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JoSS
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Editor: Güney Baver Gürbüz

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This newspaper is an independent initiative of Uskudar American Academy volunteer students.

The Joy of Sharing Science is a weekly newspaper that explores the physics/biology/chemistry/computer science behind interesting real-life phenomena in a concise and easily understandable way. Each week, 4 phenomena concerning physics, biology, chemistry, and computer science will be published. The aim of this project is to explore the science hidden in plain sight, evoke curiosity, and elevate scientific literacy.

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From the Editor:

In this issue, our topics range from Vision of Bats and Cosmetics to the DNA Damage Theory.

To start with, our Physics author Melis Ahucan Tuncel will briefly introduce to you Echolocation, its discovery, purpose, and method. After her, our chemistry author Selin Eda Sağnak will explain the benefits, drawbacks, and chemical composition of cosmetics to help you determine are they worth it. Moving on to biology, Ada Zağyapan will deep dive into DNA damage theory of aging and discover its reasons and the theory behind it.

To our dear audience, I hope that you will have lots of fun while reading JoSS and learn new phenomenal and interesting concepts. Don't forget that science is the process that takes us from confusion to understanding. On that matter, JoSS will be always here for you to help.

Digital Signature

Seeing Without Eyes: Bats

Melis Ahucan Tuncel

Echolocation, the nature's sonar system, is a technique used by various animals (including humans) to provide information about an object's distance and size; using sound waves. An animal produces an ultrasonic sound signal that hits an object and returns to the echolocating animal back by giving information about the object's physical features. In the series "Seeing Without Eyes", we will investigate different animals that uses echolocation. This article is the first piece of this series and it investigates the discovery of echolocation among bats, purpose of echolocation, how to echolocate, echolocation techniques, and call features.

Discovery of Echolocation Among Bats

The first observation of bat echolocation was done by Lazzaro Spallanzani in 1793. He realized that bats were able to avoid obstacles while flying in total darkness. Furthermore, he found that when the eyes of bats were surgically removed, bats managed to fly without bumping into obstacles. This was the first proof of their echolocation abilities. Later on, Charles Jurine conducted an experiment to see what happens when bats' audition was blocked. He plugged the ears of bats and observed their poor performance on object orientation and location tract. Both, Spallanzani and Jurine concluded that bats could "see" through their ears. However, a french naturalist, Cuvier disagreed with this statement and suggested that the sense of touch in the wing membrane caused the bats to avoid obstacles. In 1920, Hartridge hypothesized that bats emit ultrasound and listen to their echoes. And finally, the proof to these hypothesizes came from Donald R. Griffin. With a microphone sensitive to ultrasound, he demonstrated that bats emit trains of ultrasonic pulses while flying. They observed that the number of sound pulses increased as bats approached obstacles on their path. Moreover, the mouth of the bat was always open when the sounds were emitted, and when Griffin shut their mouth, their orientation was distorted. This was a clear indication which proves that bats uses sound signals generated by their mouth to gain information about their surrounding. Thus, the term "echolocation" was defined.

Purpose of Echolocation

Okay, but… bats have eyes; why don't they just use their eyes to perceive the world? Are they blind?

A very common misconseption. No, bats are not blind. In fact, their vision is quite well. Bats use their visual abilities AND echolocation abilities to increase their hunting skills. Also, most species tend to echolocate more in the dark due to less accuracy on vision at dark. Hundreds of bat species use echolocation to catch flying insects and map out their surroundings. They produce ultrasound waves at varying frequency patterns. These waves bounce off objects in the environment differently; depending on the object's size, distance, and shape. This generates a very important supplementary information for the bat (in most species). They also use this biosonar to communicate with each other and to identify familiar and unfamiliar individuals.

How to Echolocate?

Most of the bats make echolocating sounds in their larynxes by contraction and emit them through their mouths. A few species, though, click their tongues. Even weirder, Horseshoe bats *(Rhinolophidae)* and Old World leaf-nosed bats *(Hipposideridae)* emit these signals through their nostrils.

Bats do not all produce the same types of sounds or calls. There are two types of sounds that bats use. Bats use either one or combination of both depending on the situation and collect data on their flying path. During the search stage of the hunting flight, bats emit sound pulses with a low repetition rate (about 10 pulses/second.) The signal emitted at this stage is correlated with the habitat that the bat forages. For instance, fast-flying bat species with narrow and long wings prefer to search for flying insects well above tree tops. They forage in open spaces where obstacles are lacking and emit short CF pulses usually without an FM tail. On the other hand, bats that forage close to vegetation hear faint echoes in addition to their normally returning echoes. These faint echoes give information about obstacles around the bat. These bats ground emit pulses with FM sweep. However, it is good to note that, most bat species do not prefer to forage in the same specific area for too long. Most of the time, when the environment changes, the sound signal also changes.

One of the most researched species, the mustached bat, produces a bisonar sound consisting of a constant frequency portion (CF) followed by a downward frequency modulated sweep (FM), often expressed by the sound "iiiiiiiiu". This has lead to the mustached bat being classified in the literature as a CF-FM bat, along with a few other species. Other Microchiropteran bats produce only the CF component or only the FM components. It turns out that the CF and FM portions of the sonar pulse serve different purposes. The constant frequency portion of a pulse is great for detecting targets and measuring the Doppler shift. The FM portion of a pulse is excellent for honing in on the distance of an object and some of its finer details. The mustached bat often hunts in vegetation and the CF component of the pulse may help this bat focus in on insects moving within the vegetation.

Bats can detect an insect up to 5m away, work out its size and hardness, and can also avoid wires as fine as human hairs. As a bat closes in for the kill, it cranks up its calls to pinpoint the prey. The faster clicking happens when the bat detects an insect and need more accuracy to catch its prey. As most of the animals cannot hear ultrasounds, it mostly doesn't cause the prey to escape. However, some types of insects, such as moths, beetles and crickets, can hear ultrasonic sounds and run away or start to fly in zigzag, spiral or looping patterns to avoid being eaten. As bats can hear their own high frequency and loud voice, to avoid being deafened by its own calls, they turn off its middle ear just before calling, restoring the hearing a split second later to listen for echoes. You can listen to the call here.

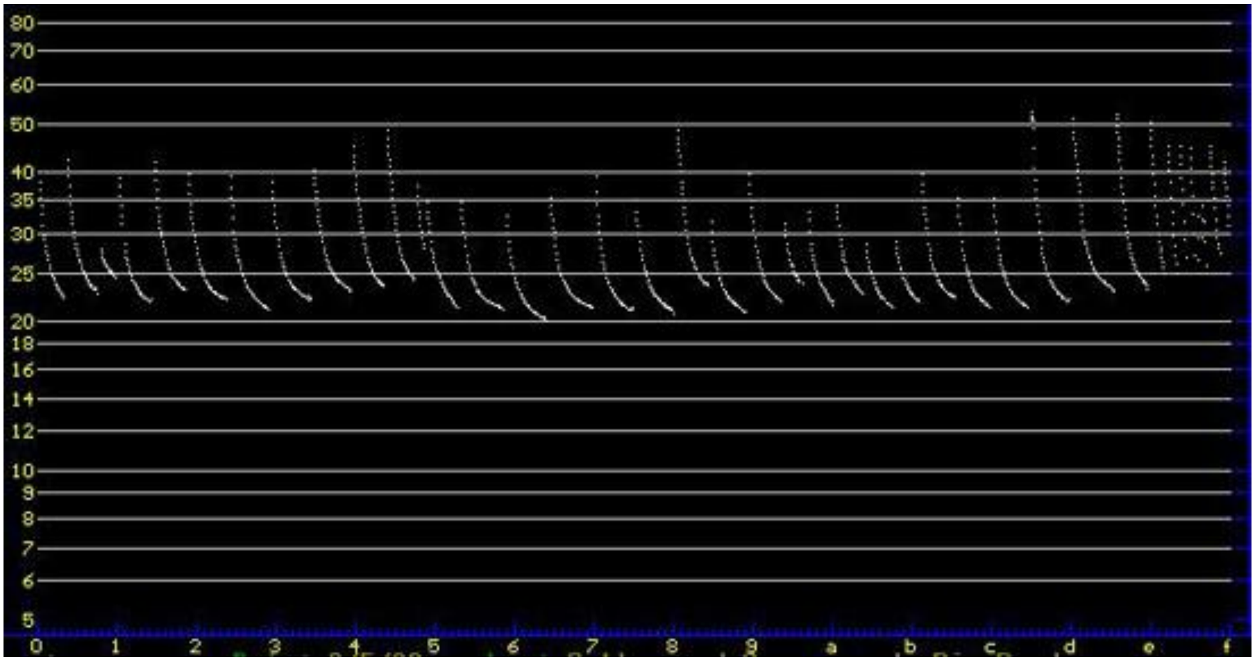

Figure 1: Sonogram of a silver haired bat screech, which detected a prey at the end.

Not only the returning echo, but also the emitted echo gives information about the environment. An animal cannot echolocate without vocalizing. Information on the nature of the insonified target is carried by the spectral and temporal differences between the parameters of the emitted sound and returning echoes. So that, in auditory imaging, the information on the nature of the animal's surrounding may be collected only by comparing the emitted signal with the returning echoes. The emission of echolocation sounds generated by bats' vocalization abilities, triggers specific auditory mechanisms that facilitate echo detection and analysis. This evidence is best for the specific task of echo ranging, but unfortunately, we cannot generalize it to all tasks due to the lack of data. There are two categories for vocalization signals: Broadband signals and Narrowband signals.

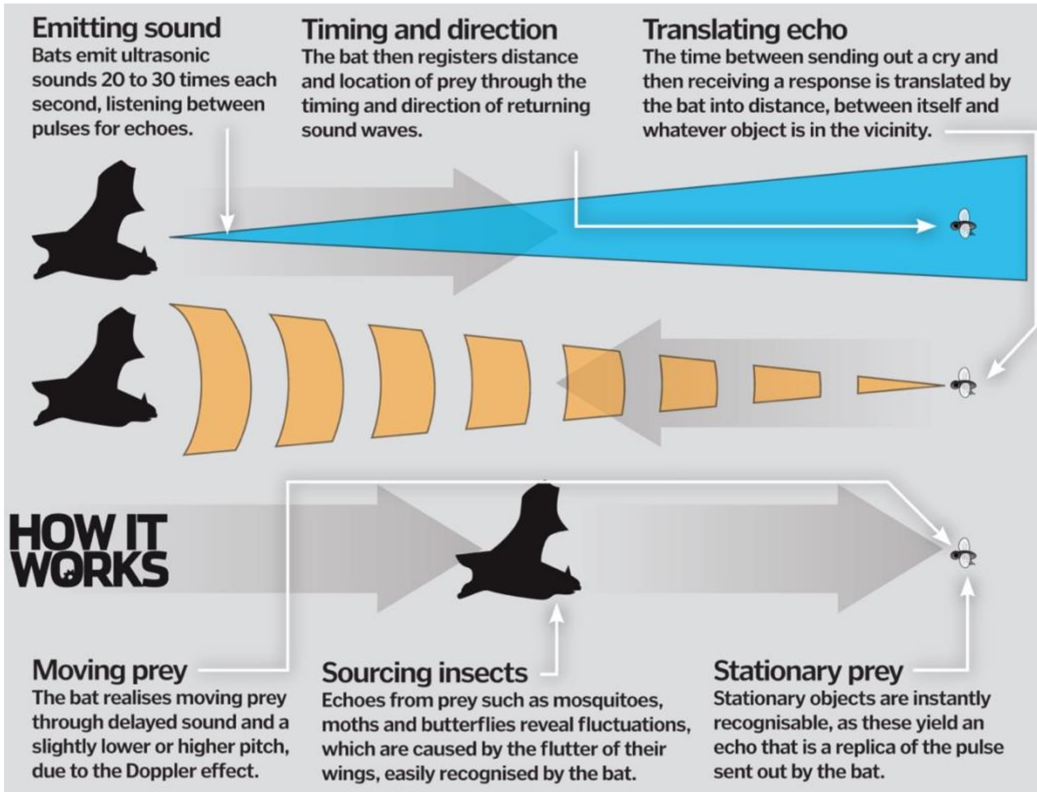

Figure 2: The steps of echolocation

The Secret of Bats

The secret behind bats' excellence in echolocation is their ears. Their ears are built to recognize their own calls, which is believed to have evolved from bats' common ancestor, who had very small eyes that made it hard to hunt at night, and had to develop an auditory brain design to make up for that. Their ears and brain cells are tuned to the frequencies of the sounds they emit and reflected echoes.

So, does it mean that bats have superior systems than other mammals and hear a wider frequency range? Well, the answer is more like a no. If you look at the frequency range of different animals [Fig. 3], you would not be able to distinguish bats and their "superior auditory skills". However, the cochlea of echolocating bats is sensitive to a broad hearing range and finely tuned for the returning echoes. Even though they have almost identical auditory systems and have similar responses to the changing frequency, bats have minimal differences compared to other mammals. For instance, Mustached bats' (*Pteronotus parnelli*) basilar membranes are thickened precisely at the frequencies which they are most interested in (61.0-61.5 kHz). Their individual spiral ganglion cells of their brains also sharp tuned to one particular frequency in this range. Mustached bats hunts in dense vegetation, which requires them to use FM signals in addition to CF. The basilar membrane specializations allow the bat to be sensitive to the returning echo, but not as sensitive to the emitted pulse. And the sharp tuning curves of the spiral ganglion cells equip the bat with a way to cut down on background noise from the surroundings. Since the cells are so sharply tuned, they will not be excited by just any frequencies returning from the periphery, but instead will be excited by the 'right' frequency from a potential meal. As we can see, bats do not have a completely different system compared to us or any other mammal. But their systems are adapted to their environment and hunting skills. Thus, have slight differences.

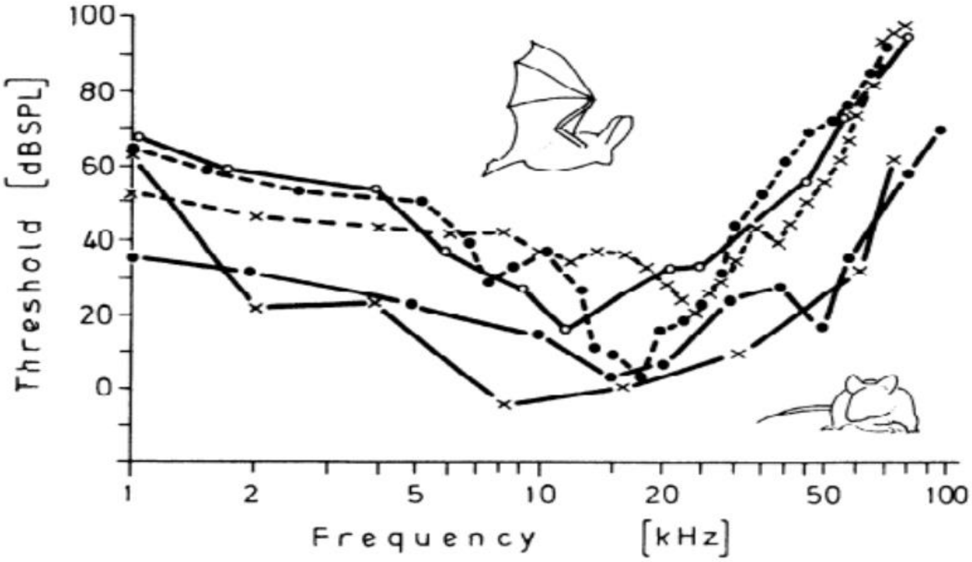

FIG. 3. Comparison of audiograms of nonecholocating ground-dwelling mammals and bats (continuous lines) and of echolocating bats (dashed lines). There is no difference in frequency range heard between 2 groups, and auditory sensitivity to ultrasound (>20 kHz) is not specific to echolocation. Behavioral audiograms: ●—●, house-mouse (15); x—x, cotton rat (35). Neuronal audiograms: ○—○, non-echolocating, fruit-eating bat *Cynopterus sphinx*; x--x, echolocating insectivorous bat *Taphozous kachhensis*; and ●--●, echolocating insectivorous bat *Tadarida aegyptiaca* (75).

According to a study on the neuronal responses of the inferior colliculus (auditory midbrain) to stimulus pairs mimicking an echolocation signal and its echo, specific neuronal mechanisms for echo detection may exist. In mammals, responses of auditory neurons to tone pulses are usually suppressed by a second simultaneous stimulus tone. In horseshoe bats, this is also true except for the group of neurons that are tuned to the range of CF (81-88 kHz). CF frequency is the frequency of the most intense harmonic of the pure tone echo. Neurons with best frequencies in the CF range are not inhibited by a simultaneous or preceding tone just below the CF but rather the responses are enhanced. When the preceding tones are 500-4000 Hz below CF, the response to a second, fainter and echo-mimicking stimulus is enhanced and its threshold is lowered by 20 dB. The lower frequency range of the first stimulus is the range emitted by a flying horseshoe bat, since it lowers the emitted frequency in order to compensate for

Doppler shifts of the echo caused by its own flight speed. The compensation done for the Doppler shift keeps the echo frequency within a narrow range of high auditory sensitivity.

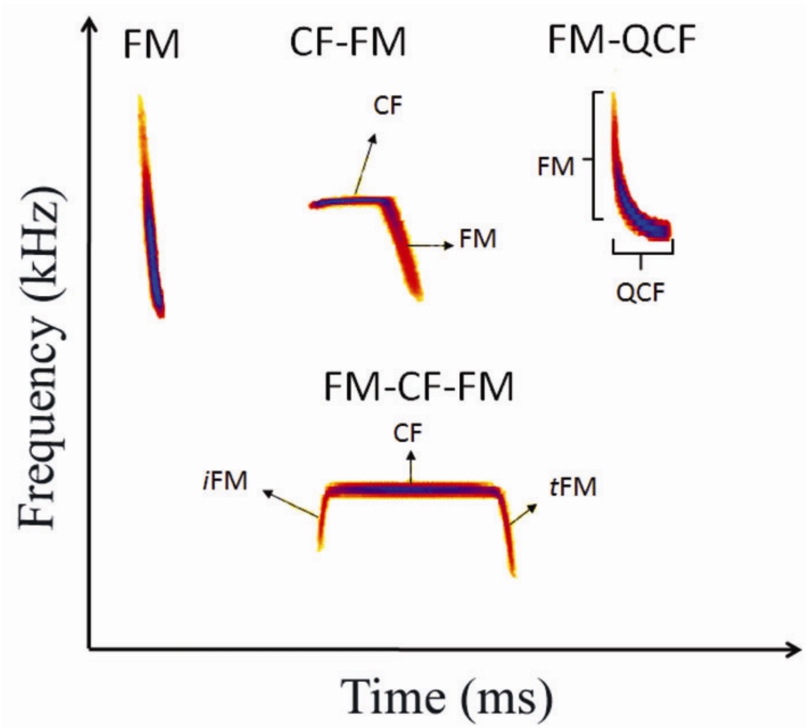

Figure 4: Different bat calls

Call Features

Echolocation calls are characterized by their frequency in kilohertz (kHz); their intensity in decibels (dB); and their duration in milliseconds (ms).

Bat echolocation calls vary in their dominant frequency between 11 and 212 kHz. Very low frequencies are not preferred by insectivorous bats since echoes with lower frequencies have longer wavelengths. These long wavelength echoes returned from insect-sized targets tend to be weak when the wavelength is longer than the insect wing length. For that reason, high frequency is necessary to detect small targets. As we discussed, bats emit brief, ultrasonic sounds containing constant frequency (CF) and broadband frequency modulation (FM) components in patterns that are species specific and tailored to the amount of acoustic 'clutter' in the environment. They use broadband echolocation calls adjust call design in a range-dependent manner so that nearby obstacles are localized accurately.

When a bat emit a sound signal to a close object, the echo will reflect back sooner and louder than a more distant object. In addition, it can determine whether there are obstacles in front of the target by the sound wave bounces back. In that way, the bat will understand the object's distance and location. Similarly, by listening the changes in the phase of the echo, bats can determine the surface type. A hard and continuous object, such as wall, will produce a sharper echo than softer objects. Due to the bumps and non-continuous structure seen on a soft surface, not all sound waves bounces back directly to the bat and some are absorbed by the pores of the softer surface.

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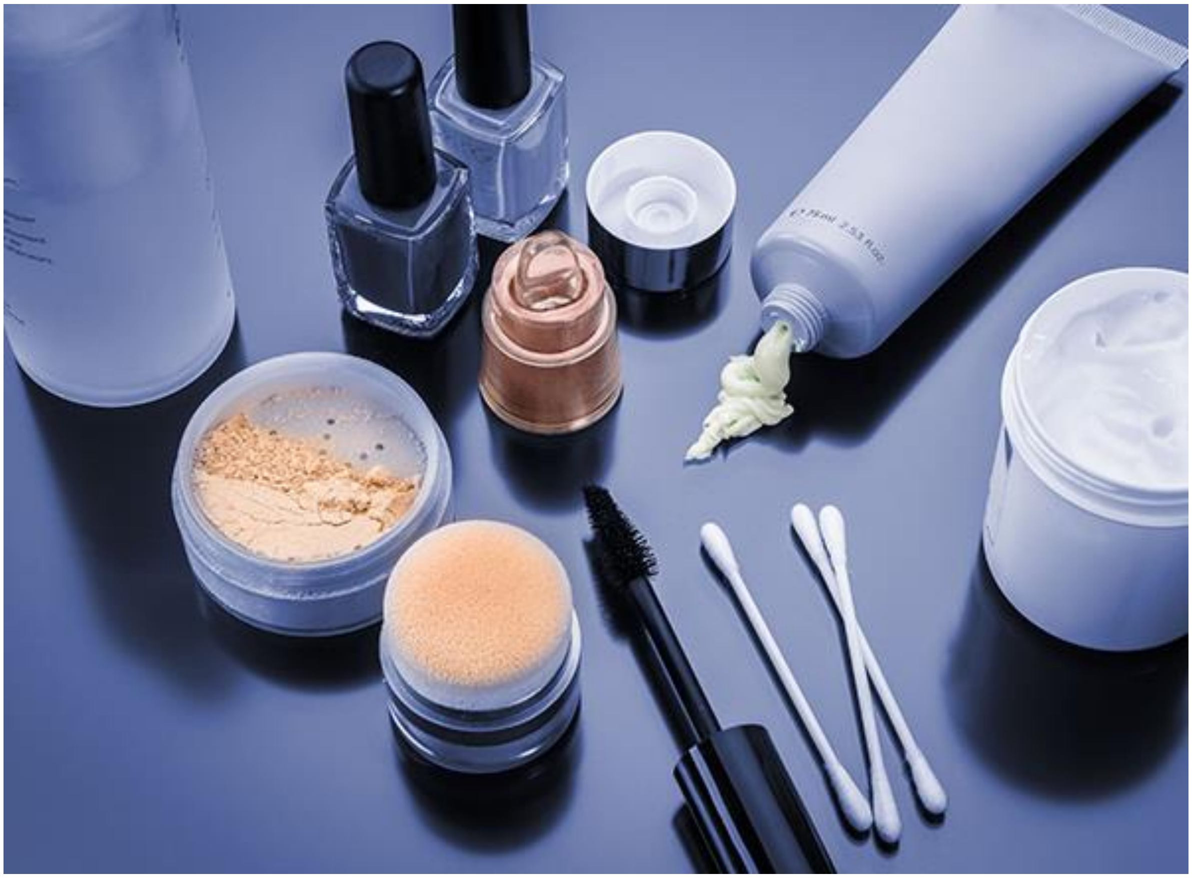
Shadows of Cosmetics



Selin Eda Sağnak

Cosmetics are one of the most common daily products used, regardless of gender. From sunscreens to eye shadow, we are given the chance to choose which one to buy and from where. Most of us look at the various brands and pick ones we prefer either by the durability of the product or the visual appeal. However, we tend to forget an important aspect of these products when buying them. And that is the list of ingredients. This list holds the future of our health in its hands. In this article, I'll walk you through the possible harmful effects of cosmetics on the human body and the environment, and the list of ingredients that cause these effects. I'll also provide ways to escape the shadowy hands of cosmetics by informing upon how to distinguish between safe and harmful cosmetics.

Side Effects of Cosmetics

<u>Health Hazards</u>

Due to being products that can stay in touch with the body for a long period of time, problems such as irritation in the area of application, allergies and acne are one of the most common side effects (Okereke). In a study by Dibaba (2013), "97.80% of the participants had a habit of using cosmetics. The most frequently used cosmetic products were body lotion 76.0% followed by deodorants 74.0% and hair cosmetics 51.3%" (Ekta, 54). People have reported to experience the negative effects mostly on the face, hair and skin, the primary reasons being use of deodorants and lotions (Ekta, 54-55).

"Shrestha and Shakya (2016) highlighted that 50% had experienced acne, almost all respondent's 98.6% got information of cosmetic products from television. Majority 82.9% of the respondents answered that cosmetic products are the substance use to enhance the appearance of body. 88.6% had knowledge that kajal cause dry eye syndrome, 97.1% had knowledge that skin lightening cream and sunscreen cause skin cancer and perfumes cause skin irritation, 87.1% had knowledge that mascara cause eye irritation, and 98.6% had knowledge that nail polish cause cancer and reading expiry and manufacture date can prevent the occurrence of adverse effects." (Ekta, 55)

Some effects seen on the skin are caused by moisturizers, skin lightening agents and sunscreens. While "[m]oisturizers increase the hygroscopic properties of the skin particularly when the concentration of these substances is high in the body" (Okereke), causing skin irritation, hydroquinone (HQ) found in skin lightening agents can cause ochronosis which is "characterised by progressive darkening of the area to which the cream containing high concentrations of HQ is applied for many years (19)" (Okereke). Sunscreen results in allergic reactions due to having phototoxic or photo-allergic properties (Okereke). "Benzophenones are the most common sensitizers, while debenzoylmethanes, para-aminobenzoicacid (PABA) and cinnamates may cause photo-allergic dermatitis [20]" (Okereke).

As the chemicals used for the function of the cosmetics is usually the main reason behind the side effects, in deodorant and perfumes, fragrances can cause adverse effects. Allergic reactions occur when fragrances "enter the body through skin(adsorption), lungs, air ways, ingestion and through pathways from the nose directly to the brain and can cause headaches, dizziness, fatigue, irritation to eyes, nose and throat, forgetfulness and other symptoms" (Okereke). "Chemicals like coumarin, phethleugenol found in fragrances are suspected carcinogens, while phthalates are suspected hormones disrupters [21]" (Okereke).

Even though not directly in contact with the skin, hair products such as shampoos and conditioners can also cause side effects, though in much smaller scale, and mostly the problems arise during the hair rinsing stage since the product can enter the eye (Okereke). "Active ingredients in hair bleaching product such as Hydrogen peroxide solutions, and Ammonium persulfate, may cause Types I and IV allergic contact reactions" (Okereke).

Preservative chemicals inside cosmetics can also be harmful for human health as they "generally have chemical structures associated with aromatic rings which generally have toxic potential, and ability to bind to metal elements that promote bioaccumulation in the body [32]" (Pereira, 69).

A list of ingredients that can be toxic and advised to be avoided is[1]:

- Talc (includes asbestos – carcinogen)
- Triclosan (may affect thyroid hormone & possible development of skin cancer in long-term)
- Lead (heavy metal)

[1]Sissons, Beth. "Are some makeup ingredients toxic?". *Medical News Today*, MediLexicon International, 16 Dec. 2019. Accessed 25 Nov. 2021. https://www.medicalnewstoday.com/articles/327318

- Mercury & Thimerosal (heavy metal / thimerosal contains mercury)
- Phthalates (unbalance hormones like testosterone, possibility of causing breast cancer)
- Parabens (mimic estrogen hence can initiate breast cancer)
- Formaldehyde (allergic reactions, respiratory system irritation)
- Toluene (may be toxic)
- Carbon Black (possible carcinogen)
- Per- & Polyfluoroalkyl Substances (various risks for human health)
- Benzophenone-type Ultraviolet Filters (disrupt hormones)

Figure 1. Check for Ingredients in Cosmetics

<u>Environmental Hazards</u>

Cosmetics include chemicals that are harmful for the environment, either in their composition or the packaging. These chemicals can enter the environment through various means, especially through water. To keep these under control, health surveillance agencies are creating restriction lists that ban the use of specific chemicals in cosmetics which encourage the industry to search for new ingredients (Pereira, 64). "Unlike medicines, there is no[t] a specific agency to assess the safety of cosmetic products, no marketing authorization with specific requirements, no evaluation of the risk-benefit ratio and no guarantee of constancy from one batch to another [6]" (Pereira, 64).

Some chemicals present that possess environmental hazard are BHA (butylatedhydroxyanisole) and BHT (butylatedhydroxytoluene) which "are closely related synthetic chemicals used as preservatives in moisturizers and lipsticks, among other cosmetics" (Okereke).

"The International Agency for Research on Cancer has classified BHA as a possible human carcinogen. The European Commission on Endocrine Disruption has also listed BHA as a Category I priority substance, based on evidence that it interferes with hormone function [23]. BHT may act as a tumour promoter in certain situations. Limited evidence suggests that high doses of BHT may mimic oestrogen, the primary female sex hormone, and prevent expression of male sex hormones, resulting in adverse reproductive affects [23]." (Okereke)

A list of example substances that harm the environment is[2]:

- Coal Tar Dyes (ex. p-phenylenediamine - toxic)
- DEA (release/react with nitrites – contaminant)
- Dibutyl Phthalate
- Parabens
- Perfume
- Polyethylene Glycols
- Petrolatum
- Siloxanes
- Heavy Metals

How to Distinguish between Cosmetics

[2]Okereke, J. N., et al. "Possible Health Implications Associated with Cosmetics: A Review". *Science Journal of Public Health*, Science Publishing Group, 17 Dec. 2015. Accessed 25 Nov. 2021. https://article.sciencepublishinggroup.com/html/10.11648.j.sjph.s.2015030501.21.html

As the list of chemicals that can be used in cosmetics consists of almost endless possibilities, it is hard to know which chemicals are exactly the toxic ones in a specific product and avoid buying it. The best approach is to get the know the four key categories that contain harmful ingredients[3]:

- Surfactants

  Thickens the products used for washing for them to spread evenly, cleanse and foam such as shower gels, shampoo, and body lotion, in combination "with additives like dyes, perfumes, and salts"(Healthline).

- Conditioning Polymers

  Prevents "products from drying out and stabilize fragrances to keep the scents from seeping through plastic bottles or tubes" (Healthline), also avoid sticking to the hands.

- Preservatives

  Prevents bacterial growth and improves shelf life.

- Fragrances (most harmful)

Being familiar with these categories and knowing the list of substances that should be avoided written above, can help prevent customers from buying cosmetics that are harmful for their body and the environment. Choosing sustainable brands (both in terms of composition and packaging) and avoiding knock-off brands -that most of the time use heavy metals in excessive amounts causing serious diseases-, are also ways to avoid risky products.

[3]Healthline Editorial Team. "Healthy Cosmetics". *Healthline*, Healthline Media, 15 Jun. 2018. Accessed 25 Nov. 2021. https://www.healthline.com/health/beauty-skin-care-cosmetics

Figure 2. Sustainable Cosmetics

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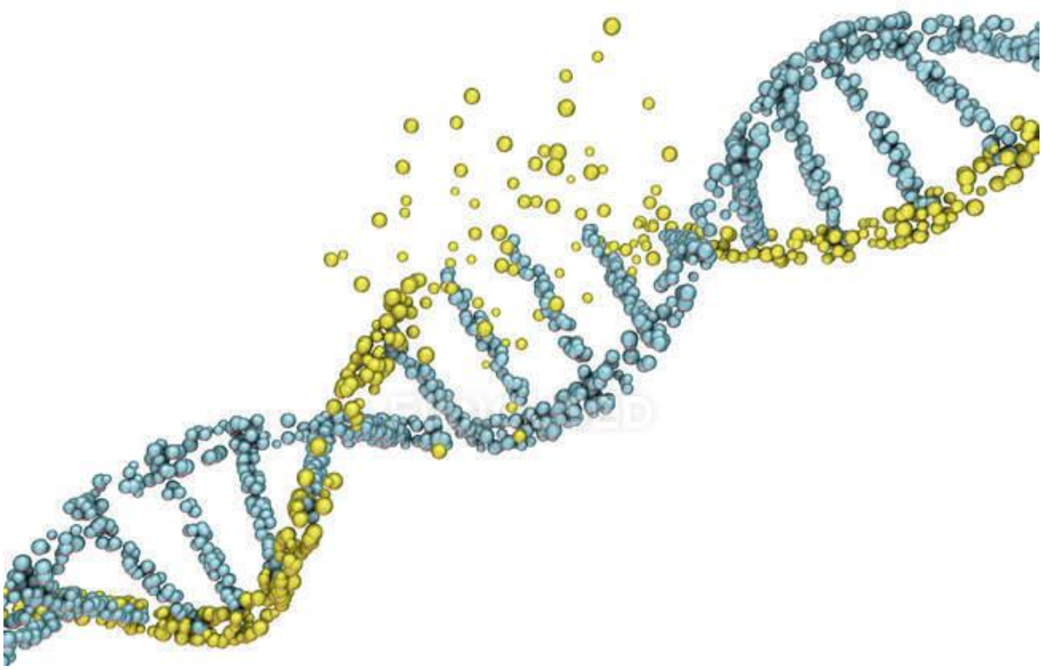
The Reason of Ageing: DNA Damage Theory



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Aging has been a very controversial topic for many years, and still a solid evidence that proves the molecular reason of aging hasn't been found. However, some theories have been put forward. Given the essential role of DNA in the concept of "life," and that aging is fundamentally seen as the gradual and irreparable breakdown of tissues, organs and organ systems, the DNA damage theory of aging remains as a comparably powerful theory. Progeroid syndromes in humans -symptoms resembling premature aging- have been closely linked to flaws in DNA repair, growth or processing, suggesting that accelerated DNA damage leads to hastened physiological decline and the spread of age-related diseases such as but not limited to cancer. Taken together, all the data and research done so far suggest a major role of DNA damage in the longevity of life, possibly through effects on cell dysfunction and loss, although understanding how to modify DNA damage repair and response systems to delay ageing remains a pivotal challenge to scientists.

DNA Damage and Mutations

To completely understand the DNA damage theory of aging, one needs to further grasp the difference between DNA damage and mutation, which are two major types of errors or flaws that occurs within the DNA. Damage and mutation differ fundamentally.

DNA damage is any physical and molecular abnormality within the DNA, including double and single strand breaks, DNA oxidation product remainders, and hydrocarbon adducts. DNA damage can be recognized and detected by enzymes, and therefore can be repaired using the complementary undamaged sequence in a homologous chromosome if it is available for copying. If the DNA of a cell is damaged, the transcription of a gene can be blocked and therefore translation into a protein will also be prevented. Replication might also be prevented and/or the cell may go through apoptosis. In contrast to DNA damage, a mutation is a change in the base sequence of the DNA. A mutation cannot be detected by enzymes and thus cannot be repaired by them. Additionally, from a cellular point of view, mutations cause alterations and flaws in protein functionality and regulation. Mutations are replicated when cell division takes place. Therefore, in a population of cells, mutations only increase and decrease as a consequence of the host cell's ability to survive and replicate.

In non-dividing and slowly dividing cells, DNA damages are a fundamental issue as flaws that cannot be repaired by cell division tend to be accumulated over time. In contrast, in rapidly dividing cells, unrepaired DNA damages that don't kill the cell by blocking replication will cause replication errors which lead to mutations. These type of DNA damages are a prominent cause of cancer because they lead to mutations.

In relation to these distinctions between mutations and DNA damage, though they are distinctly different from each other, DNA damages and mutations are related because DNA damages often cause errors of DNA synthesis during replication or repair and these errors are a major source of mutation. However, first suggested by Alexander in 1967, DNA damage -different from mutation- is the primary cause of aging according to the DNA damage theory of aging.

The Damage Theory

The DNA damage theory of ageing proposes that the main cause of the structural and functional decline in a cellular point of view associated with ageing is the consequence of the accumulation of DNA damage and the resulting cellular alterations and disturbance of tissue homeostasis. Although damage to other kinds of molecules and components found in cells may also influence ageing, DNA damage is particularly essential as, unlike other cellular components which can normally be replaced, DNA must last the lifetime of the cell. Damage to the DNA can have multiple effects, depending on the type of damage and genomic region affected. In particular, DNA damage can lead to gene expression and cellular functionality dysregulation, impair transcription, cause cell cycle arrest and (if the damage is too serious) trigger programmed apoptosis. DNA damage can also lead to mutations when the DNA is repaired and/or replicated.

Although the focused DNA damage that leads to ageing is the damage on the nuclear DNA (nDNA), a role of damage to mitochondrial DNA (mtDNA) in ageing has also been put forward. The mtDNA is much more prone to damage than nDNA, mostly since mtDNA is not protected by histone proteins. In addition, overall the repair of mtDNA is less efficient than the repair of nDNA. However, the mtDNA encodes only 37 genes and the relative importance of mtDNA damage for ageing is still controversial and less supported by experimental evidence than damage to nuclear DNA. As concluded by Khrapko and Vijg in a recent review "Mitochondrial DNA mutations and aging: devils in the details?" about this subject: ''. . .the study of mitochondrial DNA mutations has not reached a stage at which clear, definitive conclusions can be drawn regarding causal relationships.'' Thus, the focus regarding the DNA damage related to the ageing theory is mostly on nDNA damage, which accounts for about 99% of cellular DNA.

The Models and Reviews That Supports The Theory

Various review articles have shown that inadequate DNA repair, allowing accumulation of DNA damage, causes premature aging; and that increased DNA repair facilitates greater longevity. There are various models and experiments that support this theory as well. For instance, mouse models of nucleotide-excision–repair syndromes (syndromes associated with diseases such as skin cancer and developmental and neurological symptoms) reveal a strong correlation between the degree to which specific DNA repair pathways are compromised and the severity of accelerated ageing, suggesting a causal relationship between these two factors. Human population studies show that single-nucleotide polymorphisms (a variation at a single position in a DNA sequence among individuals) in DNA repair genes, causing up-regulation of their expression, correlate with increased longevity. Researcher Lombard compiled a lengthy list of mouse mutational models with pathologic features of premature ageing, all caused by different DNA repair defects.

Researchers Freitas and de Magalhães presented a comprehensive review and appraisal of the DNA damage theory of aging, including a detailed analysis of many forms of evidence linking DNA damage to aging. As an example, they described a study showing that centenarians of 100 to 107 years of age had higher levels of two DNA repair enzymes, PARP1 and Ku70, than general-population old individuals of 69 to 75 years of age. Their analysis supported the hypothesis that improved DNA repair leads to longer life span. Overall, they concluded that while the complexity of responses to DNA damage remains only partially understood, the idea that the accumulation of DNA damage with age is the fundamental cause of ageing remains a really powerful one. DNA damage has a major and crucial role in the modulation of longevity in life, and further research about the DNA damage theory of ageing may provide a new path for scientists to understand ageing and possibly prevent the effects of ageing in the future.

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