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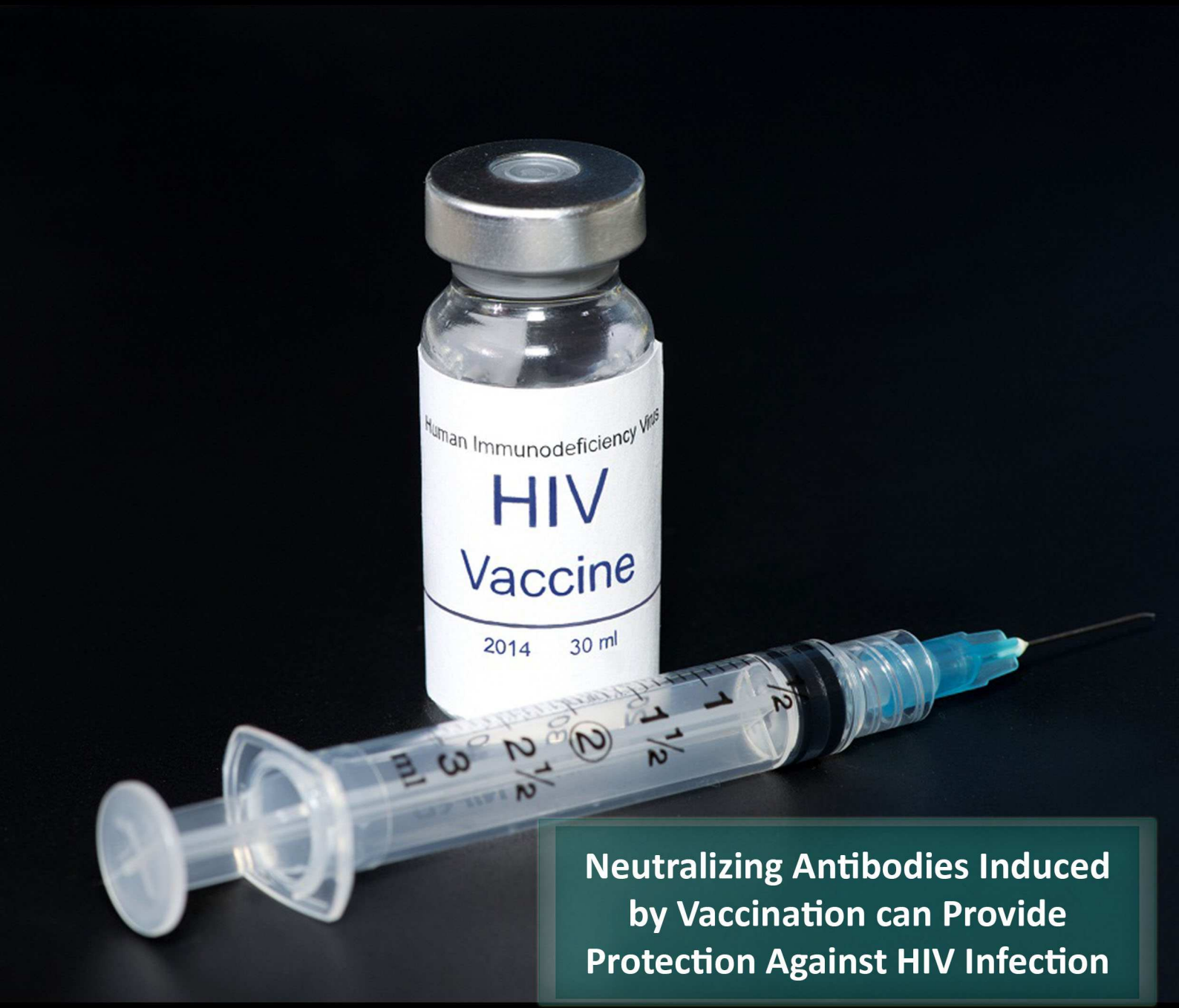

Neutralizing Antibodies Induced by Vaccination can Provide Protection Against HIV Infection

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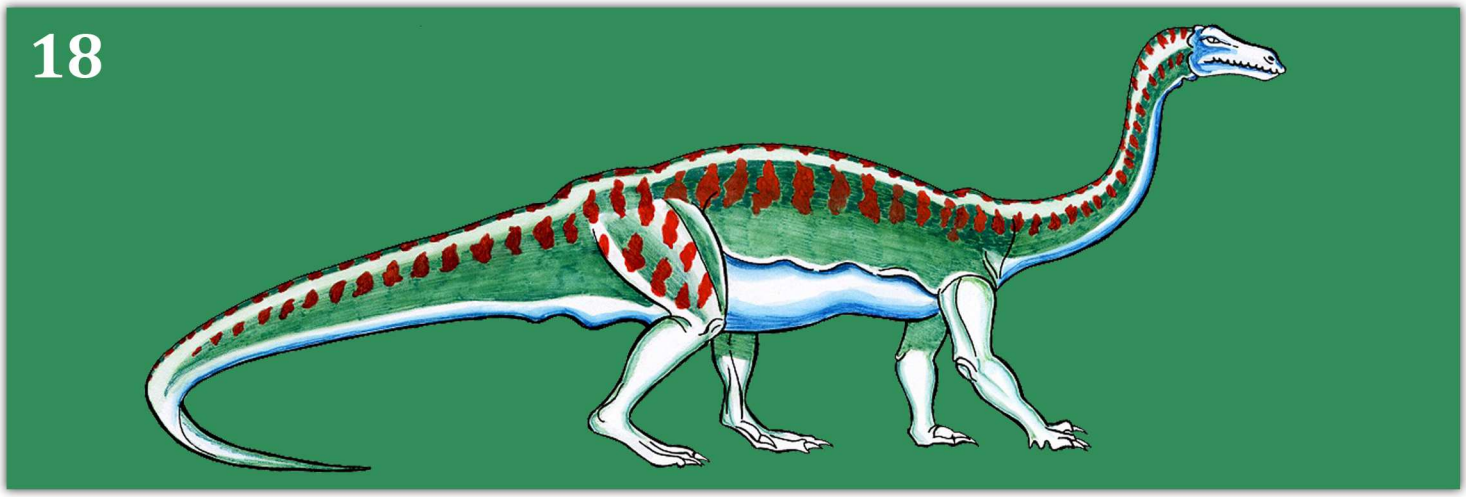

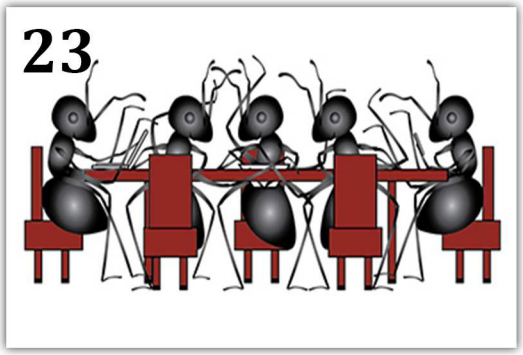

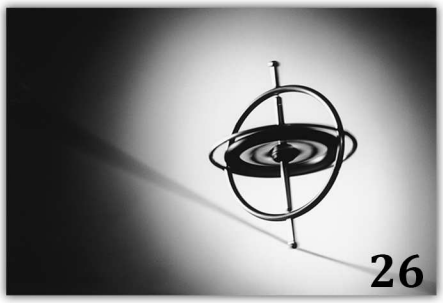

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NOTE FROM EDITOR-IN-CHIEF

We are thrilled to bring to you nine articles on recent interesting science discoveries which have the potential to bring about changes in society including new vaccine for HIV, understanding pain pathway, advances in cleaner fuel and energy, new understanding of diabetes and many more.

Hope you enjoy reading them!

Umesh Prasad

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Glucagon Mediated *Glucose Production in* Liver can Control and *Prevent Diabetes*

An important marker for diabetes development has been identified.

The two important hormones produced in the pancreas – glucagon and insulin – control proper glucose levels in response to the food that we consume. Glucagon increases Hepatic Glucose Production (HGP) and insulin decreases it. They both control blood glucose homeostasis. When we are fasting, glucagon is secreted from a-cells of the pancreas to increase the blood glucose in the body in order to protect the body from a condition called hypoglycaemia wherein a person's blood glucose levels fall drastically and leads to symptoms. Glucagon is involved in development of diabetic hyperglycaemia when Hepatic Glucose Production (HGP) in increased. Insulin suppresses glucose production through transcriptional regular in liver cells. A protein called Transcription factor Foxo1 plays an important role in regulating expression of genes and promoting HGP by increasing expression of genes which are responsible for production of glucose. Disruption of proper HGP is understood as a key primary mechanism for development of Type 2 diabetes.

In a study published in *Diabetes,* researchers from Texas A&M University USA set out to understand the role of Foxo1 in how glucagon regulates HGP. They wanted to better understand the fundamentals of blood glucose homeostasis and pathogenesis of diabetes. Glucagon does its function by binding to a GPCR

receptor, stimulating the cell membrane to activate protein kinase A which then signals gene expression to increase blood glucose. The levels of glucagon are extremely high in humans with diabetes and this stimulates excess production of HGP.

Researchers investigated Foxo1 regulation through phosphorylation i.e. attachment of a phosphoryl group. Phosphorylation is an important part of protein function and is responsible for activating or deactivating almost 50 percent of enzymes present in our body, and thereby regulating their function. Researchers used mice model and gene editing to generate Foxo1 'knock in' mice. Foxo1 was stabilised in liver of mice (who were fasting) when insulin was decreased and glucagon increased in the bloodstream. The study clearly showed that if hepatic Foxo1 was deleted, hepatic glucose production (HGP) and blood glucose was decreased in mice. Thus, a novel mechanism has been identified for the first time in which Foxo1 mediates glycogen signalling via phosphorylation in order to control blood glucose.

Foxo1 is an important protein that acts as a mediator for various pathways integrating hormones and other proteins to control insulin sensitivity. Since high glucagon levels are present both in Type 1 and Type 2 diabetes, Foxo1 will play an important role in the fundamental mechanism leading to diabetic hyperglycaemia. The study suggests that glucagon mediated HGP can be a potential therapeutic intervention for control and also possible prevention of diabetes.

Source

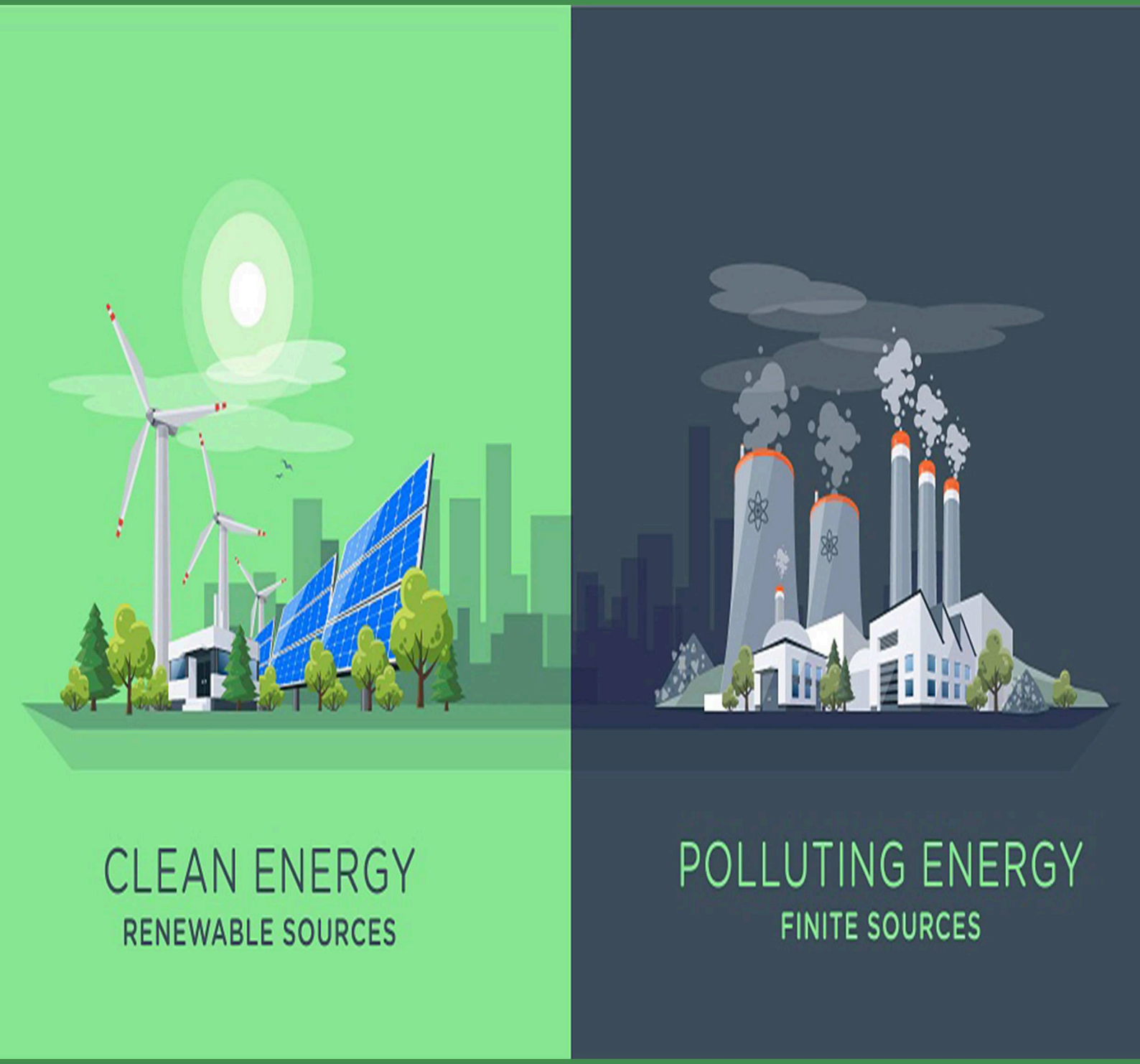
Yuxin Wu et al. 'Novel Mechanism of Foxo1 Phosphorylation in Glucagon Signaling in Control of Glucose Homeostasis', *Diabetes*, vol. 67, no.11, DOI: https://doi.org/10.2337/db18-0674 ■

Advances in Laser Technology Opens New Vistas for Cleaner Fuel and Energy

Scientists have developed a laser technology which could open avenues for clean fuel and energy technologies in the future.

We urgently need environment friendly and sustainable ways to replace fossil fuels, oil and natural gas. Carbon dioxide (CO2) is an abundant waste product produced by all activities and sources which rely on fossil fuels. About 35 billion metric tons of Carbon dioxide is released into our planet's atmosphere annually as a waste product from electricity generating power plants, vehicles and industrial setups across the globe. To mitigate the effects of CO2 on global climate, this wasted CO2 could rather be converted into usable energy like carbon monoxide and other energy-abundant sources. Example, reacting with water CO2 produces energy-rich hydrogen gas, when reacted with hydrogen it produces useful chemicals like hydrocarbons or alcohol. Such products could be used for various purposes and that too on a global industrial scale.

Electrocatalysts are catalysts which take part in electrochemical reactions – when a chemical reaction is taking place but electrical power is also involved. Example, a right catalyst can help to react hydrogen and oxygen to make water in a controlled manner, otherwise it will just be a random mixture of two gases. Or even to produce electricity by burning hydrogen and oxygen. Electrocatalysts modify or increase the rate of chemical reactions without themselves getting consumed in the reaction. In context with CO2, electrocatalysts are seen as relevant and promising in terms of achieving efficiency 'step-change' in reduction of CO2 as desired.


CLEAN ENERGY
RENEWABLE SOURCES
POLLUTING ENERGY
FINITE SOURCES

Unfortunately, the exact mechanism of how these electrocatalysts work is not completely understood and it remains a significant challenge is to differentiate between layers of short-lived intermediate molecules with the "noise" of inactive molecules in the solution. This limited understanding of the mechanism poses difficulties in any possible alteration in design of electrocatalysts.

Scientists at Liverpool University UK have demonstrated a laser-based spectroscopy technique for electrochemical reduction of carbon dioxide in-situ in their study published in *Nature Catalysis*. They used Vibrational Sum-Frequency Generation or VSFG spectroscopy for the first time along with electrochemical experiments to explore a catalyst (Mn(bpy)(CO)3Br) which is seen as a promising CO2 reduction electrocatalyst. The behaviour of crucial intermediaries which are present in a reaction's catalytic cycle for a very short interval was observed for the first time. So, the exact behaviour of how electrocatalysts operate in a chemical reaction is understood. VSFG technology makes it possible to follow behaviour and movement of even extremely short-lived species in a catalytic cycle and therefore helps us to understand how electrocatalysts operate.

This study provides insights into some of the complex chemical pathways and can allow us create new designs for electrocatalysts. Researchers are already investigating further on how to improve the sensitivity of this technique and are also developing a new detection system for better signal to noise ratio. Authors say that this approach could help open up avenues for efficient clean fuel and garner more potential for clean energy. Such a process eventually needs to be industrially scaled up for achieving more efficiency at the commercial level. Handling large volumes of CO2 produced from fossil fuel burning plants will require industrial advancement.

Key points

- We urgently need environment friendly and sustainable ways to replace fossil fuels, oil and natural gas.
- To mitigate the effects of CO2 on global climate, this wasted CO2 could rather be converted into usable energy like carbon monoxide and other energy-abundant sources.
- The study provides insights into some of the complex chemical pathways and can allow us create new designs for electrocatalysts for CO2 reduction.

Source

Gaia Neri, James. J. Walsh, Gilberto Teobaldi, Paul M. Donaldson, and Alexander J. Cowan 2018, 'Detection of catalytic intermediates at an electrode surface during carbon dioxide reduction by an earth-abundant catalyst', *Nature Catalysis*, DOI: https://doi.org/10.17638/datacat.liverpool.ac.uk/533 ■

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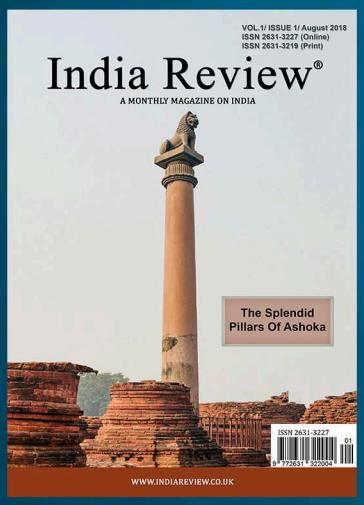

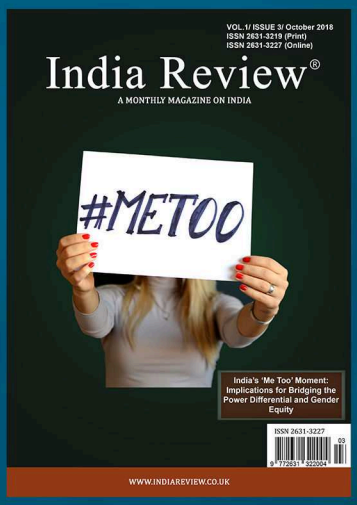

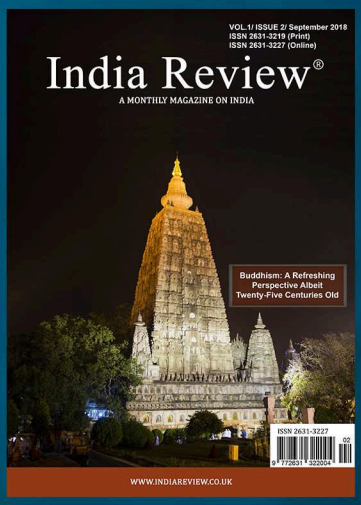

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Biological Barriers of Reproduction from *Same-Sex Mammals Overcome*

Study shows for the first time healthy mouse offspring born from same sex parents – in this case mothers.

The biological aspect of why mammals need two opposite genders to procreate has intrigued researchers for very long. Scientists are trying to understand what really hinders two mothers or two fathers from bearing an offspring. Organisms other than mammals, like reptiles, fish and amphibians produce an offspring without a partner. Animals have three different modes of reproduction (asexual, unisexual and sexual), but mammals including humans can only undergo sexual reproduction where two parents of opposite sex are involved.

Even with in-depth understanding of fertilization and advancement in medical technology in recent decades, it has been unthinkable to produce a mammalian offspring from two same sex parents. It is understood that genetic material (DNA) is needed from both parents (male and female) for development because a mother's DNA and father's DNA basically compete with one another for a place in the offspring. And there is a genomic imprinting barrier i.e. certain maternal or paternal genes are imprinted (branded or labelled based upon from whom they have come) and then turned off during different phases of embryonic development. This barrier needs to be overcome. Different genes are imprinted in mother's genetic

material, so an offspring of a mammal needs genetic material from both genders in order for all the required genes to be activated. Both genetic materials are thus crucial because an offspring who doesn't get genetic material from either father or mother will have developmental abnormalities and may not be viable enough to be born. This is simply why it is impossible to have same sex parents.

Offspring from two females

In an interesting study published in *Cell Stem Cell*, scientists at Chinese Academy of Sciences have for the first time produced 29 living and healthy mice offspring from same-sex parents, here two biological mothers. These infants went on to become adults and were able to have their own normal offspring too. Scientists achieved this by using stem cells and targeted manipulation/editing of genes which suggests that some barriers can be successfully overcome. To create bi-maternal mice (mice with two mothers), they used cells called haploid embryonic stem cells (ESCs) containing only half the number of chromosomes and DNA only from one parent (here female mouse). These cells are described to be similar to cells which are precursor to eggs and sperm and have been pointed as the main reason for this breakthrough study. Researchers deleted three genetic imprinting regions from these haploid ESCs which contained mother's DNA and these cells were then injected into eggs taken from another female mouse producing 210 embryos which then formed 29 live mice offspring.

Scientists also tried making bi-paternal mice (mice with two fathers), but using a male DNA was more challenging as it involved modifying haploid ESCs

containing male parent's DNA and required deletion of seven genetic imprinting regions. These cells were injected along with the sperm of another male mouse into a female egg cell of which the nucleus which contains female genetic material was removed. The embryos created now had only DNA from male were transferred along the placental material to surrogate mothers who did carry them to full term. However, it didn't work well for the 12 full-term mice (2.5 percent of total) that were born from two fathers as they survived only for 48 hours.

This is a crucial study where biological barriers of reproduction from same-sex mammals appear to have been overcome after genetic factors which prevent same sex reproduction had been analysed. The genetic roadblocks revealed are some of the most important DNA regions which hinder the development of mice with same sex parents. Challenging of course, this is the first study to produce healthy mice offspring with same sex parents which are comparable to regular mice.

Can this be done in humans?

Experts say that such extensive genetic manipulation may not be feasible to do in most mammals, especially humans. Firstly, identifying the genes which will need to be manipulated is tricky as 'imprinted genes' are unique to every species. There is a high risk of severe abnormalities arising and there are numerous safety issues involved. This is a long path laden with implausibility that something like this could be replicated in humans. And technological hurdles aside, it's an ongoing debate about ethical and practical issues involved in the procedure. Nevertheless, this study is an interesting milestone and can be used to strengthen our understanding of fertilization and embryonic development. It could assist in understanding infertility and origin of congenital diseases better. The study can also be utilized extensively in animals research example cloning in the future.

Source

Zhi-Kun Li et al. 2018, 'Generation of Bimaternal and Bipaternal Mice from Hypomethylated Haploid ESCs with Imprinting Region Deletions', *Cell Stem Cell*, DOI: https://-doi.org/10.1016/j.stem.2018.09.004

■

Neutralizing Antibodies *Induced by Vaccination can Provide Protection* Against HIV Infection

Research shows that neutralizing antibodies which are induced by vaccination can protect animals from HIV infection.

Developing a safe and effective HIV (Human Immunodeficiency Virus) vaccine, despite up to 30 ongoing clinical trials, is a challenge faced by research community for decades. This is the scenario in spite of making good progress is understanding how HIV virus interacts with the human immune system. One of the fundamental challenges in this area is the ability of HIV to replicate rapidly and also with slightly altered genetic makeup every time. Neutralizing antibodies generated against HIV are seen to be insufficient to completely clear an HIV infection because they can never provide protection against different strains of HIV. But even then, vaccine- induced HIV antibodies are still going to be important for protection from this infection.

Perils of an HIV infection

Unfortunately, the primary target of HIV virus is our immune system which is supposed to protect us in the first place. This is by far the biggest challenge in tackling an HIV infection. Another limitation in research on HIV vaccine is that it cannot be tested in laboratory in animal models like mice because HIV only infects humans. Some research has been carried out in a primate equivalent of HIV called SIV but this is still an imperfect model.

Scientists also tried making bi-paternal mice (mice with two fathers), but using a male DNA was more challenging as it involved modifying haploid ESCs containing male parent's DNA and required deletion of seven genetic imprinting regions. These cells were injected along with the sperm of


Human Immunodeficiency Virus
HIV
Vaccine
2014 30 ml

another male mouse into a female egg cell of which the nucleus which contains female genetic material was removed. The embryos created now had only DNA from male were transferred along the placental material to surrogate mothers who did carry them to full term. However, it didn't work well for the 12 full-term mice (2.5 percent of total) that were born from two fathers as they survived only for 48 hours.

New HIV vaccine

An experimental HIV vaccine designed by researchers at Scripps Institute USA is seen to be working in non-human primates – rhesus monkeys. The goal was to be able to make neutralizing antibodies which could be induced through vaccination and these antibodies would 'teach' the immune system to fight the HIV virus by targeting a vulnerable area on the virus. The key to strong immune response with any vaccine is to select the right antigen (here, HIV or a part of it) which can stimulate the immune system to generate a desired response. Research has shown that such antibodies should bind to the virus's outer protein trimer and if this happens the antibodies can successfully protect the organism from attack of the virus. A major challenge here is that organisms must be able to make these antibodies themselves. This can be achieved only when the immune system is exposed to the virus's outer protein trimer, thus getting trained to be able to identify the target and produce correct antibodies against it.

The protein trimer was seen to be very unstable when it was isolated alone and researchers were unable to isolate it without breakage. In 2013, scientists were able to successfully genetically engineer a stable trimer called SOSIP which looked very similar to the HIV envelope protein trimer. For the current study scientists used this to design the experimental HIV vaccine which would contain the stable SOSIP trimer and wanted to check if this can trigger the immune system to produce desired antibodies to protect from an HIV infection.

The designed vaccine was tested on two groups of non-human primate rhesus macaques. In a previous study, monkeys have been seen to develop either low or high antibody levels after a vaccination. For current study, six of each of these monkeys were selected and additional twelve unimmunized primates were used as control. The primates were exposed to a virus form called SHIV (a genetically engineered simian version of HIV containing same trimer as the human virus). This is a very resilient form of the virus called Tier 2 virus because it's difficult to neutralize and thus is challenging in the same manner as human virus and this particular strain affects most people.

The new vaccine enables the monkeys to make neutralizing antibodies against this strain of the virus and worked well on previously vaccinated monkeys with high levels of antibodies

Key points

- The biggest challenge in developing HIV vaccine is that the primary target of HIV is our immune system which is supposed to protect us in the first place.
- An experimental HIV vaccine has been designed which works on non-human primates – rhesus monkeys.
- This study provides first estimate of how much level of such neutralizing antibodies would be required in order to protect someone from HIV

protecting the animal against infection. However, the result clearly indicates that success is achieved in monkeys with already high antibody levels meaning that this would be a precondition-al criterion. Also, these animals who were previ-ously vaccinated, their antibody levels start to deplete in weeks or months following the vacci-nation. An estimation was gathered on how much antibody levels would be needed to keep away the infection.

This study published in *Immunity* provides an estimate for the first time of how much levels of neutralizing antibodies would be required in order to protect someone from HIV. Its interest-ing to note that only the production of neutraliz-ing antibodies by the immune system was seen to be critical. The aim would be to sustain high antibody levels. There is still some interval before this experimental vaccine could move to human clinical trials. The authors are confident that this is a major understanding achieved in the field of HIV vaccine almost after three decades. Such a strategy could be applied to other strains of HIV as well.

Source

Matthias G. Pauthner et al. 2018, 'Vaccine-In-duced Protection from Homologous Tier 2 SHIV Challenge in Nonhuman Primates Depends on Serum-Neutralizing Antibody Titers', *Immunity*, DOI: https://doi.org/10.1016/j.immu-ni.2018.11.011

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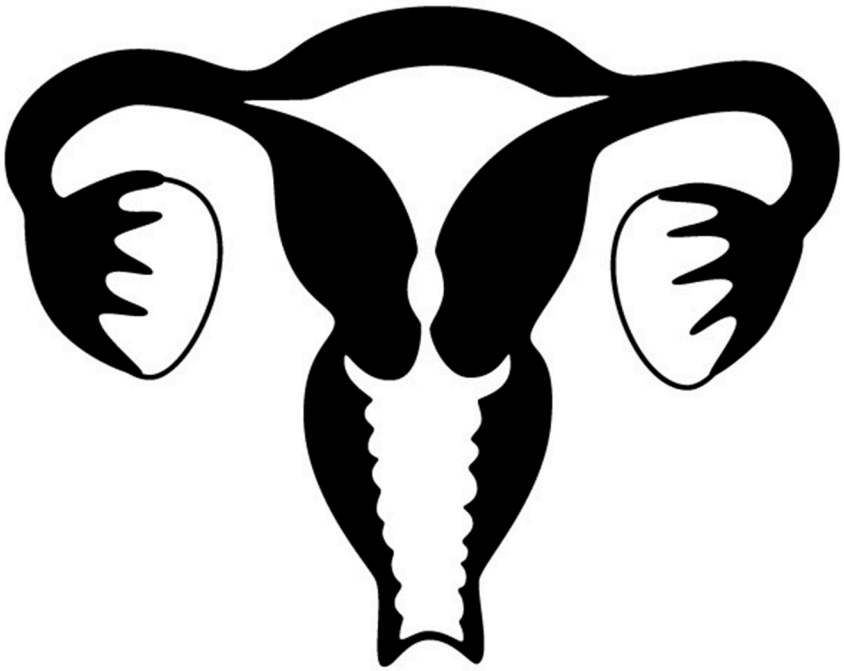
The First Successful *Pregnancy and Birth After* Womb Transplant from *a Deceased Donor*

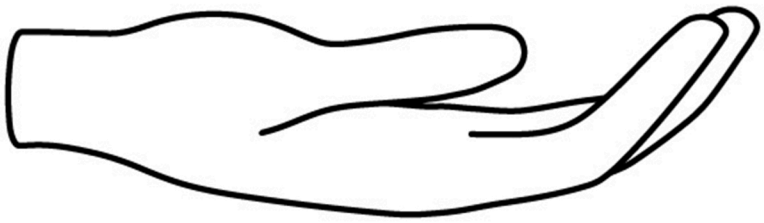
First womb transplant from a deceased donor leads to successful birth of a healthy baby.

Infertility is a modern ailment which affects at least 15 percent of population of reproductive age. A female may face permanent infertility due to underlying conditions like ovulation problems, damaged fallopian tubes, poor eggs etc. There are also cases when a female is able to produce eggs in the ovary but if she is born without the uterus (womb) she cannot bear a child. This is called uterine infertility whose main cause could be birth defects, injury or diseases like cancer. Such females have an option to either adopt children or use a surrogate who can carry their baby for the duration of pregnancy. If at all one would wish to bear their own child, they would need a uterus transplant. A significant medical milestone in 2013 created the option of using a 'living' uterus donor who is generally a near and dear one who is willing to donate. After uterus was transplanted the patient could bear a baby. Using a 'living' donor was a major limitation, obviously because of lack of donors.

Transplanting the uterus

Medical scientists set out to find an alternative to using living donors and thought of using uterus from a deceased donor. In attempting transplants, they had earlier faced at least 10 unsuccessful attempts as several factors come into play. The most important one being keeping the organ (uterus) viable after the donor's death. This is extremely challenging. In a scientific breakthrough in uterine infertility, a woman who was born without a uterus has become the first person to give birth to a living baby – a healthy baby girl weighing 6 lbs - after receiving womb transplant from a deceased donor. In the study scientists transplanted the uterus after oxygen supply to the organ was snapped for almost eight hours.





This women patient was born with Mayer-Rokitansky-Küster-Hauser syndrome, a condition in which parts of the reproductive system, like the uterus, fail to develop though other organs like ovaries (which produces eggs) develops normally and women ordinarily reach puberty also. The womb donor was a 45-year-old woman who died of brain haemorrhage. The transplant surgery was very challenging taking almost 10 and half hours to form the right connection between donor uterus and the recipient woman's blood vessels, muscles and birth canal.

Once the transplant was complete and the woman began having regular periods, in about seven months the lining of the uterus thickened enough to transplant fertilized eggs which had been frozen earlier in IVF treatment before the transplant surgery. IVF was used to retrieve the eggs from the patient and used for fertilization in the laboratory to produce embryo which were then transplanted to the uterus. The pregnancy progressed fairly normal and uncomplicated. The patient did need antibiotics for a kidney infection which could possibly have created more risk because after a transplant, a patient is given immunosuppressant drugs in order to suppress one's immune system so that it doesn't reject a transplant. The baby was born at 35 weeks via caesarean section, following which the womb was removed from the body so that the patient could stop taking immunosuppressant drugs.

This study published in *The Lancet* provides a solid proof of using an organ from a deceased donor and which could benefit many such women. In December 2018, the baby was a healthy seven months and 20 days. The major upside of this success is that the number of people willing to donate organs upon their death are more thus this can offer more donors. In comparison to live organ transplant, the costs and risks are also reduced

when it involves a deceased donor.

A controversial debate

This transplant study is also attached with many controversial facets. Example, the patient has to bear the load of immunosuppressant drugs which affect one's immune system and makes the recipient more prone to infections and injury. Thus, the female receiving the uterus transplant is at risk and experts argue if such a risk is worth taking. Also, in financial terms this procedure is very expensive as it not only involves a complex transplant surgery which has to be done by only experienced medical experts but the costs of IVF need to be factored in as well. Since infertility is not regarded as a life-threatening ailment, such huge expenditure on treatment either supported by the Govt or by insurance companies is not gladly acceptable by many policy makers.

Source

Dani Ejzenberg et al. 2018, 'Livebirth after uterus transplantation from a deceased donor in a recipient with uterine infertility', *The Lancet*, vol. 392, no.10165,
DOI: https://-doi.org/10.1016/S0140-6736(18)31766-5 ■

The Largest Dinosaur Fossil Excavated for the First Time in South Africa

Scientists have excavated the largest dinosaur fossil which would have been the largest terrestrial animal on our planet.

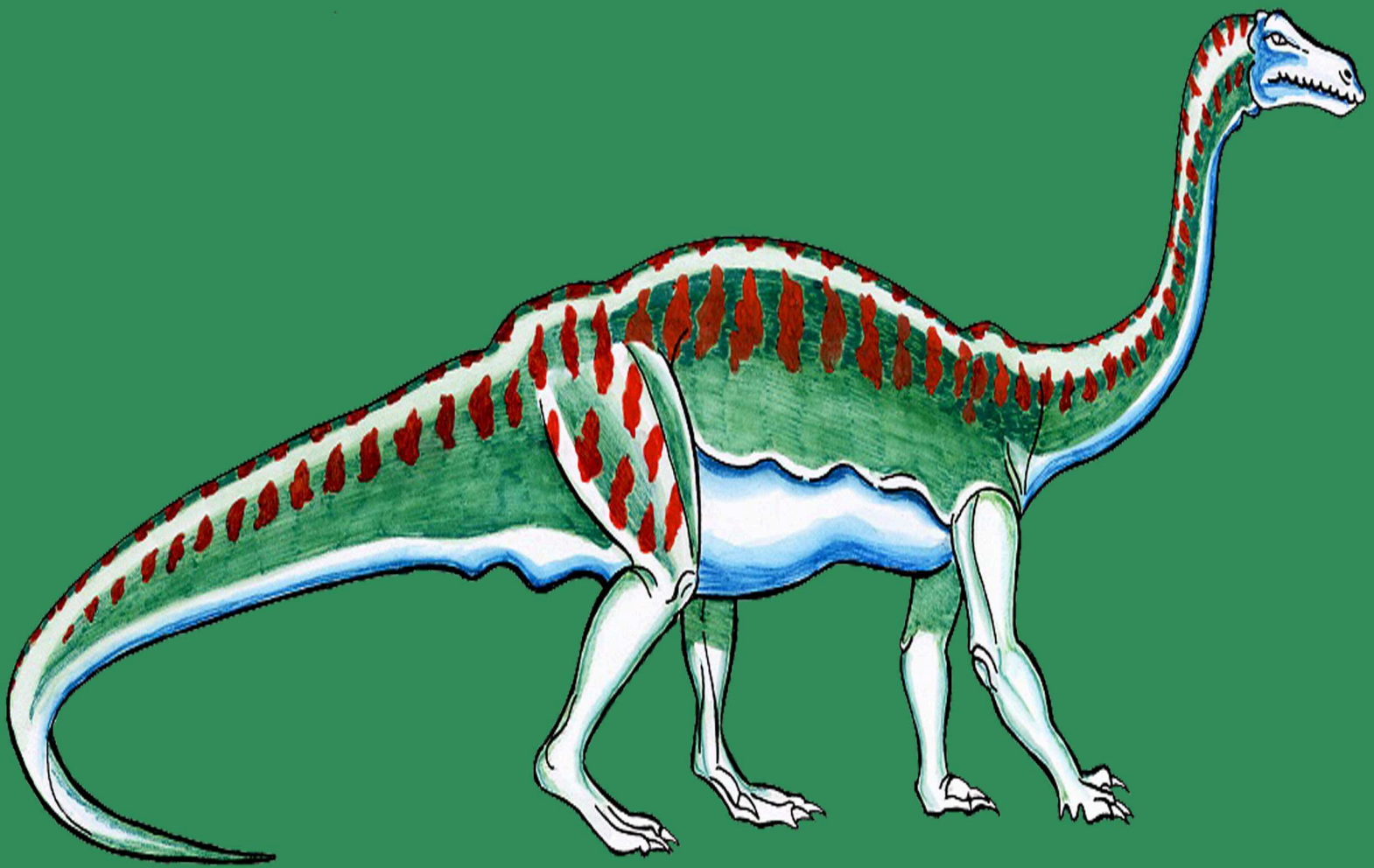
A team of scientists from South Africa, UK and Brazil led by University of Witwatersrand have discovered a fossil of a new species of dinosaur in South Africa thought to be a related to brontosaurus. This early Jurassic dinosaur weighed a huge 26,000 pounds i.e. double the size of an African elephant, and stands four meters at hip. It has been named 'Ledumahadi mafube' meaning 'giant thunderclap at dawn' in the indigenous language Sesotho of the region where it was discovered.

A gigantic dinosaur

This animal is found to be unique not just in its gigantic size but also its evolutionary history. The chance discovery was first initiated upon discovering a partial skeleton of an unknown dinosaur literally sticking out of rocks back in 2012 during a field visit. Once researchers realised how huge the size of the thigh bone was, it dawned on them about the humungous size of this animal. After years of excavation, fossil of an adult dinosaur was uncovered thought to be at least 14 years old and weighing 12 tons at time of death. Fossil's bone tissue analysis using osteohistological examination helped establish age of the animal. The fossil bone microstructure reveals that this animal grew fast to adulthood and closely-spaced growth rings at the periphery show that growth rate had decreased substantially confirming that it had reached adulthood.

An evolutionary transition

Ledumahadi is closely related to sauropod dinosaurs including the well-known species



Brontosaurus and Diplodocus. It was a plant-eating herbivore, had thick limbs and was a quadruped i.e. it walked on all four legs in a posture similar to modern elephants. Compared to sauropod's long, slender columnar limbs, Ledumahadi's forelimbs were more crouched i.e. it had more flexed limbs like primitive dinosaurs. Their ancestors walked on two legs only and they must have adapted to walk on all four and that is why they grew larger to support digestion as they were herbivores.

Researchers compared fossil data from dinosaurs, reptiles etc who walked on two or four legs and they measured limb size and thickness. This is how they concluded Ledumahadi's posture and its way of walking on all four limbs. It is understood that many other dinosaurs must have experimented walking on all four limbs which could optimally balance a bigger body. Based upon these collective observations, researchers say that Ledumahadi was definitely a 'transitional' dinosaur, as it had 'crouched' yet very thick limbs to support its large body. Their limb bones– both arms and legs - are very robust and similar in shape to giant sauropod dinosaurs but obviously thicker while sauropods had more slender limbs. The evolution of four-legged postures came before their giant bodies. Just sheer size and elephant-like limb posture helped them, example sauropods, to become one of the most dominant dinosaur groups during the Jurassic era. Ledumahadi definitely represents a transitional stage between two major groups of dinosaurs. The group of early dinosaurs were experimenting with various ways of becoming bigger in size during the first tens of millions of years of their evolution. What it means for research is that the evolutionary transition from a small, bipedal creature to a large, quadrupled sauropod is a complex path and this evolution certainly led to survival and achieving dominance.

Key points

- Scientists have discovered a fossil of a new species of dinosaur in South Africa thought to be a related to brontosaurus and is named 'Ledumahadi mafube'.
- Ledumahadi was a 'transitional' dinosaur, as it had 'crouched' yet very thick limbs to support its large body.
- This is another remarkable discovery to be made in South Africa, a region making Palaeontology breakthroughs due to its significant geography.

The discovery published in *Current Biology* tells us that even more than 200 million years ago, these dinosaurs were the largest vertebrates to be present on the planet, and this time period was almost 40-50 million years earlier than giant sauropods were first seen. The new dinosaur is closely related to giant dinosaurs who lived in Argentina around that time supporting the idea that all continents that we see today were assembled as Pangea – a supercontinent comprised of world's land mass during Early Jurassic. And at that time this region of South Africa was not mountainous as we see it today but was flat and semi-arid with shallow streams. Certainly, it was a thriving ecosystem. Like Ledumahadi, many other dinosaurs - both giant and tiny - roamed the place at the time. It is fascinating that South Africa has helped to understand the rise of giant dinosaurs during Jurassic era.

This is another remarkable discovery to be made in South Africa, a region making Palaeontology breakthroughs due to its significant geography. Though complete skeleton of this gigantic dinosaur is not available yet, and other species are still to be discovered but if Ledumahadi was around today, it would have been the largest terrestrial animal on our planet.

Source

Blair W. McPhee et al., 2018, 'Giant Dinosaur from the Earliest Jurassic of South Africa and the Transition to Quadrupedality in Early Sauropodomorphs, *Science*, vol. 28, no.19,

DOI: https://doi.org/10.1016/j.cub.2018.07.063 ■

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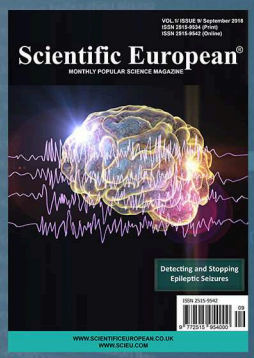

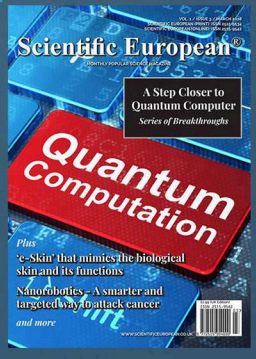

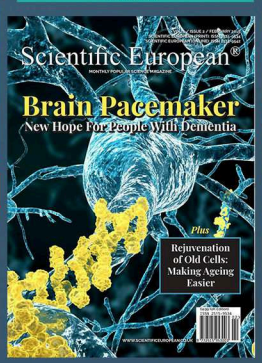

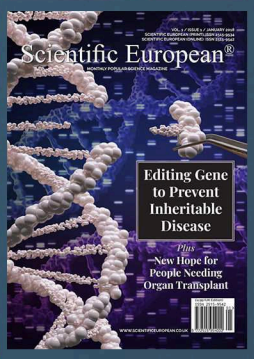

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How Ant Society Actively *Reorganizes Itself to Control* the Spread of Diseases

A first study has shown how an animal society actively reorganizes itself to reduce the spread of disease.

Generally speaking, high population density in a geographical region is the biggest factor which contributes to faster spread of a disease. When populations become dense it causes overcrowding which then leads to decline in living conditions. This causes the rate of disease transmission to increase mainly due to frequent and close contacts between individuals. Such populations become breeding grounds for infectious agents like viruses and bacteria.

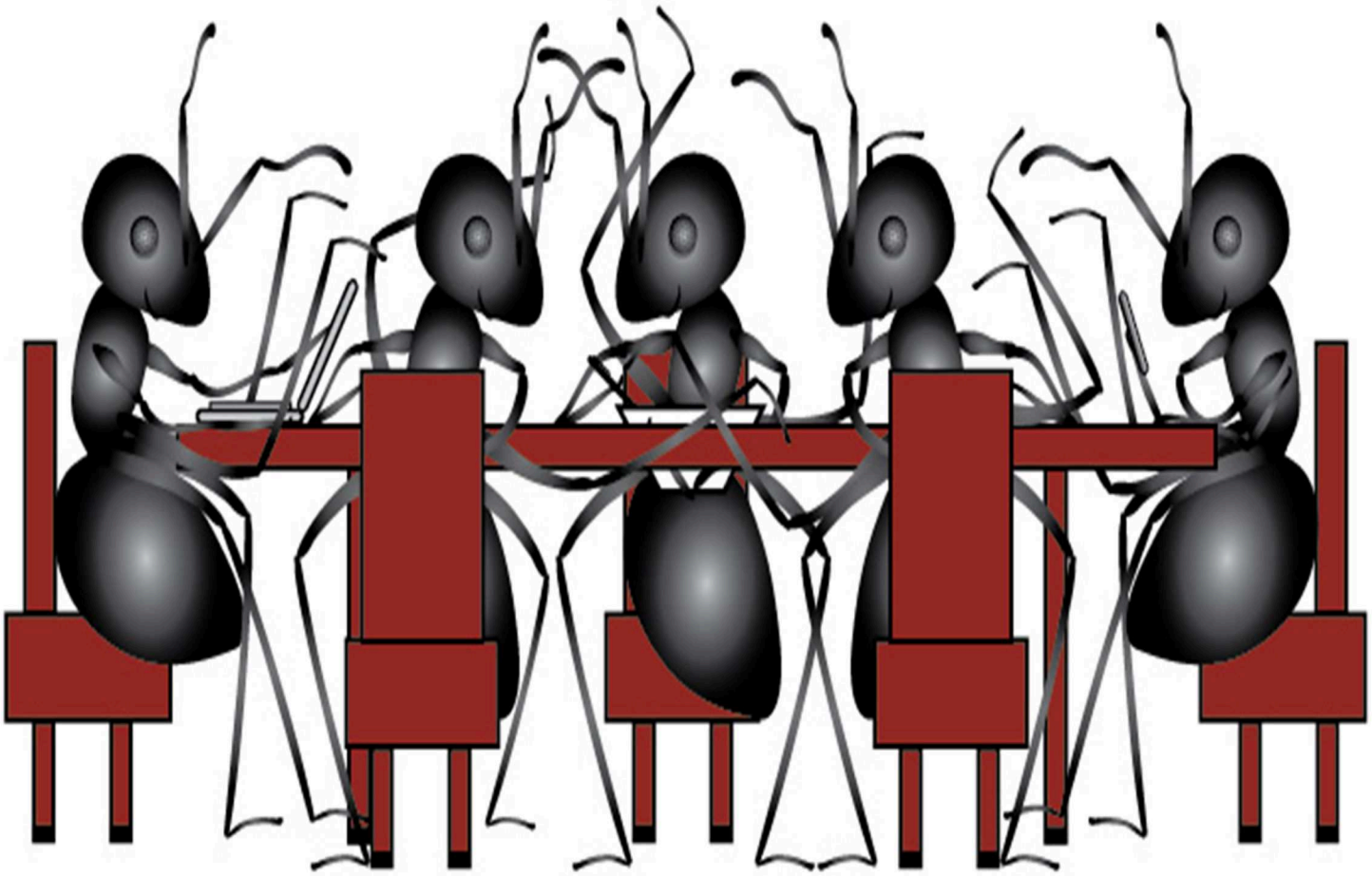
Ant colony

Ants are organisms which thrive almost everywhere be it forests or deserts and they live in large colonies or groups. Ants are known to be very social and this behaviour gives them huge advantage over insects or animals which exist solitary. An ant colony is organized in sub-groups based upon their age and the tasks which each of these groups need to carry out. There are mainly three types of ants in a colony - queen ant, females who are mainly 'workers' and males. Their main goal is survival, growth and reproduction. So, ant's interactions with other colony members are not really random as one would assume. The queen ant is the most important as only it can lay eggs and is the only member of an ant colony who can produce new members. The 'younger' ants, also called 'nurses' look after the brood at the centre of the colony. While 'older' ants act like foragers who travel and collect food from outside and for this reason older ants are more exposed and vulnerable to pathogens. A pathogenic invasion can cause spread of a disease and could likely terminate the entire colony.

A unique study published in *Science* shows that when a disease-causing pathogen enters an ant colony, ants modify their behaviour in order to protect their colony from an impending epidemic disease. They protect their queen and their entire brood from catching the disease and for this they have developed an interesting 'defence mechanism'. An important aspect of this mechanism is the 'social organization' which takes place within the colony. Researchers from Institute of Science and Technology Austria and University of Lausanne carried out this study by using a 'barcode' system to carefully follow and understand the interactions between ants within a colony in normal circumstances versus when a disease is spreading. They placed digital markers on around 2260 garden ants and infrared cameras captured image of the colony every half a second. This method enabled them to follow and measure the movement as well as position of every ant member and also their social interactions within the colony.

Defense mechanism of ants

To initiate disease transmission, around 10 percent of older ants or foragers were exposed to fungal spores which spread very fast. A comparison of ant colonies before and post pathogen exposure was made. Clearly, ants quickly realized the presence of fungal spores and they subdivided themselves into groups and changed their interactions with each other. Nurses only interacted with nurses and foragers with only foragers and their interaction with each other was diminished. The entire colony of ants changed their response, even those ants that were not exposed to fungal spores. This can be seen as a preventive measure as it reduces the risk of disease spread. qPCR technique was used to quantify the number of spores carried by an ant as spores would amplify the targeted



DNA molecule. A track was kept on the number of fungal spores. When ants changed their interaction, the pattern of fungal spores also kept changing which was noticeable in the readings.

It was interesting to see that the ant colony protects its 'valuable members' who can contribute – queen, nurses and young workers – and their survival was of utmost importance. Detailed survival experiment showed that any pathogen load 24 hours after first exposure directly corelates with death from disease and with a high value of correlation. The mortality was high in older or forager ants than nurses and the most valuable member - queen ant - was alive till the end.

This study sheds light on dynamics of a disease from the point of view of ants as they collectively handle a probable risk of disease spread. It established that social interactions between organisms is of crucial importance during spread of a disease. The research on ants can guide us to understand processes which could be relevant to other social groups of organisms. We need to evaluate what impacts disease risk and what suitable control measures can be devised. Population-wide dynamics is imperative where factors like immunology, disease transmission and population structure are taken into account.

Source

Nathalie Stroeymeyt, Anna V. Grasse, Alessandro Crespi, Danielle P. Mersch, Sylvia Cremer, Laurent Keller 2018, 'Social network plasticity decreases disease transmission in a eusocial insect', *Science*, vol. 362, no.6417, DOI: https://doi.org/10.1126/-science.aat4793

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The Smallest *Optical Gyroscope*

Engineers have built the world' tiniest light-sensing gyroscope which could be easily integrated into smallest portable modern technology.

Gyroscopes are common in every technology which we use in today's times. Gyroscopes are used in vehicles, drones and electronic devices like mobiles and wearables as they help know the correct orientation of a device in three-dimensional (3D) space. Originally, a gyroscope is a device of a wheel which helps the wheel to spin fast on an axis in ditfferent directions. A standard optical gyroscope contains a spooled optical fibre carrying a pulse laser light. This runs in either clockwise or anticlockwise direction. In contrast, modern day gyroscopes are sensors, example in mobile phones there are microelectromechanical sensor (MEMS) present. These sensors measure forces which act on two entities of identical mass but which are wavering in two different directions.

The Sagnac effect

The sensors though now widely used have limited sensitivity and thus optical gyroscopes are needed. A crucial difference being that optical gyroscopes are able to perform a similar task but without any movable parts and with more accuracy. This is achievable by the Sagnac effect, an optical phenomenon which uses Einstein's theory of general relativity to detect changes in angular velocity. During Sagnac effect, a beam of laser light is broken into two independent beams which now travel in opposite directions along a rounded path eventually meeting at one light detector. This happens only if the device is static and mainly because light travels at constant speed. However, if the device is rotating, the pathway of light also gets rotated causing the two separate beams to reach the light detector at a different timepoint. This phase shift is called Sagnac effect and this difference in synchronization is measured by the gyroscope and used to calculate orientation.

The Sagnac effect is very sensitive to noise in the signal and any surrounding noise like small thermal fluctuations or vibrations can disrupt the beams as they travel. And if the gyroscope is of a considerably smaller size then it is more prone to disruption. Optical gyroscopes are

obviously much more effective but it is still a challenge to scale down optical gyroscopes i.e. reduce their size, because as they become smaller the signal transmitted from their sensors also weakens and then gets lost in the noise which is generated by all the scattered light. This causes the gyroscope more difficulty in detecting movement. This scenario has restricted the design of smaller optical gyroscopes. The smallest gyroscope having a good performance is at least the size of a golf ball and thus unsuitable for small portable devices.

New design for a small gyroscope

Researchers at California Institute of technology USA have designed an optical gyroscope with very low noise which uses laser instead of MEMS sensors and gets equivalent results. Their study is published in Nature Photonics. They took a tiny 2-square-mm silicon chip and installed a channel on it to guide light. This channel helps to guide light to travel in every direction around a circle. Engineers weeded out reciprocal noise by lengthening the path of laser beams by using two disks. As the path of the beam becomes longer, the amount of noise is evened out resulting in accurate measurement when the two beams meet. This enables use of smaller device but still maintaining accurate results. The device also reverses direction of the light to assist in noise cancellation. This innovative gyro sensor is named XV-35000CB. The improved performance was achieved by 'reciprocal sensitivity enhancement' method. Reciprocal means that it is affecting two independent beams of light in the same manner. The Sagnac effect is based upon detection of change between these two beams as they are travelling in opposite directions and this equals to being nonreciprocal. The light travels through mini optical waveguides which are small conduits which carry light, similar to wires in an electrical circuit. Any imperfections in the optical path or outside interference will affect both the beams.

Key points

- Gyroscopes are used in vehicles, drones and electronic devices like mobiles and wearables as they help know the correct orientation of a device in three-dimensional (3D) space.
- Enhancement of reciprocal sensitivity improves signal-to-noise ratio enabling this optical gyroscope to be integrated onto a tiny chip maybe size of tip of a fingernail.

Enhancement of reciprocal sensitivity improves signal-to-noise ratio enabling this optical gyroscope to be integrated onto a tiny chip maybe size of tip of a fingernail. This tiny gyroscope is at least 500 times smaller in size than existing devices but can successfully detect phase shifts 30 times smaller than the current systems. This sensor can be primarily used in systems to correct vibrations of a camera. Gyroscopes are now indispensable in different fields and current research shows that smaller optical gyroscopes are possible to design though it may take some time for this laboratory design to be commercially available.

Source

Parham P. Khial, Alexander D. White, Ali Hajimiri. 2018, 'Nanophotonic optical gyroscope with reciprocal sensitivity enhancement', *Nature Photonics*, Vol. 12, no.11, DOI: https://doi.org/10.1038/s41566-018-0266-5 ■

Recently Identified *Nerve-Signalling Pathway for Effective Pain* Management

Scientists have identified a distinct nerve-signalling pathway which could help to recover from sustained pain after an injury.

We all know pain – the unpleasant feeling caused by a burn or ache or headache. Any kind of pain in our body involves an intricated interaction between specific nerves, our spinal cord and our brain. In our spinal cord, specialized nerves receive messages from specific peripheral nerves and they control message transmission to our brain. Whether the signal to the brain is important depends upon the severity of the pain. In the case of sudden burn, the message is transmitted as urgent while for a scratch or minor bruise, the messages are not tagged as urgent. These messages then travel to the brain and brain will respond by sending out messages to enable healing which could be either to our nervous system or brain might release pain-suppressing chemicals. This experience of pain is different in everyone and pain involves learning and memory.

Generally, pain can be categorized as short term or acute pain and long term or chronic pain. Acute pain is the severe or sudden pain which occurs due to illness or injury or surgery. While chronic pain is which persists for longer duration of time and becomes an illness or condition in itself.

Chronic pain

For example, after a stubbed toe or a prickle in foot or palm or touching something too hot, after a feeling of shock the body reflexes to retrieve from the activity or source of danger. This happens instantly but the reflex is strong enough to push us away from further danger. This is defined

as an evolutionary response which is conserved across multiple species to maximize survival but the exact pathways are still not understood. A persistent pain or ache then sets in after the initial shock of injury has gone by. And this persistent pain takes time to alleviate which could be seconds, minutes or even days. A person keeps trying to alleviate the pain by say applying pressure, hot compress, cooling methods etc.

Scientists at Harvard Medical School set out to analyse the various ways a pain stimuli travels from the site of trauma or injury in the body to the brain. The traumatic stimuli results from complex neurology involving sensory nerves called nociceptors and there are various pathways that carry signals to the spinal cord and areas of the brain. The details of this scenario are still not well understood. Scientists think the "pain matrix" in the brain is responsible for the hurt but there could be something else too.

Understanding pain mechanism

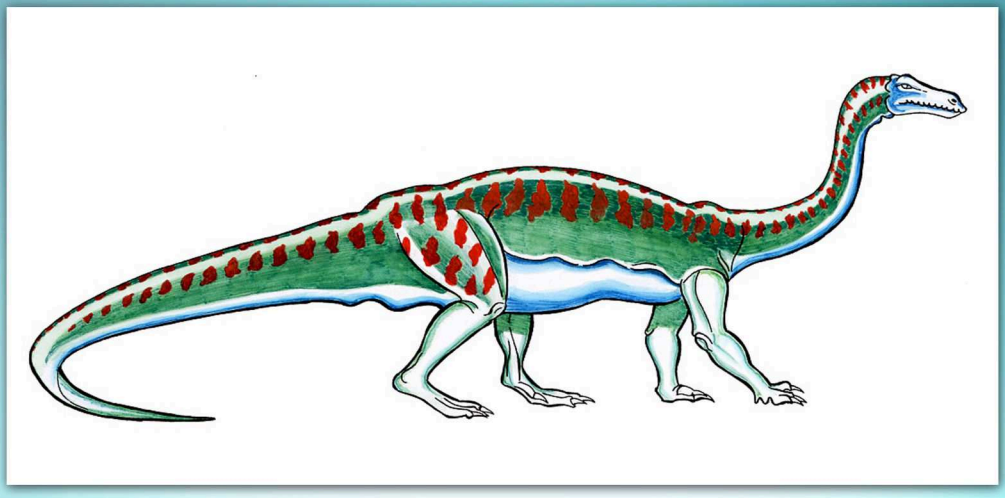
In a study published in *Nature,* scientists looked into spinal nerve cells which are associated with noxious stimuli. A gene called Tac1 expressed on these cells was seen to have a critical role in neuron functions. And their research shows that there might be different pathways followed by two different types of pain. They identified a new pathway of nerves in mice which look like chiefly responsible for persistent pain or ache which occurs after the initial shock of pain has gone by. Upon switching off this gene, mice still exhibit a response to sudden acute pain. And when their feet were pricked or they were pinched etc they showed signs of aversion. However, mice did not show any later signs of persistent discomfort which tells that the brain was not informed of this damage conveying that these spinal nerves might play a role in informing the brain.

Thus, there are two distinct pathways of the initial burst of pain and for persistent discomfort. This could maybe be the sole reason why many pain-relieving medications are good for initial pain but are unable to combat the persistent lingering pain, aching, stinging etc which could be rather defined as a coping mechanism. The results also explain why many drug candidates translated poorly from pre-clinical studies to effective therapeutics for pain.

This study has for the first time mapped how responses arise outside our brain and this knowledge provides important clues and could help understand various neural circuits which are responsible for chronic pain and discomfort. The presence of two distinct defense responses to avoid injury which are controlled by separate nerve-signalling pathways. It is clear that first line of defence is the rapid withdrawal reflex and second is the pain coping response which is activated to reduce suffering and avert tissue damage as a result of an injury. In the ongoing opioid crisis, it's a pressing need to develop new pain treatments. As chronic pain becomes a condition and illness in itself, it has become crucial to address this aspect of pain management.

Source

Tianwen Huang et al. 2018, 'Identifying the pathways required for coping behaviours associated with sustained pain', *Nature*, DOI: https://-doi.org/10.1038/s41586-018-0793-8 ■

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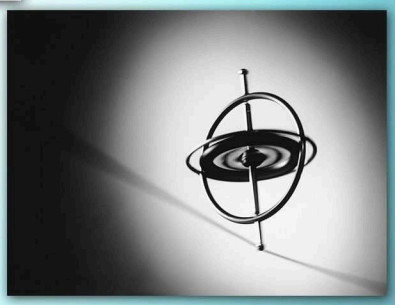

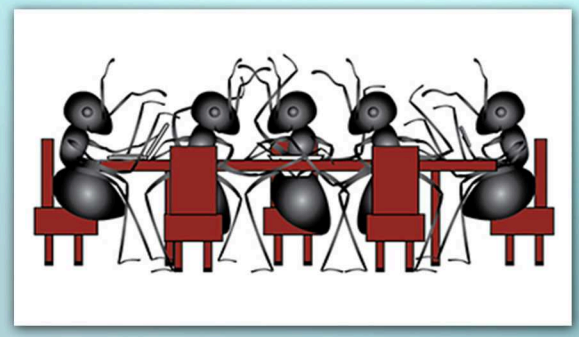


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