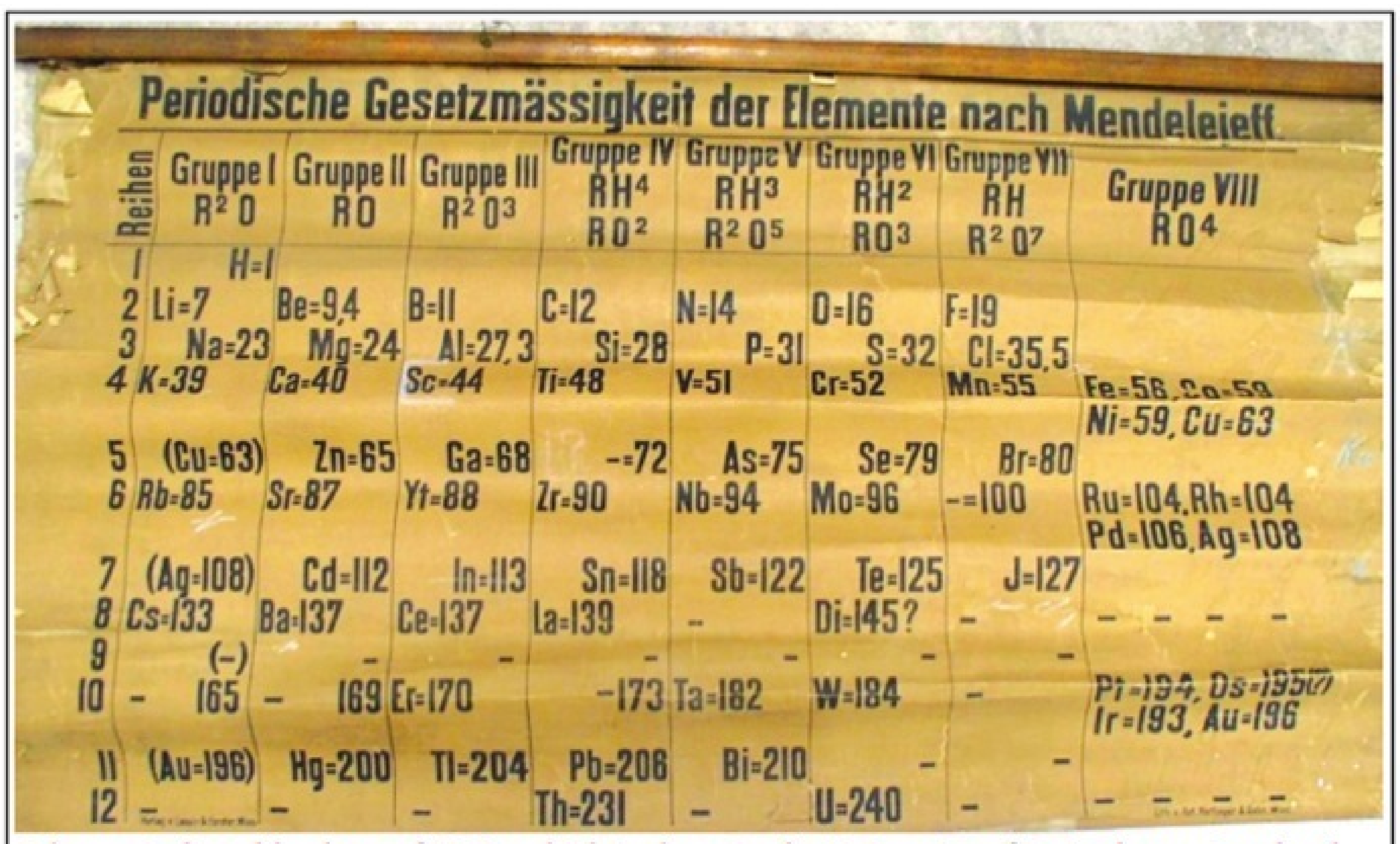
150 years of the periodic table



Periodische Gesetzmässigkeit der Elemente nach Mendelejeff

Reihen	Gruppe I R^2O	Gruppe II RO	Gruppe III R^2O^3	Gruppe IV RH^4 RO^2	Gruppe V RH^3 R^2O^5	Gruppe VI RH^2 RO^3	Gruppe VII RH R^2O^7	Gruppe VIII RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	Sc=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59 Ni=59, Cu=63
5	(Cu=63)	Zn=65	Ga=68	–=72	As=75	Se=79	Br=80	
6	Rb=85	Sr=87	Yt=88	Zr=90	Nb=94	Mo=96	–=100	Ru=104, Rh=104 Pd=106, Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	Ce=137	La=139	–	Di=145?	–	– – – –
9	(–)	–	–	–	–	–	–	
10	– 165	– 169	Er=170	–173	Ta=182	W=184	–	Pt=194, Os=195(?) Ir=193, Au=196
11	(Au=196)	Hg=200	Tl=204	Pb=206	Bi=210	–	–	
12	–	–	–	Th=231	–	U=240	–	– – – –

The periodic table chart of 1875, which is there in the University of St Andrews, Scotland

Russian chemist Dmitri Mendeleev published what is regarded as the first clear classification of the elements based on a measure of the mass of the atoms, in 1869

S ANANTHANARAYANAN

The periodic table of the elements is a piece of insight that laid the foundation for what was discovered about atoms and the nature of matter in the years that followed. It is a sign of the creative wave that swept through the 19th century, that while Dalton had proposed a bare-bones atomic theory at the start of the 1800s, Dmitri Mendeleev published what is regarded as the first clear classification of the elements based on a measure of the mass of the atoms, in 1869.

Physics World, the magazine published by the Institute of Physics, reports that the University of St Andrews, in Scotland, which houses the 1875 display, the oldest known, of the periodic table of the elements, is conducting special events to commemorate this 150th year. The United Nations has also declared 2019 to be the International Year of the Periodic Table.

The atomic theory of Dalton was a far cry from the understanding of the atom that we have today. Dalton built on the observations that gases, when they combined, seemed to do so in simple ratios of volumes or masses. His own studies had shown that if given quantities of gases, in a container, exerted certain pressures by themselves, then the gases , when placed together in the same container, exerted the sum of the individual pressures.

This suggested that the gases were "porous" or allowed other gases to "pass through", as if they were crowds of people merging together, and hence that the gases consisted of particles that were very small, compared to the distances that separated them. These particles were considered the smallest division of an element which had the properties of the element. Dalton chose the word, "atom", to describe these particles, from "atomos", the Greek word for "uncut".

The available data on the weights of different elements that went into forming compounds now helped Dalton estimate the ratios of the weights of atoms. He set the weight of the hydrogen atom as "1". The "atomic weights", of the elements would then be the number of times the atoms were heavier than the hydrogen atom. Water had been found to be 85 per cent oxygen, by weight, and 15 per cent hydrogen. This put the weight of oxygen about six times that of hydrogen. Dalton took the numbers to be seven and one and placed the atomic weight of oxygen at seven. We know now that an atom of oxygen combines not with one atom of hydrogen but with two. And the ratio is eight, rather than seven, which puts the atomic weight of oxygen at 16. But Dalton had made a start, and like he had done with oxygen, he estimated the atomic weights of many other elements.

At the time, the elements had been classified, in terms of their properties, as gases, metals or non-metals. Dalton's theory gave new direction to the study of the chemical properties of the elements. It had been seen that the elements did not always combine as one atom of a metal with one other, but some combined with two or more atoms of another element. The atomic weights of the known elements had been determined accurately, as well as the tendency to combine with different numbers of other elements.

Another feature that had been observed was that many elements formed groups of three elements with similar properties. Lithium, sodium, and potassium, for example, were a group of three soft, reactive metals. And then, in these triplets, the atomic weight of the middle member was nearly the average of the atomic weights of the outer two. Soon, such relationships were found in groups of four and five and more relationships were found in different groups of elements.

An extension of this feature was then noticed, that characteristic properties of elements seemed to repeat as one ascended the order of atomic weights. Arrangements to show this periodicity were devised, based both on atomic weight and the tendency to combine with more or different atoms. But it was Dmitri Mendeleev, a Russian professor of chemistry, who first published a table that displayed the periodic trends of the elements then known. Mendeleev, and the German chemist, Julius Lothar Meyer, independently, but just after Mendeleev, organised the elements, according to atomic weights, which were accurately known by then, in rows or columns, with elements that showed a cyclical return of properties appearing in the same row, or as now the practice, the same column. Mendeleev used the atomic weight not as an exact indicator of the position of an element in the table, but as a guide, along with other factors. The result was a tabulation that fit observation closely and, what is more important, there were gaps in the table, corresponding to elements still not known, and these elements were later discovered!

What is remarkable is that all this classification was done at a time when very little was known about the atom itself. That the atom had component parts, the electrons, was announced only in 1897. And still, nothing was known of the structure of the atom. It was only in 1911 that Lord Rutherford discovered that the mass of the atom was concentrated at the centre. And only later was it understood that the centre was positively charged, with many, much lighter, negatively charged electrons in orbit around the centre.

Our current understanding of the distribution of electrons of the atom and of how atoms combine readily explains why certain atoms are metals, which combine with the other category, the non-metals. We know that the different elements have successively increasing charge in the nucleus, and hence the number of electrons, which form a series of shells around the nucleus. And it is the filling up of shells, as one moves up the order of elements, and the start of new shells, that accounts for the cyclic repetition of characteristic properties of elements.

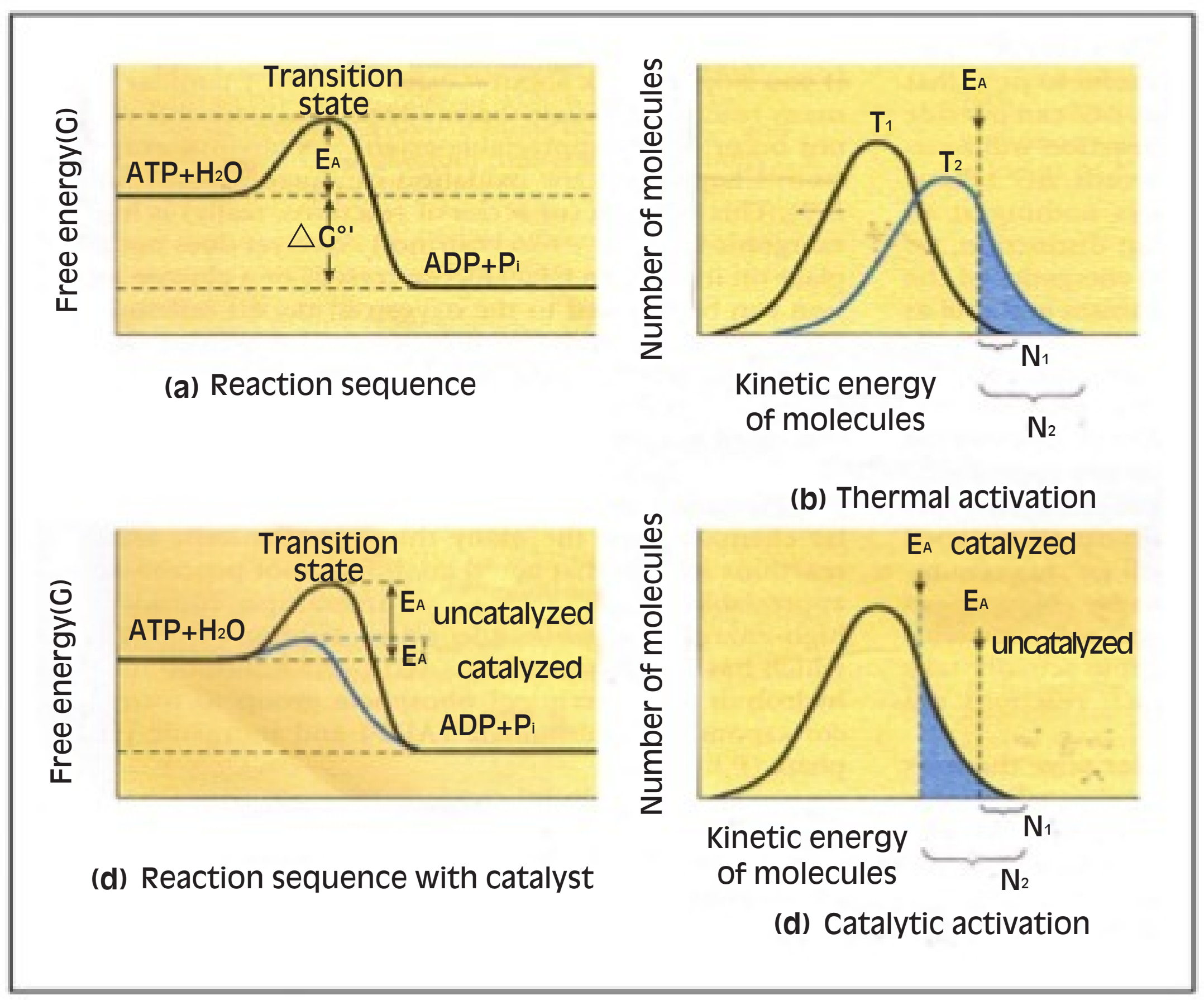
We also know that the mass of the atom is not a result of only the positively charged particles, but there is nearly an equal number of neutral particles. The chemical properties of elements thus depend not on the atomic mass, or atomic weight, but on the number of charged particles, called the atomic number. It is because some elements have more or less neutral particles that the periodic table does not strictly follow the sequence of atomic weights, a refinement that Mendeleev was able to make long before its reason was known.

But the periodic table of the elements documented a relationship among the elements which guided the course of investigation into the nature of matter and led to the integration of different discoveries.

The writer can be contacted at response@simplescience.in

An important stimulant

Almost all the cellular reactions or processes are mediated by protein (or RNA) catalysts called enzymes



The Effect of Catalysis on Activation Energy and Number of Molecules Capable of Reaction.

TAPAN KUMAR MAITRA

The topic of enzyme catalysis, because virtually all cellular reactions or processes are mediated by protein (or, in certain cases, RNA) catalysts called enzymes. It is only as we explore the nature of enzymes and their catalytic properties that we begin to understand how reactions that are energetically feasible actually take place in cells and how the rates of such reactions are controlled.

Consider why thermo-dynamically spontaneous reactions do not usually occur at appreciable rates without a catalyst, and then we will look at the role of enzymes as specific biological catalysts, the rate of an enzyme-catalysed reaction is affected by the concentration of substrate available to it, as well as some of the ways in which reaction rates are regulated to meet the needs of the cell.

Activation Energy and the Metastable State are familiar with many reactions that are thermodynamically feasible yet do not occur to any appreciable extent. An obvious example is the oxidation of glucose. This reaction (or series of reactions, really) is highly exergonic ($\triangle G^{\circ\prime}$ = -686 kcal/mol) and yet does not take place on its own. In fact, glucose crystals or a glucose solution can be exposed to the oxygen in the air indefinitely, and little or no oxidation will occur. The cellulose in the paper on which these words are printed is another example- and so, for that matter, are consisting as you do of a complex collection of thermodynamically unstable molecules.

Not nearly as familiar, but equally important to cellular chemistry, are the many thermodynamically feasible reactions in cells that could go, but do not proceed at an appreciable rate on their own. As an example, consider the high-energy molecule adenosine triphosphate (ATP), which has a highly favourable $\triangle G^{\circ\prime}$(-7.3 kcal/mol) for the hydrolysis of its terminal phosphate group to form the corresponding diphosphate (ADP) and inorganic phos-phate (Pi):

$ATP + H_2O \quad ADP + Pi \rightleftarrows$

This reaction is very exergonic under standard conditions and is even more so under the conditions that prevail in cells. Yet despite the highly favorable free energy change, this reaction occurs only slowly on its own, so that ATP remains stable for several days when dissolved in pure water. This property turns out to be shared by many biologically important molecules and reactions, and it is important to understand why.

Before a chemical reaction can occur, the activation energy barrier must be overcome. Molecules that should react with one another often do not because they lack sufficient energy. For > every reaction, there is a specific activation energy (EA), which is the minimum amount of energy that reactants must have before collisions between them will be successful in giving rise to products. More specifically, reactants need to reach an intermediate chemical stage called the transition state, the free energy of which is higher than that of the initial reactants.

The actual rate of a reaction is always proportional to the fraction of molecules that have energy content equal to or greater than EA. When in solution at room temperature, molecules of ATP and water move about readily, each possessing a certain amount of energy at any instant. The energy distribution among molecules will be bell-shaped; some molecules will have very little energy, some will have a lot, and most will be near average. The important point is that the only molecules that are capable of reacting at a given instant are those with enough energy to exceed the activation energy barrier.

The metastable state is a result of the activation barrier for most biologically important reactions at normal cellular temperatures, the activation energy is sufficiently high that the proportion of molecules possessing that much energy at any instant is extremely small. Accordingly, the rates of uncatalysed reactions in cells are very low, and most molecules appear to be stable even though they are potential reactants in thermodynamically favoured reactions.

Such seemingly stable molecules are said to be in a metastable state. For cells and cell biologists, high activation energies and the resulting metastable state of cellular constituents are crucial, because life by its very nature is a system maintained in a steady state a long way from equilibrium. Otherwise, all reactions would proceed quickly to equilibrium, and life would be impossible.

Catalysts overcome the activation energy barrier as it is to the maintenance of the metastable state, the activation energy requirement is a barrier that must be overcome if desirable reactions are to proceed at reasonable rates. Since the energy content of a given molecule must exceed EA before that molecule is capable of undergoing reaction, the only way a reaction involving metastable reactants can be made to proceed at an appreciable rate is to increase the proportion of molecules with sufficient energy. This can be achieved either by increasing the average energy content of all molecules or by lowering the activation energy requirement. One way to increase the energy content of the system is by the input of heat. Simply increasing the temperature of the system from T, to T2 will increase the kinetic energy of the average molecule, thereby ensuring a greater number of reactive molecules (N2 instead of N,). Thus, the hydrolysis of ATP could be facilitated by heating the solution, giving each ATP and water molecule more energy.

The problem with using an elevated temperature is that such an approach is incompatible with life, because biological systems require a relatively constant temperature. Cells are basically isothermal (constant-temperature) systems and require isothermal methods to solve the activation problem.

Providing a reactive surface is the task of a catalyst, an agent that enhances the rate of a reaction by lowering the energy of activation, thereby ensuring that a higher proportion of the molecules are energetic enough to undergo reaction without the input of heat. A primary feature of a catalyst is that it is not permanently changed or consumed as the reaction proceeds. It simply provides a suitable surface and environment to facilitate the reaction.

For a specific example of catalysis, consider the decomposition of hydrogen peroxide (H_2O_2) into water and oxygen:

$2H_2O_2 \rightleftarrows 2 H_2O + O_2$

This is a thermodynamically favoured reaction, yet hydrogen peroxide exists in a metastable state because of the high activation energy of the reaction. However, if we add a small number of ferric ions (Fe^{3+}) to a hydrogen per-oxide solution, the decomposition reaction proceeds about 30,000 times faster than without the ferric ions. Clearly, Fe^{3+} is a catalyst for this reaction, lowering the activation energy and thereby ensuring that a significantly greater proportion (30,000-fold more) of the hydrogen peroxide molecules possess adequate energy to decompose at the existing temperature without the input of added energy.

In cells, the solution to hydrogen peroxide breakdown is not the addition of ferric ions but the enzyme catalyse, an iron-containing protein. In the presence of catalyse, the reaction proceeds about 100,000,000 times faster than the uncatalysed reaction. Catalyse contains iron atoms bound in chemical structures called porphyrins, thus taking advantage of inorganic catalysis within the context of a protein molecule. This combination is obviously a much more effective catalyst for hydrogen peroxide decomposition than ferric ions by themselves. The rate enhancement of about 108 for catalyse is not at all an atypical value; the rate enhancements of enzyme-catalysed reactions range from 107 to as high as 1014 compared with the uncatalysed reaction. These values underscore the extraordinary importance of enzymes as catalysts and bring us to the main theme.

The writer is associate professor and head, department of botany, Ananda Mohan College

---

PLUS POINTS

Discovery in riverbed

The remains of a freshwater shark that swam the rivers of South Dakota 67 million years ago have been unearthed by scientists.

Tiny teeth sifted from over two tonnes of prehistoric earth revealed a bottom-dwelling creature similar to some modern-day carpet sharks that ambush their prey from the ocean floor.

It was these teeth which reminded the team of the spaceships from the 1980s video game Galaga-- that gave the creature its name, Galagadon nordquistae.

The shark was discovered in the ancient sediment found alongside Sue the Tyrannosaurus rex, a famous specimen held at the Field Museum of Natural History in Chicago.

However, there was no suggestion the shark had any interaction with the enormous predatory dinosaur beyond living in the river from which it may have drunk.

"Galagadon was not swooping in to prey on T. rex, Triceratops, or any other dinosaurs that happened into its streams," said Dr Terry Gates, a palaeontologist at North Carolina State University who led the study.

The teeth, which were no bigger than pinheads, were all that remained of the ancient fish, as shark skeletons are made of cartilage which does not fossilise well.

Karen Nordquist, a Field Museum volunteer who helped discover the fossils and in whose honour the species was named, said the teeth were incredibly difficult to spot.

The resemblance of these teeth to those found in carpet sharks such as the wobbegong of Australia gave the scientists an idea of what it would have looked like.

They suggested it had a flat face and mottled colouration that would have allowed it to lie hidden at the bottom of the river.

Besides revealing a new species of shark, the scientists say their discovery also provide new evidence of the Cretaceous habitat in which Sue the T. rex lived alongside rivers that were not far from newly formed oceans. The discovery was outlined in the Journal of Paleontology.

The independent

Halting next pandemic

British scientists are developing gene-edited chickens designed to be totally resistant to flu in a new approach to trying to stop the next deadly human pandemic. The first of the transgenic chicks will be hatched later this year at the Roslin Institute at the University of Edinburgh in Scotland, said Wendy Barclay, a professor of virology at Imperial College London who is co-leading the project.

The birds' DNA has been altered using a new gene editing technology known as CRISPR. In this case the "edits" are to remove parts of a protein on which the flu virus normally depends, making the chickens totally flu-resistant. The idea is to generate poultry that cannot get flu and would form a "buffer between wild birds and humans", Barclay said. Global health and infectious disease specialists cite the threat of a human flu pandemic as one of their biggest concerns.

The death toll in the last flu pandemic in 2009/10 - caused by the H1N1 strain and considered to be relatively mild - was around half a million people worldwide. The historic 1918 Spanish flu killed around 50 million people.

The greatest fear now is that a deadly strain could jump from wild birds via poultry into humans, and then mutate into a pandemic airborne form that can pass easily between people.

In research published in 2016 in the journal Nature, Barclay's team found that a gene present in chickens called ANP32 encodes a protein that all flu viruses depend on to infect a host. Laboratory tests of cells engineered to lack the gene showed they cannot be infected with flu. Roslin Institute scientists gained fame in 1996 as creators of "Dolly the sheep", the world's first cloned animal. They have also created gene-edited pigs to make them resistant to a virus.

Barclay said one of the biggest hurdles to this approach would be poultry producers' concerns about public acceptance.

The straits times/ann