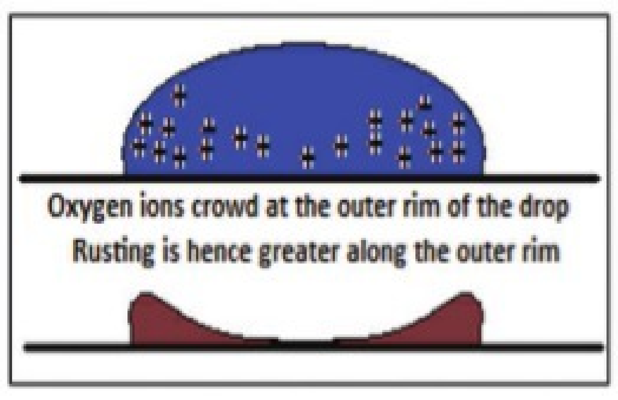
Divert rust and preserve steel

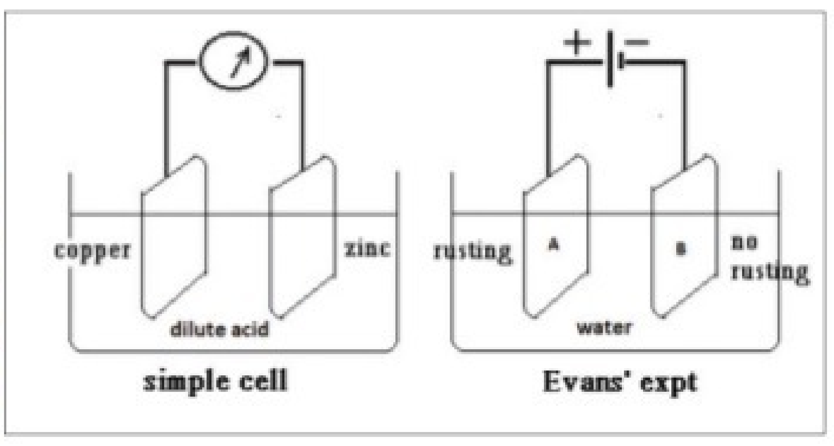
DRAWING RUSTING ACTION AWAY FROM ITS TARGET COULD SAVE RAILWAY TRACKS FROM PITTING AND FRACTURE, WRITES S ANANTHANARAYANAN

Rusting of steel structures leads to disastrous loss of life and vital infrastructure — the loss can be particularly serious when the structure that fails is a high speed railway track.

British Steel, a company that came into existence when India's Tata group sold its interests in the UK steel industry, has announced an innovation that bagged the award for the "most interesting new product of the year" at an event of the national rail industry in December last year. The product is called Zinoco and consists of a coating that protects rails from corrosion in the harshest conditions.

"Corrosive environments can reduce rail life vastly, with unprotected rail lifetimes below six months being reported in some instances," says a page in the British Steel website. "Whilst loss of rail section due to corrosion can occur generally or in more localised areas (like around rail fastenings) it is also important to note that foot fatigue failures often occur as a result of foot corrosion. Corrosion pits (often unseen) on the bottom of the rail can initiate fatigue cracks, which can then grow undetected, resulting in failure," the website says. Rusting is not the principal danger that rails face in the normal course where the punishment from the loads they carry is much more severe. But in specific places like coastal or low-lying areas, level crossings or special fittings, rusting can become a significant threat.





The process takes place in the presence of water and oxygen. Water, or H2O, consists of a pair of positively charged hydrogen atoms and a negatively charged oxygen atom, held together by electrical attraction. The components also partially separate and float about as charged particles. When there is also dissolved oxygen in the water, there are more oxygen atoms, which are not balanced by oppositely charged hydrogen atoms, and oxygen combines with iron to form the oxide, which we call rust. Rusting causes wasting away of the pure metal and the oxide with which it is replaced has none of the strength of the original. As rusting involves the movement of charged particles in water, the presence of salts that increase the electrical conductivity of water leads to faster rusting. This is the reason that salt sea water, even the salty spray in coastal areas, leads to rapid corrosion. In a celebrated experiment, scientist Ulick Richardson Evans showed that running a current through a salt solution and a pair of iron plates led to as much rusting of one of the plates as there was electric current.

Even without an external current, within a drop of water, there is a distribution of the charged atoms, which acts like an electric cell and drives a current. Within a small drop of water, placed on a piece of iron, negatively charged oxygen atoms repel each other and collect at the outer rim of the drop. This sets up a current from the centre of the drop to the rim with heavy formation of rust in the iron at the rim of the drop.

A simple trial of placing a drop of water on an iron sheet would show that the rust forms as a crater, higher on the outside, with a pit in the centre. Conversely, water that has been boiled to drive out the oxygen is not corrosive, as there is no free oxygen to combine with iron.

Paints and varnish form a coat that physically separates iron and steel from water or moisture.

If there is a scratch in the paint cover, rust forms within the scratch and takes the place of the paint lost, and protects the metal underneath. Stainless steel is an alloy of iron, chromium, manganese, silicon and some other metals. These elements react with oxygen contained in water and air to form a very thin, stable film of corrosion products. The film acts like a coat of paint, just a few atoms thick, and it forms very fast, with very little "corrosive" loss of body.

Painting is no use, of course, in the case of railway tracks, as the paint would degrade quite fast under the impact of wheels and the rigours of track maintenance. Different specialised coatings also fail under heavy corrosion or mechanical loading. This is the context of the British Steel development, of a covering that diverts any rusting to itself, rather than the steel rails when there is a breach in the covering.

In the case of the simple cell, shown in the picture, electrons flow from the zinc plate (which is called the anode) to the copper plate (called the cathode), because zinc (being a less "noble" metal) is electrically more active than copper. And as current flows, zinc reacts and passes into solution while hydrogen ions or the metal from dissolved copper salts collects at the copper plate. In the case of the iron plates in Evans' experiment, shown in the picture, electrons flow from the plate B to the plate A and it is the former plate that loses metal to rusting.

In the same way, when iron and steel come in contact with water, there is a simple cell in action. The iron now plays the part of the anode and loses metal by combining with oxygen to form rust. And traditionally, the method to protect iron has been to keep the surface clean and dry or covered with a passive layer of grease or paint. The difference in the method developed by the British Steel researchers is to get the covering to play an active role by participating in the electrochemical rusting process.

The Zinoco cover has a metallic component that is more electrically active than iron (in the same sense that zinc is more active than copper in the simple cell).

In case of a rupture in the cover, the material takes the role of the anode while the exposed iron becomes the cathode.

The iron thus collects the positive, hydrogen part of the dissociation of water (in place of oxygen) and is saved from oxidation, or rusting. The loss of metal is of the Zinoco cover, which becomes the "sacrificial" anode.

That the new material protects railway tracks from corrosion has been demonstrated in trials by the track division of British railways, the French national railways and also the tracks in the Paris Metro system, the British Steel website says.

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MIGHT BE OUR LAST CHANCE

SCIENTISTS HAVE URGED THAT GORILLAS, MONKEYS AND OTHER PRIMATES MUST BE SAVED FROM 'IMPENDING EXTINCTION', WHICH IS MAINLY CAUSED BY THREATS FROM HUMANS. IAN JOHNSTON REPORTS

Thirty-one leading scientists have issued an urgent plea to save humanity's closest biological relatives, saying scores of different species of apes, monkeys and other primates are all now facing "impending extinction".

Despite gorillas, orang-utans and lemurs being among the most popular wild animals — a factor that helps fund conservation efforts — their main threats are almost entirely caused by humans.

Primates are hunted for meat and body parts or captured for life as pets; their habitats are destroyed as industrial-scale farms to make foodstuffs like palm oil take over previously wild land, dams are built, or mining, oil and gas companies move in; and new threats like climate change and the spread of human diseases to animals are also emerging.

Of the 504 primate species, about 60 per cent are threatened with extinction and 75 per cent have declining populations. However, the researchers, who published the findings of a major review of primates in the journal Science Advances, insisted they could still be saved. "Despite the impending extinction facing many of the world's primates, we remain adamant that primate conservation is not yet a lost cause, and we are optimistic that the environmental and anthropogenic pressures leading to population declines can still be reversed," they argued.


Hainan gibbon

But they said this would only happen if effective measures were taken "immediately". "Unless we act, human-induced environmental threats in primate range regions will result in a continued and accelerated reduction in primate biodiversity," the scientists said. "Primate populations will be lost through a combination of habitat loss and degradation, population isolation in fragmented landscapes, population extirpation by hunting and trapping, and rapid population decline due to human and domestic animal-borne diseases, increasing human encroachment, and climate change."

They said that "perhaps the starkest conclusion of this review" was the collective failure to preserve primate species and their habitats.

"We have one last opportunity to greatly reduce or even eliminate the human threats to primates and their habitats, to guide conservation efforts, and to raise worldwide awareness of their predicament," the researchers added.

"Primates are critically important to humanity. After all, they are our closest living biological relatives." Professor Paul Garber, of Illinois University, who co-led the study with Alejandro Estrada of the National Autonomous University of Mexico, emphasised how close extinction was for some iconic species. "This truly is the eleventh hour for many of these creatures," he said, "Several species of lemurs, monkeys and apes — such as the ring-tailed lemur, Udzunga red colobus monkey, Yunnan snub-nosed monkey, white-headed langur and Grauer's gorilla — are down to a population of a few thousand individuals.

"In the case of the Hainan gibbon, a species of ape in China, there are fewer than 30 animals left."

The critically endangered Sumatran orang-utan lost 60 per cent of its habitat between 1985 and 2007, Professor Garber added. And he said at times humans were exploiting forest habitats "in needlessly destructive and unsustainable ways".

The biggest problem was the increasing amount of land being used for farming. "Agricultural practices are disrupting and destroying vital habitat for 76 percent of all primate species on the planet," he said, "In particular, palm oil production, the production of soy and rubber, logging and livestock farming and ranching are wiping out millions of hectares of forest." And that meant many primates were now "clinging to life" in the forests of China, Madagascar, Indonesia, Tanzania, the Democratic Republic of Congo and other countries.

"Sadly, in the next 25 years, many of these primate species will disappear unless we make conservation a global priority," Professor Garber said.

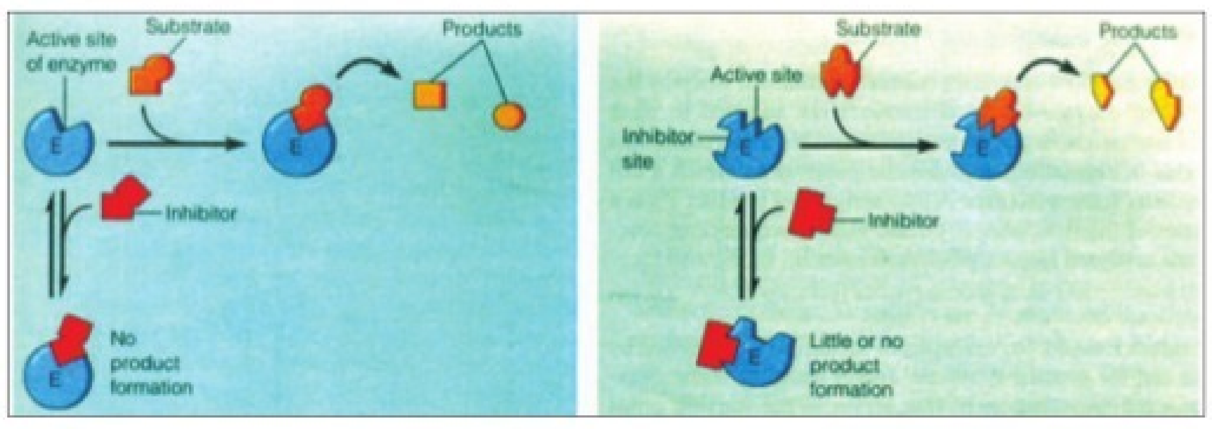
"This, by itself, would be a tragic loss. Now, consider the hundreds of other species facing a similar fate around the world, and you get a sense of what's truly at stake."

THE INDEPENDENT

Curtailing vital activity

TAPAN KUMAR MAITRA EXPLAINS THE ACTION OF ENZYME INHIBITORS

Thus far, the only substances in cells that affect the activities of enzymes are their substrates. However, enzymes are also influenced by products like alternative substrates, substrate analogues, drugs, toxins, and an especially important class of regulators called allosteric effectors. Most of these substances have an inhibitory effect on enzyme activity, reducing (or sometimes even abolishing) the reaction rate with the desired substrate.



Both (left) competitive and noncompetitive inhibitors (red) bind reversibly to the enzyme (E), thereby inhibiting its activity. The two kinds of inhibitors differ in the site on the enzyme to which they bind.

This inhibition of enzyme activity is important for several reasons. First, enzyme inhibition plays a vital role as a control mechanism in cells. Enzyme inhibition is also important in the action of drugs and poisons, which frequently exert their effects by inhibiting specific enzymes. Inhibitors are also useful to enzymologists as tools in their studies of reaction mechanisms. Especially important in the latter case are substrate analogues — they are compounds that resemble the real substrate closely enough to bind to the active site but are then chemically unable to undergo reaction.

Inhibitors may be either reversible or irreversible. An irreversible inhibitor binds to the enzyme covalently, causing an irrevocable loss of catalytic activity. Not surprisingly, irreversible inhibitors are usually toxic to cells. Ions of heavy metals are often irreversible inhibitors, as are alkylating agents and nerve gas poisons. This is, in fact, the reason many insecticides and nerve gases are so toxic. These substances bind irreversibly to acetylcholinesterase — an enzyme that is vital to the transmission of nerve impulses. Inhibition of acetylcholinesterase activity leads to rapid paralysis of vital functions and therefore to death. One such nerve gas is di-isopropyl fluorophosphate, which binds covalently to the hydroxyl group of a critical serine at the active site of the enzyme, thereby rendering the enzyme molecule permanently inactive.

Many natural toxins are also irreversible inhibitors of enzymes. For example, the alkaloid physostigmine, a natural constituent of calabar beans, is toxic to animals because it is a potent inhibitor of acetylcholinesterase. The antibiotic penicillin is an irreversible inhibitor of serine-containing enzymes involved in bacterial cell-wall synthesis. Penicillin is therefore effective in treating bacterial infections because it prevents the bacterial cells from forming cell walls.

In contrast, a reversible inhibitor binds to an enzyme in a non-covalent, dissociable manner, such that the free and bound forms of the inhibitor exist in equilibrium with each other. Clearly, the fraction of the enzyme that is available to the cell in an active form depends on the concentration of the inhibitor and the strength of the enzyme-inhibitor complex.

The two most common forms of reversible inhibitors are called competitive inhibitors and noncompetitive inhibitors. A competitive inhibitor binds to the active site of the enzyme and therefore competes directly with substrate molecules for the same site on the enzyme and reduces enzyme activity to the extent that the active sites of the enzyme molecules have inhibitor molecules rather than substrate molecules bound to them at any point in time.

A noncompetitive inhibitor, on the other hand, binds to the enzyme surface at a location other than the active site. It therefore does not block substrate binding but nonetheless inhibits enzyme activity because binding the inhibitor to its site greatly reduces or even eliminates the catalytic reaction at the active site.

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PLUS POINTS

New explanation

One of nature's greatest mysteries — the Fairy Circles of Namibia — may have been unravelled by researchers at the University of Strathclyde and Princeton University.

The cause of the circular patches of earth surrounded by grass, which are arranged in honeycomb-like patterns in huge areas of the Namib Desert, has been the source of scientific debate for decades. The new research, published last week in the scientific journal *Nature*, suggests that the interaction between termite engineering and the self-organisation of vegetation could be jointly responsible for the phenomenon.

Regular vegetation patterns form spectacular landscapes across the globe, with the Fairy Circles in Namibia holding special interest for scientists since the 1970s. Some have argued that termites alone create these patterns by destroying vegetation to reduce competition for water while others have suggested the circles follow patterns of rainfall and are solely caused by competition between plants.

Juan Bonachela from the University of Strathclyde's department of mathematics and statistics, said, "There have long been two theories on how these regular patterns, and especially Fairy Circles, are formed, and both theories are normally presented as mutually exclusive.

"Our findings harmonise both theories and find a possible explanation for regular vegetation patterns observed around the globe. In the case of Fairy Circles, termites remove vegetation on their mounds to increase moisture, which is essential for the insects' survival in dry environments, thus creating the bare disk. Vegetation around the mound takes advantage of this water accumulation to grow, and this taller vegetation forms the circle. Regular repetition of the pattern results from different termite colonies competing next to one another."

The multi-disciplinary approach employed by the researchers included field data from four different continents and computer simulations. Thanks to the latter, the authors were able to explore their theory on a variety of scales, testing different environ-mental scenarios, which would have been almost impossible to achieve on ground due to cost and time issues.

Mars rehearsal

Six scientists have entered a dome perched atop a remote volcano in Hawaii where they will spend the next eight months in isolation to simulate life for astronauts travelling to Mars, the University of Hawaii said.

The study is designed to help Nasa better understand human behaviour and performance during long space missions as the US space agency explores plans for a manned mission to the Red Planet. "I'm proud of the part we play in helping reduce the barriers to a human journey to Mars," said Kim Binsted, the mission's principal investigator.

The crew will perform geological field work and basic daily tasks in the 365 sq m dome, located in an abandoned quarry 2.5km above sea level on the Mauna Loa volcano on Hawaii's Big Island.

There is little vegetation and the scientists will have no contact with the outside world, said the university, which operates the dome. Communications with a mission control team will be time-delayed to match the 20-minute travel time of radio waves passing between Earth and Mars. "Daily routines include food preparation from only shelf-stable ingredients, exercise, research and fieldwork aligned with Nasa's planetary exploration expectations," the university said. The project is intended to create guidelines for future missions to Mars, some 56 million km away, a long-term goal of the US human space programme. The Nasa-funded study, known as the Hawaii Space Exploration Analog and Simulation, is the fifth of its kind.

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