Overture to a stellar swansong

Scientists have heard snatches of the first bars that usher the Supernova crescendo, says s ananthanarayanan

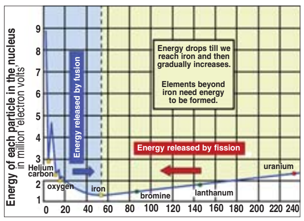
SUPERNOVAE are the most energetic of stellar explosions and they drive movement and change in the cosmos. The event can be as luminous as to outshine a galaxy and within a fleeting span, sometimes just a few weeks, it emits the energy the sun would send out in its lifetime. The supernova is usually the end of the life story of a star, with all the star's material being scattered through space, to merge with other star systems or with clouds of dust that form new stars.

As supernovae are short-lived, there is not much information about what happens during their course and even less about the changes in the star that brings about the final explosion. A team of scientists from Israel, the UK and USA report in the journal *Nature* that they have documented changes and activity, which were suspected to precede supernovae, in a massive star just 40 days before it exploded.

Stars form when interstellar dust, or just hydrogen atoms, which is spread over millions of light years of space gradually comes together because of mutual gravity. Squeezing the material of the mass of a star, which was spread out in the near vacuum of space, into the confines of the star itself is an act of compression and this raises the temperature. In the process of increasing its mass by attracting more material, the star can heat up to millions of degrees — till it is so hot that nuclear reactions start between hydrogen atoms. The nuclei of hydrogen atoms, being positively charged, stay well apart because of mutual repulsion. But at very high temperature, they move so rapidly that they could collide and come close enough for short-range attractive forces to get active, and pairs of hydrogen nuclei, along with two neutral particles called neutrons, merge to form nuclei of another element, helium.

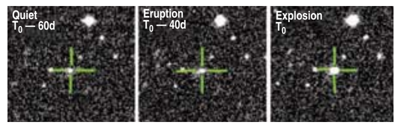
Helium is a more stable, or less-energy state of the separate particles that make it up, and in the process of its formation there is a release of the extra energy, which is stupendous – the source of the energy of the *hydrogen bomb*!

Thus, while much of the hydrogen gets converted into helium the gas in the star gets hotter still and rapidly expands. The expansion causes cooling, which draws the gas in, into another spell of compression and heating, which leads to more nuclear reactions and expansion, etc. In the course of this see-saw of pressure and temperature, other nuclear reactions take place and in many stars helium nuclei get converted to nuclei of more massive elements, like lithium, which has three hydrogen nuclei and three neutrons, and so on. Each of these reactions releases energy and stars that are large enough go through innumerable cycles, till all the material in the star is converted usually as far as oxygen, but can continue till it reaches the element iron. The nucleus of iron, which has the mass of 56 hydrogen nuclei, is a low-energy state and the more nuclear reactions cannot be self-sustaining.



Many stars thus stop auto-generation of elements at iron, or earlier, and as they do not have a source of energy they begin to collapse under their own gravity. The intense compression that follows can have different results, depending on the mass of the stars. They may reduce to intensely hot *white dwarfs* or cool *red giants*. As a sequel, the positive and negative parts of atoms may merge and the stars further collapse as *neutron stars*, those of the greatest density possible. And if the stars have sufficient mass, the gravity at their surface may be so high that it holds back the light they emit, as *black holes*.

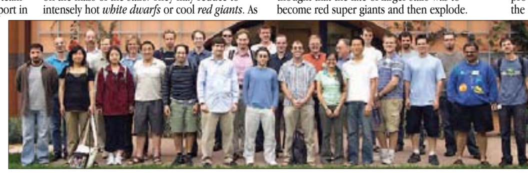
But larger stars, or more likely white dwarfs that grab more material or merge with another white dwarf, continue with processes that lead to a sudden release of energy. The increased mass raises temperatures and brings about fusion of carbon nuclei. This fusion reaction is so energetic that in seconds a substantial part of the white dwarf could get consumed, leading to a shock wave of expansion. These high temperatures and pressures lead not only to huge luminosity — supernovae are billions of times brighter than the sun — but also to the generation of elements with more nuclear particles than iron. Supernovae, in fact, are the source of these elements in the universe.



Sixty days before explosion. Forty days before explosion. Day of the explosion.

The final stage

Very little has been known of the stages of a star's final progress to a supernova. It was first thought that the fate of larger stars was to become red super giants and then explode.



The team at the Palomar Transient Factory, the automated star image and data acquiring facility.

Tracing the available past data of the progenitor of a supernova discovered in 1987, the nearest supernova since the last, and celebrated, near one seen in 1604, showed that its parent star was a *blue super giant*. This was a departure from the model of *red giant progenitors*. Through other observations since then, it is found that supernova progenitors can be of lesser mass and a feature of the 1987 supernova was that showers of very light, neutral particles called *neutrinos* had been detected a few hours before the explosion. It is now considered that massive stars lose energy in the final stages, not in the form of light but by neutrino emission. But neutrinos are elusive and almost undetectable and the final stages of stars have remained unknown territory.

In the study now reported in *Nature*, EO Ofek of the Benoziyo Centre for Astrophysics, Weizmann Institute of Science, Israel, and colleagues scanned data of mass loss in a class of objects called *Luminous Blue Variables* and observed an outburst of material about 1/100 of the mass of the sun, from a giant star just over a month before it exploded. So far, the study of stars that go supernova has been based on the remnants of the supernova, which is after the event. Here, Ofek and others stepped back to the parent star, which they estimate to have had about 50 solar masses. And, based on statistical analysis of the images and data collected by the Palomar Transient Factory, an automated survey of the night sky, they suggest that the pair of events — eruption of material from the star and its explosion soon after — cannot be unrelated. If this turns out to be the case, it becomes one of the few cases where there is information about the late stages of a star that becomes a supernova.

Stars with more than some 25 solar masses are known to have eruptions of extreme loss of matter. Why they occur and what drives them is not known, but a number of supernova models provide for such mass loss. The present study, of the eruptions in a star that went supernova soon after such loss, affords a chance to compare eruption behaviour of candidate supernovae and to propose possible mechanisms that lead to their evolution.

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Ofek and colleagues find that the timing and the matter ejected best fits a supernova model that is based on the instabilities in the flow of material in the star — a finding that may be refined with more work.

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Kepler's supernova

NOVA means new and denotes a new star, or one that suddenly comes into view, as a result of getting brighter. The more luminous ones are visible to the naked eye and many stand out brighter than any of the other stars for the few days or months that they last.

Kepler's Star, which was "brighter than all in the sky" for three weeks, was seen in Italy in 1604 and was documented by Johannes Kepler. The supernova has been named after him because he tracked the object for a year and wrote a book, entitled *De Stella nova in pede Serpentarii* (*On the new star in Ophiuchus's foot*), Prague 1606.

Keepler's star is the nearest supernova, at 20,000 light years, seen so far. It is in our own galaxy, in the constellation *Ophiuchus*, or the *serpent gatherer*.

Kepler's original illustration: The supernova is at "N", on the right heel of the serpent gatherer.

Faster than Bolt

Squid can eject water through a nozzle near its head as a form of jet propulsion, write steve connor

IN a study that confirms the extraordinary aerial prowess of the edible mollusk, scientists in Japan have calculated that squid can fly through the air faster than Usain Bolt can run. Based on photographs of flying squid in the Pacific Ocean, the study estimates that they can reach a speed of up to 11.2 metres per second, which is significantly faster than the 10.31 metres per second that Bolt averaged in the 100-metre final at the London Olympics.

Over the past few years, a number of anecdotal accounts have emerged of squid streaking through the air above the sea for several metres and now a team of Japanese marine biologists has photographed them doing it en masse.

The squid, which normally swims backwards through the water using its fins, can eject water through a nozzle near its head as a form of jet propulsion in emergencies. It is this technique they use to glide through the air like flying fish.

"There were always witnesses and rumours that such squid were seen flying, but no one had clarified how they actually do it. We have proved that it really is true," Jun Yamamoto, of Hokkaido University, told the AFP news agency.

The researchers were following a shoal of about 100 members of the Japanese flying squid family in the north-west Pacific Ocean, about 370 miles from Tokyo, when they started photographing them shooting out of the water and gliding for several metres with their fins extended.

"Once they finish shooting out the water, they glide by spreading out their fins and tentacles. The fins and the web between the tentacles create aerodynamic lift and keep the squid stable on its flight arc," said Professor Yamamoto. "We have discovered that squid do not just jump out of the water, but have a highly developed flying posture. This finding means that we should no longer consider squid as things that live only in the water.

"It is highly possible that they are also a source of food for sea birds," he added.

The independent, london

Points to ponder

That modest spoonful of sugar you sprinkle on your cereal or add to your coffee deserves to be treated with respect, says tapan kumar maitra, **because it plays an important role in the energy metabolism of all the cells in your body**

WHILE it's important to acquire an academic understanding of processes like glycolysis and gluconeogenesis, it is equally important to appreciate what that knowledge means for you as a person. Will you be able to use the information to understand how your body meets its energy needs and what it does with the nutrients you eat?

To be more specific, can you relate what you are learning to what the cells in your body are doing with the food you had for breakfast? As you add sugar to your coffee or cereal, can you fathom "what happens to the sugar?" Let's focus on your bowl of cereal, considering the disaccharide sucrose (from the sugar), the disaccharide lactose (in the milk), and the polysaccharide starch (in the cereal).

Let's start with a spoonful of cereal you've just eaten. The sucrose and lactose remain intact until they reach your small intestine, but the digestion of starch begins in your mouth because saliva contains salivary amylase, an enzyme that splits starch into smaller polysaccharides. Further digestion occurs in your small intestine, where pancreatic amylase completes the breakdown of starch to disaccharide maltose.

The maltose generated from starch is hydrolysed to glucose in your intestine by the enzyme maltase. Maltase is one of a family of intestinal disaccharidases, each specific for a different disaccharide. The lactose from the milk and the sucrose you sprinkled on the cereal are hydrolysed by other members of this family — lactase and sucrase, respectively. Lactose yields one molecule each of glucose and galactose, whereas sucrose is hydrolysed to one molecule each of glucose and fructose. In some people, intestinal lactase disappears gradually after the age four or so, when milk-drinking usually decreases. If such people ingest milk or other dairy products, they are likely to experience cramps and diarrhoea, a condition called lactose intolerance.

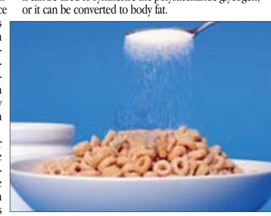
Glucose, galactose and fructose molecules are absorbed by intestinal epithelial cells. These cells have numerous microvilli that project into the lumen of the intestine, thereby greatly increasing the absorptive surface of the cell. Moreover, only two layers of epithelial cells separate nutrients in the lumen of your intestine from the blood in your capillaries. Some sugars, such as fructose, move across the plasma membrane of an epithelial cell by facilitated diffusion, because the concentrations of these sugars are lower in capillary blood than in the intestinal lumen. Glucose, however, is moved by active transport because of its high concentration in the blood.

Fructose and galactose are transported by your bloodstream to the various tissues of your body. These sugars are eventually absorbed by body cells and converted to intermediates in the glycolytic pathway. The pathway for galactose utilisation is more complex than that of most other simple sugars, with five reactions required to convert a molecule of galactose into glucose-6 phosphate. A genetic defect in this pathway may result in an inability to metabolise galactose, resulting in high levels of galactose in the blood and high levels of galactose-1 phosphate in tissues. This disorder, called galactosemia, has serious consequences, including mental retardation.

Not surprisingly, it occurs most commonly in infants because the major dietary source of galactose is milk. Provided the condition is detected early, the symptoms can be prevented or alleviated by removing milk and dairy products from the diet.

The main sugar in the blood, of course, is glucose. Its concentration in your blood a few hours after a meal is probably about 80 mg% (80 mg per 100 ml of blood, or about 4.4 mm). The level may rise to 120 mg% (6.6 mm) shortly after you've eaten. In general, however, the blood glucose level is maintained within rather narrow limits. Maintenance of blood glucose level is one of the most important regulatory functions in your body, particularly for proper functioning of the brain and nervous system. Your blood glucose level is under the control of several hormones, including insulin, glucagon, epinephrine and norepinephrine.

Once in your bloodstream, glucose is transported to cells in all parts of your body, where it has four main fates: It can be oxidised completely by aerobic respiration to C02; it can be fermented anaerobically to lactate; it can be used to synthesise the polysaccharide glycogen; or it can be converted to body fat.



Aerobic respiration is the most common fate of blood glucose because most of the tissues in your body function aerobically most of the time. Your brain is particularly noteworthy as an aerobic organ. It needs large amounts of energy to maintain the membrane potentials essential for the transmission of nerve impulses, and it normally depends solely on glucose to meet this need.

In fact, your brain needs about 120 gm of glucose per day, which is about 15 per cent of your total energy consumption. When you're at rest, your brain accounts for about 60 per cent of your glucose usage. The brain also accounts for about 20 per cent of your total oxygen consumption. As the brain has no significant stores of glycogen, the supply of both oxygen and glucose must be continuous. Even a short interruption of either has dire consequences.

Your heart has similar requirements because it is also a completely aerobic organ and has little or no energy reserves. The supply of oxygen and fuel molecules must, therefore, be constant, though the heart, unlike the brain, can use a variety of fuel molecules, including glucose, lactate and fatty acids.

In addition to aerobic respiration in a wide variety of tissues, glucose can also be catabolised anaerobically (fermented to lactate), especially in red blood cells and in skeletal muscle cells. Red blood cells have no mitochondria and depend exclusively on glycolysis to meet their energy needs. Skeletal muscle can function in either the presence or absence of oxygen. When you exert yourself strenuously, oxygen becomes limiting, so the rate of glycolysis exceeds that of aerobic respiration and excess pyruvate is converted to lactate. Lactate is released into the blood and taken up not only by your heart for use as fuel but also by gluconeogenic tissues, especially your liver. When lactate molecules enter a liver cell, they are reoxidised to pyruvate, which is then used to make glucose by gluconeogenesis. The glucose is returned to the bloodstream, where it can be taken up by muscle (or any other) cells again.

Skeletal muscle is the main source of blood lactate and the liver is the primary site of gluconeogenesis, so a cycle is set up. Lactate produced by glycolysis in hypoxic (oxygen-deficient) muscle cells is transported via the blood to the liver. There, gluconeogenesis converts the lactate to glucose, which is released into the blood. This process is called the *Cori cycle*, for Carl and Gerti Cori, whose studies in the 1930s and '40s described it. The next time you rest after strenuous exercise, think of what is happening: the lactate your muscle cells have just released into the bloodstream is being taken up by liver cells and converted back to glucose. The reason you are breathing heavily is to provide the oxygen your body needs to return your muscle cells to aerobic conditions and to generate all the ATP and GTP needed for gluconeogenesis in your liver and for rebuilding body glycogen stores.

Glycogen storage is the third significant fate of blood glucose. Glycogen is stored primarily in the cells of your liver and skeletal muscle. Muscle glycogen is used to supply glucose during times of strenuous exertion. Liver glycogen, on the other hand, is used as a source of glucose when the liver is stimulated hormonally to release glucose into the bloodstream to maintain the blood glucose level.

The fourth possible fate of blood glucose is its use for the synthesis of body fat. The route to fat is via pyruvate to acetyl CoA, just as in the initial phase of aerobic respiration.

Whenever you eat more food than the body needs for energy and for the biosynthesis of other molecules, excess glucose is oxidised to acetyl CoA and used for the synthesis of triacylglycerols and then stored as body fat, especially in adipose tissue that is specialised for this purpose. Thus, your body has three sources of energy at all times: the glucose in your blood, the glycogen in your liver and skeletal muscle cells and the triacylglycerols stored in adipose tissue.

To conclude, let's reconsider "what happens to the sugar?" All the glucose and other sugars in your body come originally from the food you eat – either directly as monosaccharides or from the breakdown of disaccharides and polysaccharides in your intestinal tract. The ultimate fate of that glucose is oxidation to $C0_2$ and water, which you then exhale and excrete. But in the meantime, glucose molecules can circulate in your bloodstream or be stored as glycogen in liver or muscle cells. In its circulating form, glucose can be oxidised immediately by aerobic tissues such as the brain, it can be converted to lactate and become a part of the Cori cycle, or it can be used to synthesise glycogen or fat for storage.

It may look like just a modest spoonful of sugar that sprinkle on your cereal or add to your coffee, but treat it with respect — it plays an important role in the energy metabolism of all the cells in your body!

The writer is associate professor and head, Department of Botany, Ananda Mohan College, Kolkata