Eggshell marvel

Reptile and bird eggshells take good care of the embryo but let go when it's time to hatch

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The eggshell's first function is protection while the fertilised egg develops. During this time, the eggshell also dissolves from the inside, to be a source of calcium for the growing embryo. This thinning of the inner layers of the shell structure, in turn, helps weaken the shell, so that it cracks when the chick is ready to emerge.

Dimitra Athanasiadou, Wenge Jiang, Dina Goldbaum, Aroba Saleem, Kaustuv Basu, Michael S Pacella, Corinna F Böhm, Richard R Chromik, Maxwell T Hincke, Alejandro B Rodríguez-Navarro, Hojatollah Vali, Stephan E Wolf, Jeffrey J Gray, Khanh Huy Bui and Marc D McKee, from McGill University, Montreal; John Hopkins University, Baltimore; Friedrich-Alexander-University, Germany, and the University of Ottawa, describe in the journal, *Science Advances*, their study of how the nanostructure of the eggshell forms and how it facilitates its diverse functions during the incubation period. And then, the team shows that the protein that brings about the eggshell structure can create structure in non-biological material, just like it does in the eggshell.

Reptile and bird eggshells are remarkable containers that allow the embryo to develop in the rich nutrients of the egg, and in safety. The researchers discover that the eggshell is not the same at all parts of its thickness, and it is a protein called osteopontin, which was first found to help bone tissue to form, that gives the eggshell its structure. Osteopontin is a chain molecule that has many points along its length where it shows a negative charge. Atoms of calcium and minerals bind to these points along the protein molecule. Osteopontin thus forms a scaffold and the calcium carbonate (the same thing as chalk), which forms 95 per cent of the eggshell, grows into a matrix, to form a shell with the optimum structure that makes for strength.

Marc D Mckee

"Eggshells are notoriously difficult to study by traditional means, because they easily break when we try to make a thin slice for imaging by electron microscopy," a press release reports McKee from McGill University to have said. "Thanks to a new focused ion beam sectioning system recently obtained by McGill's Facility for Electron Microscopy Research, we were able to accurately and thinly cut the sample and image the interior of the shell."

Using these methods, the team finds that the eggshell material of the eggs of the domestic chicken (Galus gallus) consists of nano-granules, whose size varies as one passes from the outer to the inner surface. The paper in *Science Advances* explains that living things create a variety of biominerals, in the form of hardened structures, like human bones. In human bones, the material is mainly nano-crystals of calcium phosphate, which forms within a matrix of large organic molecules. In the case of other organisms, the material is mainly calcium carbonate (limestone or chalk), which form rigid structures, typically shells.

In the case of shells of mollusk, coral skeletons, the granular structure has generally been found to be uniform, with the material behaving as if it were just one crystal. In the case of the eggshell, analysis has revealed a varying pattern in the grain size as one passes though the thickness of the shell.

It is found that in the outermost layer, called the vertical crystal layer, the grain size is 30 nanometres. The upper palisades layer, where grain size is 33 nm, comes next. The grain size rises again to 59 nm in the middle PL, to 74 nm in the lower PL and 68 nm in the innermost mammillary layer. This variation in the granular size was found to correspond to the levels of osteopontin present — a large presence in the VCL resulted in fine grain size.

While the gradient in grain size was noted, further study of the PL region, the largest in the section of the eggshell, revealed a pattern of clustering of domains from five to seven nm in size. As a mechanism of how the pattern forms, the researchers suggest that it is similar to the formation of patterns in distribution of pigment, as in leopards' spots or tigers' stripes, and also related to the abundance of osteopontin during different stages of the eggshell formation.

The team also studied the progression of hardness and elasticity of the eggshell material. It was found that the outermost VCL layer was the hardest and most elastic, with the properties reducing till the middle of the PL, and then rising towards the innermost of the ML. That the hardness was highest in the VCL, where the grain size was the smallest is in keeping with the known principles of composite materials, but the rise in hardness towards the ML is still not understood, the study says.

The first understanding from the study is the structure of the avian eggshell and its twin roles — the inner layer being easily dissolved to provide the embryo with calcium for bone development and thereby weakening so that the chicken can hatch when it is ready. But an important finding is that the shell strength can be varied by quantity of osteopontin that is present. It was shown by the team that even outside a biological setting, the mineralising of calcium carbonate was just like in the eggshell when osteopontin was present. And then, more osteopontin led to finer grain size, as in the eggshell.

The paper says that a problem that the poultry industry faces is that when a hen has been laying eggs for about a year, the shells start getting brittle. This could allow salmonella infection and food safety. Knowledge about the eggshell structure and the role of osteopontin could suggest genetic engineering methods for stronger eggshells.

Understanding the role of organic components in structure of composite materials would also help "inform design concepts for synthetic nanocomposites that have novel properties," the study says.

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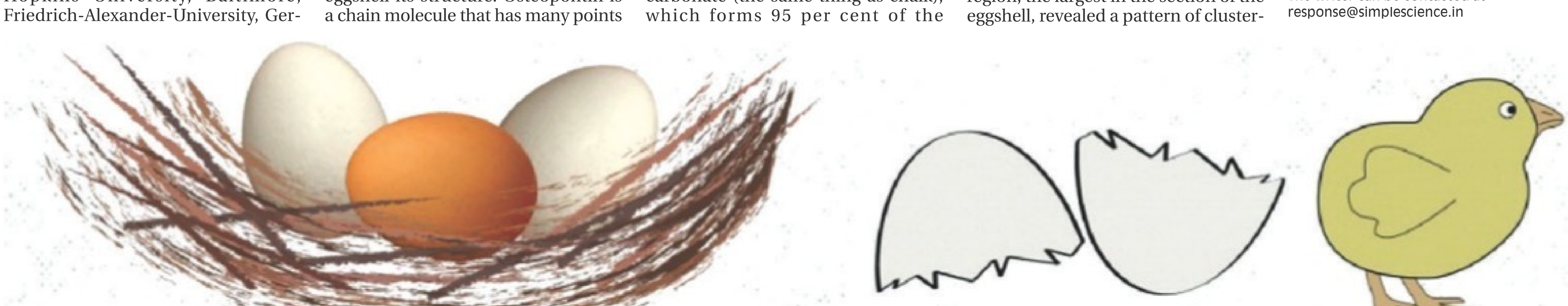


pic from press release by Mc Gill Univ

An eye on the sky

You don't need a supercomputer to predict the weather — just check the type of clouds around

HANNAH CHRISTENSEN

Modern weather forecasts rely on complex computer simulators. They use all the physics equations that describe the atmosphere, including the movement of air, the sun's warmth, and the formation of clouds and rain. Incremental improvements in forecasts over time mean that modern five-day weather forecasts are as skillful as three-day forecasts were 20 years ago.

But you don't need a supercomputer to predict how the weather above your head is likely to change over the next few hours — this has been known across cultures for millennia. By keeping an eye on the skies above you, and knowing a little about how clouds form, you can predict whether rain is on the way.

Clouds form when air cools to the dew point, the temperature at which the air can no longer hold all its water vapour. At this temperature, water vapour condenses to form droplets of liquid water, which we observe as a cloud. For this process to happen, we require air to be forced to rise in the atmosphere, or for moist air to come into contact with a cold surface.

And moreover, a little understanding of the physics behind cloud formation highlights the complexity of the atmosphere, and sheds some light on why predicting the weather beyond a few days is such a challenging problem.

So here are six clouds to keep an eye out for, and how they can help you understand the weather.

■ **Cumulus:** On a sunny day, the sun's radiation heats the land, which in turn heats the air just above it. This warmed air rises by convection and forms cumulus. These "fair weather" clouds look like cotton wool. If you look at a sky filled with cumulus, you may notice they have flat bases, which all lie at the same level. At this height, air from ground level has cooled to the dew point. Cumulus clouds do not generally rain — you're in for fine weather.

■ **Cumulonimbus:** While small cumulus clouds do not rain, if you notice cumulus getting larger and extending higher into the atmosphere, it's a sign that intense rain is on the way. This is common in the summer, with morning cumulus developing into deep cumulonimbus (thunderstorm) clouds in the afternoon.

Near the ground, cumulonimbus clouds are well-defined, but higher up they start to look wispy at the edges. This transition indicates that the cloud is no longer made of water droplets but ice crystals. When gusts of wind blow water droplets outside the cloud, they rapidly evaporate in the drier environment, giving water clouds a very sharp edge. On the other hand, ice crystals carried outside the cloud do not quickly evaporate, giving a wispy appearance.

Cumulonimbus are often flat-topped. Within the cumulonimbus, warm air rises by convection. In doing so, it gradually cools until it is the same temperature as the surrounding atmosphere. At this level, the air is no longer buoyant so cannot rise further. Instead it spreads out, forming a characteristic anvil shape.

■ **Cirrus:** Cirrus form very high in the atmosphere. They are wispy, being composed entirely of ice crystals falling through the atmosphere. If cirrus are carried horizontally by winds moving at different speeds, they take a characteristic hooked shape. Only at very high altitudes or latitudes do cirrus produce rain at ground level.

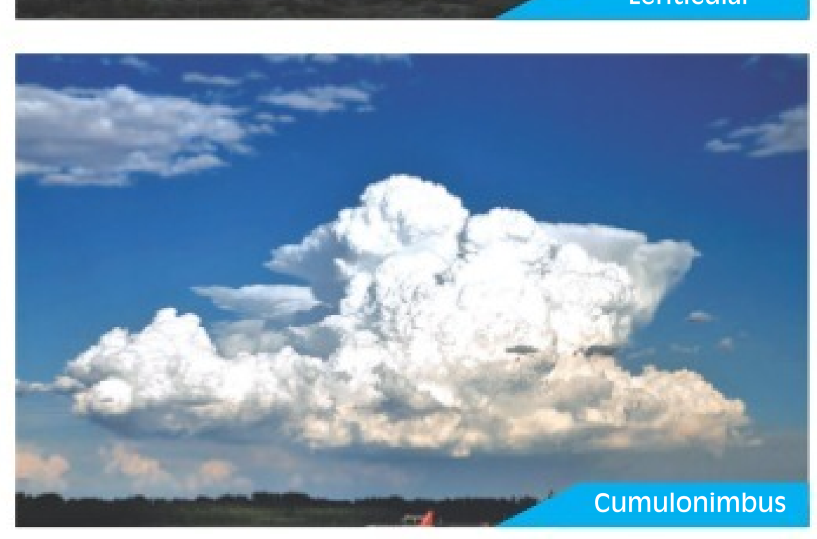
But if you notice that cirrus begins to cover more of the sky, and gets lower and thicker, this is a good indication that a warm front is approaching. In a warm front, a warm and a cold air mass meet.

The lighter warm air is forced to rise over the cold air mass, leading to cloud formation. The lowering clouds indicate that the front is drawing near, giving a period of rain in the next 12 hours.

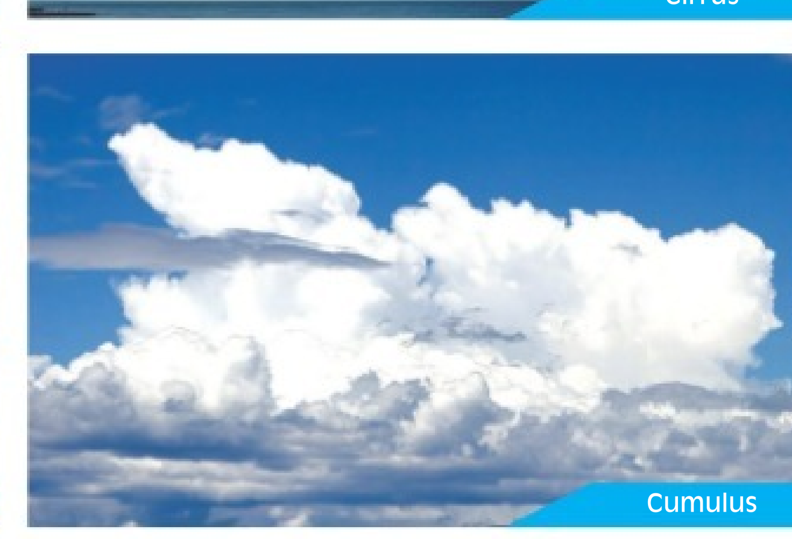
■ **Stratus:** This is a low continuous cloud sheet covering the sky. Stratus forms by gently rising air, or by a mild wind bringing moist air over a cold land or sea surface. Stratus cloud is thin, so while conditions may feel gloomy, rain is unlikely, and at most will be a light drizzle. Stratus is identical to fog, so if you've ever been walking in the mountains on a foggy day, you've been walking in the clouds.

Lenticular

Cirrus

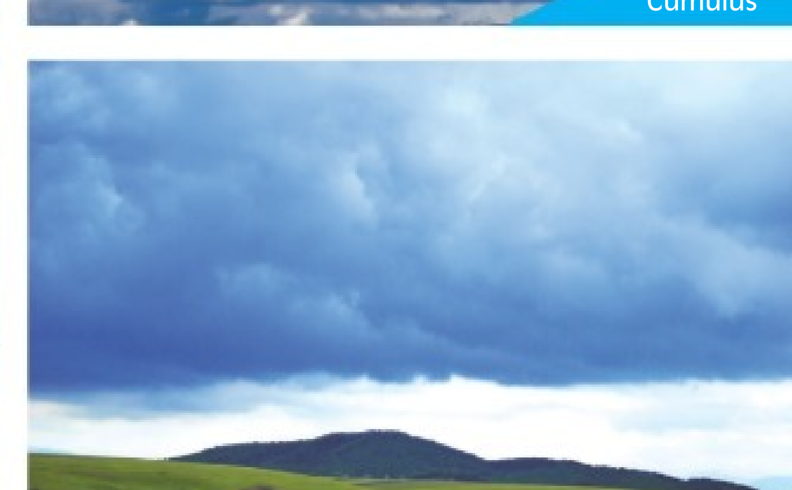


Cumulonimbus



Cumulus

Kelvin-Helmholtz



Stratus

■ **Lenticular:** Our final two cloud types will not help you predict the coming weather, but they do give a glimpse of the extraordinarily complicated motions of the atmosphere. Smooth, lens-shaped lenticular clouds form as air is blown up and over a mountain range.

Once past the mountain, the air sinks back to its previous level. As it sinks, it warms and the cloud evaporates. But it can overshoot, in which case the air mass bobs back up allowing another lenticular cloud to form. This can lead to a string of clouds, extending some way beyond the mountain range.

The interaction of wind with mountains and other surface features is one of the many details that have to be represented in computer simulators to get accurate predictions of the weather.

■ **Kelvin-Helmholtz:** And lastly, my personal favourite. The Kelvin-Helmholtz cloud resembles a breaking ocean wave. When air masses at different heights move horizontally with different speeds, the situation becomes unstable. The boundary between the air masses begins to ripple, eventually forming larger waves.

Kelvin-Helmholtz clouds are rare — the only time I spotted one was over Jutland, western Denmark — because we can only see this process taking place in the atmosphere if the lower air mass contains a cloud. The cloud can then trace out the breaking waves, revealing the intricacy of the otherwise invisible motions above our heads.

The writer is the visiting researcher of atmospheric oceanic and planetary physics at the University of Oxford

The Independent

PLUS POINTS

The Sahara has expanded

The Sahara Desert has grown significantly over the last century, and climate change is largely to blame, according to a new study.

Analysing data collected since 1923, a research team examined the different factors that contributed to changes in rainfall in the Sahara region. They found the desert, already around the size of the US, had expanded by about 10 per cent over the period covered by this data.

These results have implications for those living in the border region of the Sahara known as the Sahel, but the scientists noted that climate change-driven desertification is not a phenomenon unique to the Sahara.

"Our results are specific to the Sahara, but they likely have implications for the world's other deserts," said professor Sumant Nigam, an atmospheric and oceanic scientist at the University of Maryland and the senior author of the study. As the world's population continues to grow, people in desert border regions cannot afford to lose more arable land to the desert.

As with any desert, the Sahara undergoes seasonal patterns of expansion and contraction but Nigam and his colleagues were able to establish the extent of its overall expansion. In order to single out the effects of climate change, the scientists used statistical methods to remove the effects natural climate cycles such as the Atlantic Multidecadal Oscillation had on rainfall variability.

Their results revealed a combination of natural climate cycles and human-caused climate change that is responsible for this effect over the past century — with the latter accounting for around a third of the increase. The study was published in the *Journal of Climate*.

Natalie Thomas, a graduate student in atmospheric and oceanic science who contributed to the research, said, "With this study, our priority was to document the long-term trends in rainfall and temperature in the Sahara. Our next step will be to look at what is driving these trends, for the Sahara and elsewhere.

"In Africa, winters are holding steady but summers are getting warmer. So the stresses are already more severe compared to say, North America."

The independent

Brains & bees

Researchers from the University of Sheffield have discovered that looking at honeybees in a colony in the same way as neurons in a brain could help us better understand the basic mechanisms of human behaviour.

The team studied a theoretical model of how honeybees decide where to build their nest and viewed the bee colony as a single super organism, which displays a coordinated response to external stimuli — similar to the human brain. The study concluded that the way in which bees "speak" with each other and make decisions is comparable to the way the many individual neurons in the human brain interact.

The study, published in *Nature: Scientific Reports*, which has fundamentally found that super organisms may obey the same laws as the human brain, is important because it suggests that the mechanisms that generate such psychophysical laws are not only happening in brains as previously thought. This discovery will enable scientists to better understand the basic principles that generate such laws by studying super organisms such as bee colonies, which is much simpler than watching brain neurons in action when a decision is being made.

Andreagiovanni Reina, research associate in collective robotics in the University of Sheffield's department of computer science, said, "Parallels between bees in a colony and neurons in a brain can be traced, helping us to understand and identify the general mechanisms underlying psychophysics laws, which may ultimately lead to a better understanding of the human brain."