything, and this is why clean rooms have such strict policies and have humans dress from top to toe in sealed suits.

The dermis is the layer directly below the epidermis and is what cushions the body and holds everything in place that's below. It is made up of layers of cells and has a plentiful blood supply. It also contains the hair follicles, sweat glands, and the nerves that give us our sensation of touch, feeling cold / heat, etc. The dermis is where the collagen is found, and it is this collagen that breaks down with prolonged exposure to sunlight and radiation. When we age, the breakdown of collagen causes us to get wrinkles.

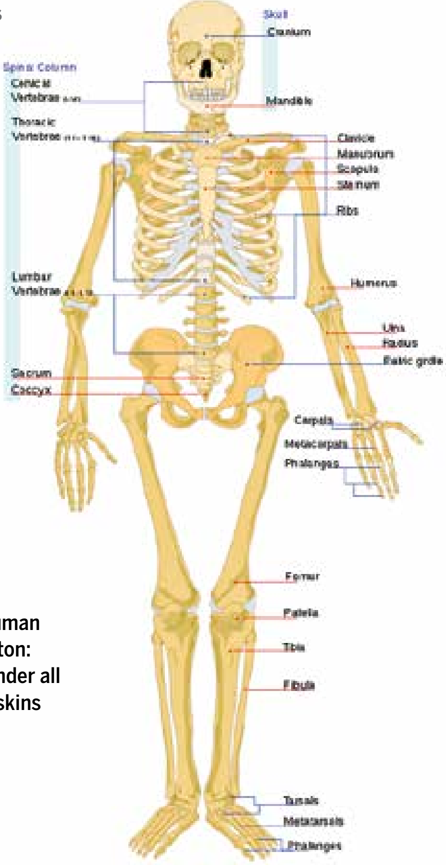
Muscular and Skeletal system

This is the system that gives us our form and shape, and is the foundation on which all of us are built. The skeletal system consists of the skeleton, which in adults is 206 bones that join together to form the base on which everything else sits.

Bone mass of our skeletal structure reaches peak density at around 30 years of age, after which it gradually loses mass and strength. The skeleton isn't just a rack that everything hangs on though, because it also is responsible for housing our spinal cord, which controls all our movements, and also produces all of the blood cells that flow through our body. The rib cage of our skeleton also helps protect our most vital organs – heart, lungs and liver. Between the two genders, the average male skeleton is usually larger and heavier, and the pelvic region of females is different (wider) in order to facilitate childbirth. Amongst all primate species, it is in humans that the differences between genders are the least, indicating an evolutionary move towards more physical equality (as compared to other primates).

The skeleton can be divided into two groups. The first is the axial skeleton, which consists of 80 bones and includes the skull, neck, spine and ribcage. These are called the axial skeleton because all of these bones are located close to the axis of the body.

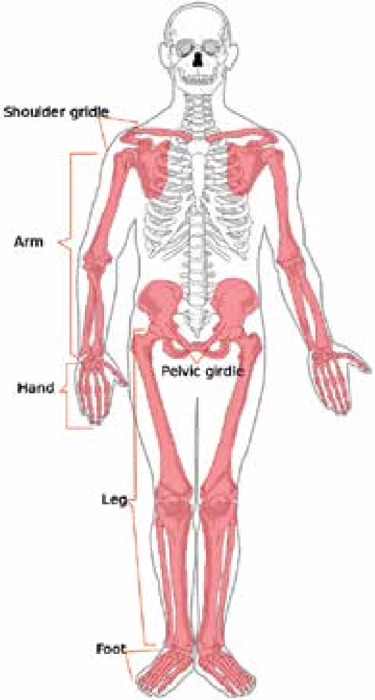
The appendicular skeleton is the second group of bones and is made up of 126 bones that include our limbs (arms and legs), shoulders and our pelvic region. The reason the bone count is higher is because this group contains the complex skeletal structures that



The Human Skeleton: What's under all of our skins are the hands and feet which are made up of many bones each. Each hand is made up of 27 bones, and each foot contains 26 – that's 106 bones in just our two hands and feet, leaving a mere 20 for the shoulders, arms, legs and pelvis. The appendicular skeleton is what makes it possible for us to move, and also to skillfully manipulate things using our hands. Basically, the appendicular skeleton is what our humanness is built on top of!

Bones and joints are covered by a muscular system that consists of tendons, ligaments and muscles, and are what we use to do pretty much everything physical that we do. Every movement, from the tiny blinking of an eye to lifting heavy weights, walking, running, jumping… everything… is because of muscles and the muscular system. All of our strength comes from muscles and they also perform the role of keeping the body warm. Muscles are closely joined to the nervous system which enables the brain to consciously or subconsciously control the muscles to make movement possible. In the case of some muscles, such as the heart, there is no conscious control possible, and it beats to its own rhythm.

We have about 640 skeletal muscles (muscles that attach to the skeletal structure), which is over three times the amount of bones we have. This is because we need more muscles than bones to move. Just bending your arm at the elbow uses at least three muscles, and it's a similar story for all of your body's joints that can be moved.



Left: The appendicular skeleton in pink and the axial skeleton in white. Right: the muscles of the human body

Muscles are special types of cells and organs, and are very good at repairing themselves. When you exercise, you are basically ripping up your muscles by exerting them, and they then repair themselves to become even stronger than they were before. There's a fine line between exercise and overdoing it, so we encourage all of you to workout in order to stay healthy, but do so with care.

Conclusion

We've skipped past the reproductive system in humans because we just don't have the space to cover it here. We have only scratched the surface of the wonders of the human body, and as we said before, we could probably write a dmystify or three on each of the organs mentioned in this book. We hope we have at least sparked an interest in the human body for some of you, and if we have played a miniscule role in getting you interested enough to read more about the wonderful science of biology, we will have succeeded in the aim of this book. We do aim to cover more complex biochemistry in different dmystify topics later. Remember to write in and demand which ones you want us to tackle first. *dmystify@digit.in* is the place to give us a shout out and let us know how we're doing, and also to make those demands for topics. ■


Watch how the human body evolved – http://dgit.in/wdwcf