Flexing to change colours

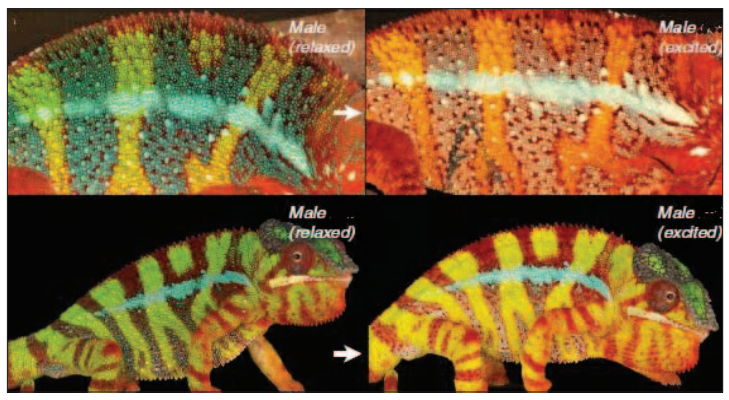
THE CHAMELEON TRICK HAS BEEN FOUND TO BE MECHANICAL RATHER THAN CHEMICAL, WRITES **S ANANTHANARAYANAN**

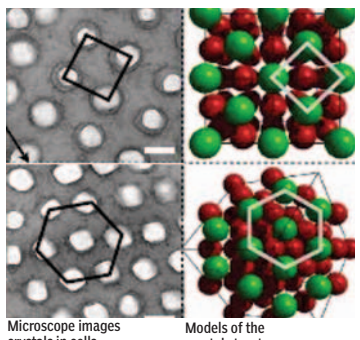
The natural world has been found to use great innovation in the use of colours for identity, communication and camouflage. The colours found in plants are largely based on chemicals in leaves or petals, but in animals, more so with birds and insects, and in the butterfly, especially, great variation of shade and pattern, not even possible with chemicals, is achieved by optical tricks. And the chameleon takes the lead in being able to change colours at will!

This change in colours of the chameleon was considered to arise from a dispersion or the coming together, in the skin of the animals, of light reflecting cells that contain pigments. But Jérémie Teyssier, Suzanne V Saenko, Dirk van der Marel and Michel C Milinkovitch of the University of Geneva, in the journal *Nature Communications*, report the discovery of a different mechanism. It is found that the skin of the male chameleon contains two layers of a mesh of minute crystals that have no affinity to colours but whose orientation and separation affects the shades of light that the skin reflects. Stress or excitation brings about changes in the distances between the nanocrystals, which changes the wavelengths of light that are strongly reflected and thus the colours of the animal's skin.

The variety of colours found in plants comes from selective reflection of light by chemical factors present in cells. The main function of plants surfaces being the collection of light for photosynthesis, the main colour is green, the colour of *chlorophyl*, which absorbs the yellow and blue wavelengths. Another colouring factor in plants is *carotenoids*, the red and yellow shades found in carrots. These assist photosynthesis and also help save the plant cells from damage. And then there are the *anthocyanins* (meaning flower blue) which take shades from red to blue, depending on the acidity of the medium and serve to reflect light that has passed through the leaf or petal to parts that contain chlorophyll, for optimising photosynthesis. Another group of pigments is the red or yellow *Betalains*, found where there are no anthocyanins, like in beetroot or bougainvillea.

Colouration by pigments does not depend on the angle of light or the viewing angle, unlike *structural colouration* found in birds and insects. Here, colour is not because of absorption of wavelengths but suppression of reflected components by the interference of waves, like the rainbow colours seen on a thin sheet of oil spilt on water. Just as light waves of some colours interfere when reflected off the inner and outer surfaces of the film of oil, rainbow effects arise on the thin layers, or step formation of reflecting surfaces on the wings of birds and insects. As the angle at which light falls on these surfaces, or the angle from which they are seen would affect which wavelengths get suppressed, there can be a rapid change of colours or patterns as the animal moves. Animals do not carry out photosynthesis or need to attract bees or butterflies for pollination, and the role of colours in animals is mainly camouflage or to show aggression or attract mates. Most of the action takes place in cells called *chromatophores*, or cells that contain pigment, which can be red, dark, as in black or yellow. The pigment expressed can be controlled and many animals, particularly marine species, are able to make an extent of changes in colours. Many marine species also have fluorescent or bioluminescent structures on their scales. The squid is even known to harbour bacteria that glow to match surroundings so that the host is not seen by predators.




Microscope images crystals in cells

Models of the crystal structure


Pigments

Colouration in animals can also come from structures known as *photonic crystals* in the skin. These are patterns of microscopic crystals that have no colours of their own but affect the passage of particular wavelengths of light by their distribution, with distances between crystals being of about a quarter of the wavelength. In many marine species, such crystal filters create a variety of colours and modifications in the geometry of the reflecting surfaces have been suggested as a way of changing colours too.

The chameleon

Certain kinds of chameleon can display great changes of basic colour, not just variation of shade, which could be explained by changes in the distribution of chromatophores. The *panther chameleon*, native of Madagascar, is one such. It is found to possess two types of dark pigment, which both sexes and all ages can control to strongly modulate the brightness of the skin. But adult males can do a lot more, with various combinations of white, red, green and blue skin and the ability to rapidly change colour. In the presence of a male competitor or a potentially receptive female, a mature male panther chameleon can shift the background colour of its skin from green to yellow or orange, while blue patches turn whitish and red becomes brighter, all within a couple of minutes and fully reversible.

The Geneva researchers analysed the distribution of wavelengths and used high resolution videos to study the colour changes. The specific changes, from blue to green to red, were so marked that they were clearly not only due to pigment change within chromatophores and had to involve structural effects, like multilayer interference. Sensitive microscopic analysis then showed that the chameleon skin contained two layers of reflective cells, called *iridophores*, which contained a matrix of transparent crystals of different shapes and sizes. In adult males, the upper layer was stocked with small, close-packed crystals arranged in a triangular lattice.

This lattice created a pattern of alternating path length for light and the effect was like that of a *photonic crystal*, which is an optical device that can block out a range of wavelengths. Now, further study of chameleon skin at times when it was blue or green (relaxed) and yellow or white (exited), showed that nanocrystals were of the same size, but the distances separating the crystals were about 30 per cent greater when the animal was excited. As the nature of photonic crystals is that the slightest change in geometry leads to large changes in the wavelengths suppressed, variation of crystal separation appeared to be the way the chameleon managed its colour changes.

To test out this suggestion, the researchers took samples of chameleon skin in the excited (white) state and exposed the skin to chemical media of different salinity to create pressures that would shrink the lattice to the relaxed state. "This treatment indeed results in a blue shift," says the paper. "... Furthermore, cell tracking during increase of extracellular osmolarity (ie, salinity) indicates that individual cells experience a gradual shift in colour across the whole visible spectrum."

The group followed up with computing the colour-changing effects that a model optical crystal, with the same properties and dimensions of the chameleon skin lattice would show, and they found that this tallied with what was observed. The finding is thus strongly that the wide colour changes of the chameleon come from physical changes in the layout of photonic crystal elements in the skin, rather than changes in pigments or even orientation of reflecting surfaces.

Another result of the study is that the second layer in the chameleon skin also contains crystals that reflect in the infra-red or radiation that carries heat. As chameleons have evolved in environments of bright sunshine, the function of this layer appears to be a regulation of the temperature of the animal in conditions of intense heat. "The organisation of iridophores into two superposed layers constitutes an evolutionary novelty for chameleons that allows some species to combine efficient camouflage with spectacular display.

Additional analyses are warranted to identify whether the deep layer of iridophores in chameleons further provide them with improved resistance to variable sunlight exposure," the paper says.

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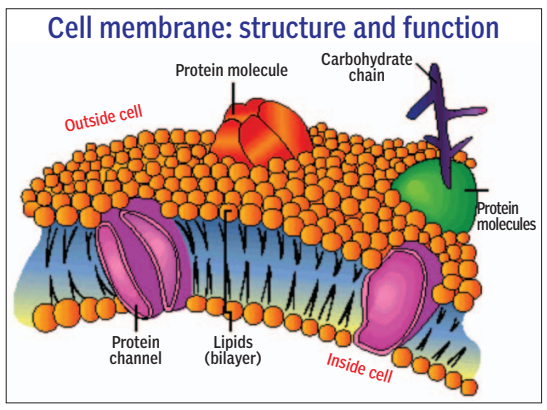
COMPOUND INTEREST

TAPAN KUMAR MAITRA EXPLAINS THE STRUCTURE, FUNCTION AND CHEMISTRY OF MEMBRANES



Cells need membranes to define and compartmentalise space, facilitate and regulate the flow of materials, detect external signals and mediate interactions between cells. Our current understanding of membrane structure represents the culmination of more than a century of studies, beginning with the recognition that lipids are an important membrane component and moving progressively from a lipid monolayer to a phospholipid bilayer.

Once proteins were recognised as important components, Hugh Davson and James F Danielli proposed their "sandwich" model, with the lipid bilayer surrounded on both sides by layers of proteins. This model stimulated much research and was presumed to apply to the variety of membranes revealed by electron microscopy. As membranes and membrane proteins were examined in more detail, however, the "sandwich" model was called increasingly into question and was eventually discredited.

In its place, SJ Singer and GL Nicholson's fluid mosaic model emerged and is now the universally accepted description of membrane structure. According to this model, proteins with varying affinities for the hydrophobic membrane interior float in and on a fluid lipid bilayer. Prominent lipids in most membranes include phospholipids (both phosphoglycerides and phosphorsphingolipids) and glycolipids such as cerebrosides and gangliosides.

In eukaryotic cells, sterols are also important membrane components; these include cholesterol in animal cells and several related phytosterols in plant cells. Sterols are not found in the membranes of prokaryotes, but at least some bacterial cells contain somewhat similar compounds called hopanoids.

In terms of their association with the lipid bilayer, membrane proteins are classified as integral, peripheral or lipid-anchored. Integral membrane proteins have one or more short segments of predominantly hydrophobic amino acids that anchor the protein to the membrane. In many cases, these are transmembrane segments, such that portions of the protein are exposed on both sides. Most of these transmembrane segments are a-helical sequences of about 20-30 predominantly hydrophobic amino acids. Peripheral membrane proteins are hydrophilic and remain on the membrane surface. Lipid-anchored proteins are also hydrophilic in nature but are covalently linked to the membrane by any of several lipid anchors that are embedded in the lipid bilayer.

Most membrane phospholipids and proteins are free to move within the plane of the membrane unless they are specifically anchored to structures on the inner or outer membrane surface. Transverse diffusion, or "flip-flop", between monolayers is not generally possible, except for phospholipids when catalysed by enzymes called phospholipid translocators or flippases. As a result, most membranes are characterised by an asymmetric distribution of lipids between the two monolayers and an asymmetric orientation of proteins within the membranes, so that the two sides of the membrane are structurally and functionally dissimilar.

Membrane proteins function as enzymes, electron carriers, transport molecules and receptor sites for chemical signals such as neurotransmitters and hormone. Membrane proteins also stabilise and shape the membrane and mediate intercellular communication and cell-cell adhesion. Many proteins in the plasma membrane are glycoproteins, with carbohydrate side chains that protrude from the membrane on the external side, where they play important roles as recognition markers on the cell surface.

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One parent, many issues

ON THE CLONING FRONT, **PARTHASARATHI CHAKRABORTY** VOICES THE HOPES AMID ETHICAL AND TECHNICAL PROBLEMS

In an amazing step forward in genetic research, Dolly, the first cloned sheep who was born in Edinburgh on 5 July 1996, was honoured at her birthplace on 25 February this year with a special blue plaque from the Society of Biology. Dolly was unveiled to the world in 1997 and revolutionised scientific understanding of the mechanism of development at the Roslin Institute, University of Edinburg.

The process of creating carbon copies of domestic animals is intricate and dangerous, indeed. Scientists working on genetic engineering in South Korea produced a cloned dog created from the skin cells of a healthy Afghan hound decades ago.

In cloning a human, scientists would employ the same comprehensive technique as used for animals. Though the research is ambitious, the technique raises many ethical and philosophical questions. There is also a dispute among scientists regarding the efficacy of the research. Some have warned that the cloning process may produce genetically abnormal or defective offspring, while others have argued that the research would lead the culture of science in a wrong direction.

Cloning is a departure from the process of fertilisation that occurs from the union of sperm and an ovum, usually inside the mother's womb. Geneticists, on the other hand, produce offspring from an individual body or tissue cells without fertilisation. This then is cloning, or asexual reproduction.

A cloned offspring has one parent. A baby can be produced solely with the help of the mother's body (tissue) cell and there is virtually no need for a male counterpart. The cell taken from a female body would develop a baby with the mirror image of a single parent and hundreds of similar offspring could be produced. It is well known that the genetic code directs the creation of all the proteins in the body. However, when a change in the genetic code takes place, it is called mutation and can lead to genetic disorder.

Scientists are able to change the genetic code in order to produce a desired outcome. Testing the unborn can be done and this helps a pregnant mother to ascertain whether any genetic disorder persists in her unborn child so that the parents could consider an abortion. Abortion, however, is a controversial matter. Completely curing a genetic disorder is difficult, which explains why scientists have introduced a new correct genetic material into the cell.

An African frog was cloned about three decades ago by Professor JB Gordon of Oxford University. He extracted an unfertilised frog ovum, destroyed its nucleus with ultraviolet light and then collected a body cell from the frog, extracted its nucleus with the help of a microscope and implanted this nucleus in the ovum's cell. The cell division started immediately and finally a mature frog developed.

The most striking feature of a cloned offspring is that it is always a replica of the parent of the body cell donor and will not inherit any genetic characteristics from the ovum cell. It is surprising that a woman can donate both ovum cell and body cell for the purpose of cloning. In which case the baby will be identical to the female parent. A male counterpart would not be required for the reproduction process. However, the male would be able to donate his body cell for cloning, in which case the baby would be his identical.


An artist's concept of human cloning and Dolly the sheep.

Though cloning is used as common parlance today, it has many technical problems. During the development of an embryo, its cells specialise for definite functions and gradually "turn off". Turning these specialised cells back "on" with all their original genetic materials for the development of an individual is a new phenomenon.

The geneticists are confident about producing a clone human baby any time. They believe that about 70 million infertile men across the world would be able to have their children by this process. According to many geneticists, it is also a religious culture, an article of faith aimed at perpetuating life and definitely not against the creation of the creator.

However the anti-cloning lobby has argued that the entire process has not yet been mastered. Even experiments with animals so far have produced abnormal babies. About 18 per cent of the cloned mice died, as did 38 per cent goats before maturity. The same result may bring disaster during human cloning.

The idea of breeding humans selectively involves much more than technical problems and there's no avoiding the ethical or philosophical questions. Who will decide what human traits are to be preserved or bred? If the natural genetic variability is bred out of the human population, what would be its consequences? What type of society will geneticists bring? Who will be empowered to decide what is a good or a bad genetic make-up? What would be the relationship of a clone with society?

Despite the hue and cry on human cloning, it transpires that geneticists are determined to go ahead. It is true that there is danger of manipulating human genetic code. But it is hoped that cloning a human baby by genetic engineering would be a work of art. An artist paints a picture with brush, colour and paper. The geneticists' ingredients are different.

THE WRITER, A FORMER READER IN CHEMISTRY, PRESIDENCY COLLEGE, KOLKATA, WAS ASSOCIATED WITH THE UNIVERSITY GRANTS COMMISSION

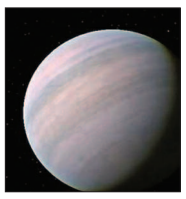
PLUS POINTS

It's real

Astronomers have found new evidence of the existence of an earth-like planet that lies a comparative stone's throw from our solar system. The discovery of GJ 581d was heralded in 2007 but new research last year cast doubt on the claims, saying data used to find it was probably just misinterpreted signals from stars. Astronomers had used a spectrometer to spot the planet, which measures "wobbles" in the wavelength of light emitted by a star caused as a planet orbits it. GJ 581d was said to be a super-earth with a mass seven times that of our own planet orbiting a red dwarf star that could also support up to four other planets. It was believed to be in the habitable "Goldilocks zone" in its solar system, where it is neither too hot nor too cold for liquid water to exist and support life on the surface.

Researchers revisiting the evidence claimed the body was actually just "stellar activity masquerading as planets" and its existence was widely dismissed without further questioning. But now astronomers from Queen Mary University, in London, and the University of Hertfordshire have claimed the statistical techniques used to discount GJ 581d is "inadequate" for planets of its small size.

Dr Guillem Anglada-Escudé, lead author of the paper published in *Science*, said, "The existence (or not) of GJ 581d is significant because it was the first earth-like planet discovered in the 'Goldilocks'-zone around another star and it is a benchmark case for the Doppler technique. There are always discussions among scientists about the ways we interpret data but I'm confident that GJ 581d has been in orbit around (its star) Gliese 581 all along."



If GJ 581d does exist, it could be one of the most earth-like planets yet discovered as ranked by the Earth Similarity Index but that does not mean its surface is the same. For astronomers, the most exciting aspect is its relative proximity – 20 light years away in a galaxy that is 100,000 light years wide.

LIZZIE DEARDEN/THE INDEPENDENT

Oldest *Homo* remains

A fossilised mandible and teeth from an ancient hominin has been found in Ethiopia and may be one of the earliest specimens of the genus *Homo*. The fossil, described in a paper in *Science* on 4 March, is estimated to be between 2.8 million and 2.75 million years old and exhibits a combination of *Homo* characteristics and those of the more primitive hominin genus, *Australopithecus*.

"It is a remarkable new fossil discovery from a really poorly understood timeframe in human evolutionary history," said biological anthropologist Darryl de Ruiter of Texas A&M University who was not involved in the research. Until now, he added, "the earliest really reliable fossil evidence we had for the appearance of *Homo* was about 2 million years old".

However, the fossil record for the earliest *Homo*, *H. habilis*, does not start until about 2 million years ago. Between those two time periods, "there is a big gap in the fossil record", said anthropologist Brian Villmoare of the University of Nevada, Las Vegas, lead author of the new paper. Indeed, there wasn't much more than "a handful of isolated teeth", de Ruiter agreed.

With the hope of filling that gap, Villmoare and colleagues started scouring a site in the lower Awash Valley of Afar, Ethiopia, which geologist Ramón Arrowsmith of Arizona State University and his

colleagues had confirmed contained sediments from 2.84-2.58 million years ago, as described in an accompanying *Science* paper. "One of the convenient things about East Africa," said Villmoare, "is that it is a very volcanic area." When a volcano erupted, he explained, it sent out ash containing crystals that started to decay and could be dated radiometrically. "When the ash lands it starts a timer ticking… so if you are between two ash layers, you know that you are sandwiched between those two dates."

The specimen, which is from an adult and "likely female", said co-author William "Bill" Kimbel of Arizona State, exhibited a similar overall size to the jaws and teeth of *A. afarensis*, but had "somewhat slim" molars and a "more modern and less ape-like" canine area.

RUTH WILLIAMS/THE SCIENTIST