# Going at the speed of sound

An artist's impression of the hyperloop terminal

Elon Musk

The Delft team after topping the most imaginative hyperloop design contest.

## Not touching the ground and no wind in one's face could be the new mode of travel

**S ANANTHANARAYANAN**

The railways were developed in the course of finding better ways of transport than wagons on mud roads. Hard-wearing steel rails formed the "permanent way" for a train of wagons to move goods and passengers with speed and over long distances.

Those rails are now welded, without a break for kilometres on end, wagon axels have roller bearings and speeds reach over 300 km an hour. Going faster, however, is challenging, because of friction at the wheel and the resistance of the air, both of which grow enormously at high speeds. A team at the Technology University at Delft, in the Netherlands, is trying out a new concept that overcomes these hurdles, to connect cities at the speed of sound.

The new concept, first formally stated by Elon Musk, inventor, entrepreneur and founder of Tesla, the electric car company, uses two devices to reduce resistance. One is air pressure or magnetic levitation to sidestep the rail-wheel resistance. The other is to drive the vehicle through a tube in a near vacuum, to avoid air resistance. The TGV, the high-speed train running on a de-dicated track, replaced air routes becau-se it connected city-centres. Musk's vision of go-ing from Los Angeles to San Francisco (600 km) in 35 mi-nutes, would better air speeds even during the run.

The conventional train is supported and guided by the rails and the wheel flange. It is also propelled by the friction of the wheel turning against the rails. For this to work, and for the train to be stable at high speed, the locomotive and the coaches need to be heavy. Weight and speed, however, increase the friction at the rail and axel bearings, which limits how fast conventional trains can go.

Holding the train off the track would be a way to avoid this limitation. An early method, developed in Germany, was to support the train just above the tracks by electro-magnets. This is the method used in the first commercial application, which connects the Pudong airport to the Shanghai Metro. The train reaches a top speed of 431 km an hour and covers 30 km in seven minutes and 20 seconds.

A Japanese method, said to be superior, is to place magnets in the floor of the train and push the train up by repelling electro-magnets. This method has been tested at 600 km an hour. In both the methods, the electromagnets need be powered only where the train is running and there can be more than one power supply, for safety in case of power failure.

The method in Musk's concept, the "hyperloop", as he named it, was to use high pressure air jets to lift a coach on to an "air cushion". The coach would then glide over the track without direct contact. This would be like the plastic disk, in the indoor game of air hockey, where the disk is supported by air jets emerging from tiny holes in the board.

The other major impediment to speed, in the conventional technology, is air resistance. We have all experienced it when going downhill on a bicycle and we may know that it is air resistance that slows raindrops when they fall from clouds. The drops speed up for just the first seconds, till the air resistance is equal to the force of gravity, and the speed stays at about eight metres a second. This is the same reason that a parachutist can delay opening her parachute — she never falls faster than 53 metres a second!

Air resistance, however, is no good thing when a train, or an airplane, is trying to catch speed. The crucial feature is that air resistance not only gets stronger when an object moves faster, it gets stronger by the cube of object's speed, or the speed multiplied by itself thrice over. It is not difficult to understand why — if we move five times faster than before, we meet five times the number of air molecules. We also meet them five times harder. And then, every second, we overcome this force over five times the distance. The number five thus gets multiplied three times, to give us the cube!

The air resistance of a train hence increases by 2x2x2=8 times when its speed doubles. And the resistance of a train at 300 km an hour is 5x5x5=125 times the resistance at 60 km an hour. At 300 km an hour, the air resistance is estimated to account for 85 per cent of the total resistance the train has to overcome. This is also the reason that long distance aircrafts fly most of the time at high altitudes, where there is less air resistance.

The hyperloop answer, to reach high speeds, is to run an airliner-size module through a tunnel from which the air had been evacuated. This is not something entirely unusual. Even conventional, underground metro systems need to handle the air in the tunnels. When a train moves forward, it acts as a piston and pushes all the air in front. At the same time, it creates a partial vacuum in the space behind, which would drag the train back. To avoid both effects, Metro train tunnels use elaborate "ventilation" systems. Effectively the same technology can create a near-vacuum in the tubes through which the "hyperloop" coach travels. The coach itself, of course would be sealed and pressurised, for the comfort of passengers.The result is then a system in which a vehicle moves with no frictional resistance, as it is not in contact with any surface, and with no air resistance, as the space in which it moves has been evacuated. The question that remains is what mechanism makes the vehicle move forward?

Loyal to the policy of avoiding contact, with the rails or with air, the technology to push the coach in the hyperloop tube is "contactless". Electric motors that we used for almost a century worked because a coil of wire with a current feels a force when it is in the range of a magnet. The coil hence turns around till the magnetic fields are aligned. And then, to keep the movement going, the direction of the current is reversed, so that turning force continues to act. This is done by switching the electric connections to the coil when the coil rotates and presents a different portion to the "brushes" that make the electrical contact. This changed with the use of alternating current, which changes direction, usually 50 times a second. The changing current in a coil creates a current and magnetic effect in another coil and the pair can act like a pair of magnets that are switching their poles. A motor based on this effect is an "induction motor", as it depends on "induced" magnetism, rather than a real magnet. Induction motors hence have no "brush" contacts to maintain!

The same idea, of coils carrying alternating currents, has been modified for propelling or retarding the hyperloop coach, without making physical contact. Propulsion coils are thus ranged along the hyperloop tube, and in the body of the coach. With little resistance to overcome, the arrangement soon drives the coach to speeds quite beyond the reach of the existing technology.

Several start-ups the world over are working to implement Musk's idea of mass transit at the speed of sound. Earlier this year, a team from the Technology University at Delft topped a contest for the most imaginative hyperloop design and they have created a company to take the dream forward.

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# It's all about atomic bonding

## Here's why carbon-containing molecules are so stable and diverse

**TAPAN KUMAR MAITRA**

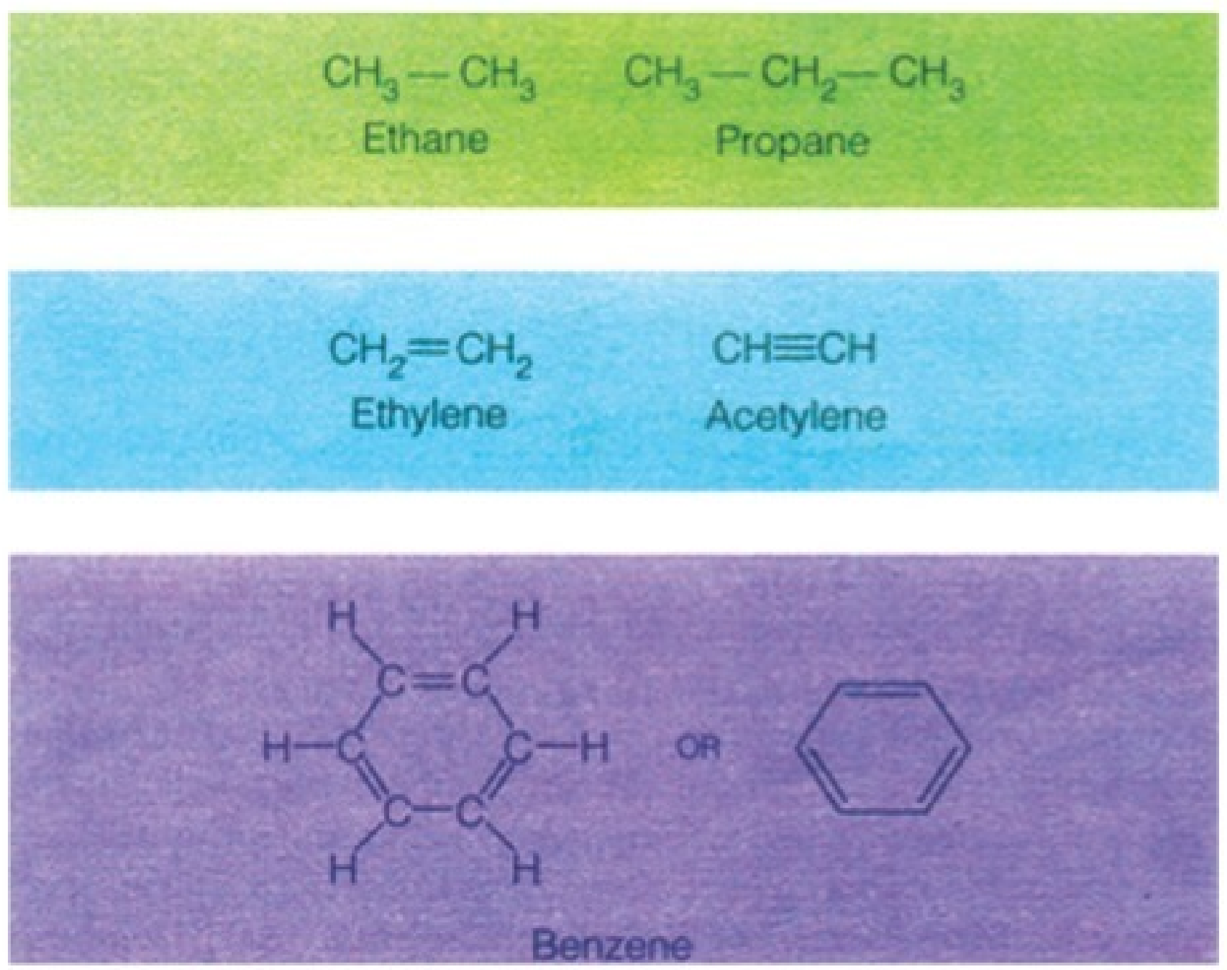
The stability of organic molecules is a property of the favourable electronic configuration of each carbon atom in the molecule. This stability is expressed in terms of bond energy — the amount of energy required to break one mole (about 6x1023) of such bonds. The term bond energy is a frequent source of confusion — it is not the energy that is somehow "stored" in the bond but rather the amount of energy needed to break the bond. Bond energies are usually expressed in calories per mole (cal/mol), where a calorie is the amount of energy needed to raise the temperature of one gram of water by one degree centigrade.

It takes a large amount of energy to break a covalent bond. For example, the carbon-carbon (C-C) bond has a bond energy of 83 kcal/mol. The bond energies for carbon-nitrogen C-N, carbon-oxygen C-O, and carbon-hydrogen C-H bonds are all in the same range — 70, 84, and 99 kcal/mol respectively. Even more energy is required to break a carbon-carbon double bond (C=C; 146 kcal/mol) or a carbon-carbon triple bond (C=C; 212 kcal/mol), so these compounds are even more stable. One can appreciate the significance of these bond energies by comparing them with other relevant energy values. Most non-covalent bonds in biologically important molecules have energies of only a few kilocalories per mole, and the energy of thermal vibration is even lower — about 0.6 kcal/mol. Covalent bonds are much higher in energy than non-covalent bonds and are therefore very stable.

The fitness of the carbon-carbon bond for biological chemistry on Earth is especially clear when its energy is compared with that of solar radiation. There is an inverse relationship between the wavelength of electromagnetic radiation and its energy content. Specifically, the energy of electromagnetic radiation is related to the wavelength by the equation E = 28,600//l, where X is the wavelength in nm, E is the energy in kilocalories per einstein, and 28,600 is a constant with the units kcal-nm/einstein. (An einstein is equal to one mole of photons.)

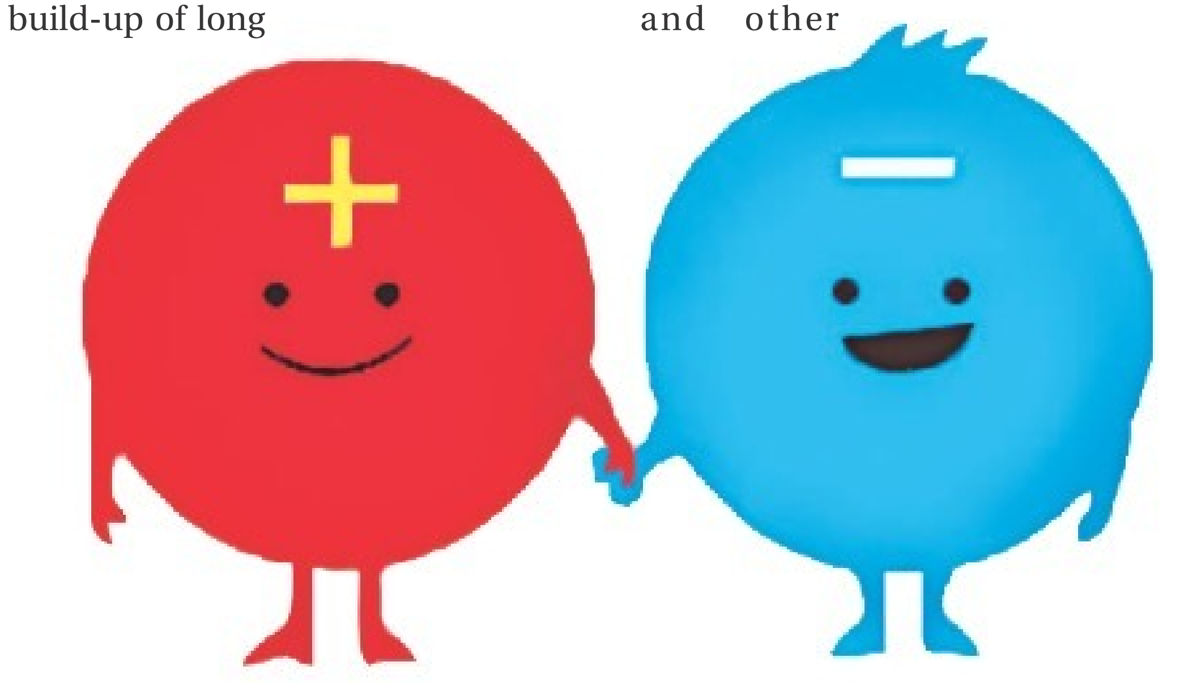
Using this equation, one can readily calculate that the visible portion of sunlight (wavelengths of 400-700 nm) is lower in energy than the carbon-carbon bond. For example, green light with a wavelength of 500 nm has an energy content of about 57.2 kcal/einstein. The energy of green light is therefore well below the energies of covalent bonds. If this were not the case, visible light would break covalent bonds spontaneously, and life as we know it would not exist.

Another important point is the hazard that ultraviolet radiation poses to biological molecules. At a wavelength of 300 nm, for example, ultraviolet light has an energy content of about 95.3 kcal/einstein, clearly enough to break carbon-carbon bonds spontaneously. This threat underlies the current concern about pollutants that destroy the ozone layer in the upper atmosphere, because the ozone layer filters out much of the ultraviolet radiation that would otherwise reach the Earth's surface and wreak havoc with the covalent bonds that literally hold biological molecules together.



Compounds in the top row have single bonds only, whereas those in the second row have double or triple bonds. The condensed structure shown for benzene is an example of the simplified structures that chemists frequently use for such compounds.

In addition to their stability, carbon-containing compounds are characterised by the great diversity of molecules that can be generated from relatively few different kinds of atoms. Again, this diversity is due to the tetravalent nature of the carbon atom and the resulting propensity of each carbon atom to form covalent bonds to four other atoms — because one or more of these bonds can felicitate the build-up of long chains of carbon atoms. Ring compounds are also common. Further variety is possible by the introduction of branching and of double and single bonds into the carbon-carbon chains. When only hydrogen atoms are used to complete the valence requirements of such linear or circular molecules, the resulting compounds are called hydrocarbons. Hydrocarbons are very important economically because gasoline and other petroleum products are mixtures of short-chain hydrocarbons such as octane, an eight-carbon compound (C8H18).



In biology, on the other hand, hydrocarbons play only a very limited role because they are essentially insoluble in water, the universal solvent in biological systems. There is an important exception to this general rule, however. The interior of every biological membrane is a non-aqueous environment from which water and water-soluble compounds are excluded by the long hydrocarbon "tails" of phospholipid molecules that project into the interior of the membrane from either surface. This feature of membranes has important implications for their role as permeability barriers.

Most biological compounds contain, in addition to carbon and hydrogen, one or more atoms of oxygen and often nitrogen, phosphorus, or sulphur as well. These atoms are usually part of various functional groups that confer both water solubility and chemical reactivity on the molecules of which they are a part. Even the phospholipid molecules whose hydrocarbon tails contribute so importantly to the non-aqueous nature of the membrane interior contain atoms other than hydrogen and carbon.

Several of such groups are ionised or protonated (have lost or gained a proton, respectively) at the near-neutral pH of most cells, including the negatively-charged carboxyl and phosphate groups and the positively charged amino group. Other groups, such as the hydroxyl, sulfhydryl, carbonyl, and aldehyde groups, are uncharged at pH values near neutrality. However, they cause a significant redistribution of electrons within the molecules to which they are attached, thereby conferring on these molecules greater water solubility and chemical reactivity.

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**PLUS POINTS**

## Forgetting is also important

The "absent-minded professor" is a stereotype that dates back to Ancient Greece with the philosopher Thales of Miletus reportedly so focused on surveying the night sky that he fell down a well. Even one of the world's greatest minds, Albert Einstein, was considered an example by some.

This combination of intelligence and forgetfulness has long puzzled neuroscientists as a bad memory was seen as a failure of the brain's mechanism for storing and retrieving information.But a new paper in the journal *Neuron*, based on a review of research into the subject, has concluded that forgetting is actually a key part of learning. In fact, the purpose of our "memory" is not to remember facts, but to help making intelligent decisions by retaining only valuable information.

So the brain is not malfunctioning when it forgets something, it may have been actively trying to ditch the memory so it can focus on something more important or create a picture that is easier to understand. One of the authors of the paper, Toronto University's Blake Richards, said, "It's important that the brain forgets irrelevant details and instead focuses on the stuff that's going to help make decisions in the real world."

For example, someone like a supermarket cashier who meets many people every day will probably only remember them for a short time, while a barista working from their own coffee van would start to remember the regulars. The paper in *Neuron* said the "predominant focus" in the study of memory had been on remembering or "persistence". Instead, the paper said, "We propose that it is the interaction between persistence and transience that allows for intelligent decision-making in dynamic, noisy environments". "The goal of memory is to optimise decision-making. As such, transience is as important as persistence in mnemonic (memory) systems."

Ian johnston/the independent

## Ideal system

Bali's famous rice terraces look like colourful mosaics because some farmers plant synchronously while others do so at different times. The resulting fractal patterns are rare for man-made systems and lead to optimal harvests without global planning, said a research team led by Professor Stephen Lansing of the Nanyang Technological University, Singapore and Professor Stefan Thurner of the Medical University of Vienna. Both of them are external faculty at the Santa Fe Institute in the US. The institute said the rice fields could serve as an example that under certain conditions, it is possible to reach sustainable situations that lead to maximum payoff for all parties, where every individual makes free and independent decisions.

The straits times/ann

## Ticking off

A tick whose bite makes victims allergic to meat is spreading. The Lone Star tick — named for its white, Texas-shaped marking — carries a sugar molecule called alpha-1, 3-galactose, or Alpha-Gal for short, which re-programmes people's immune systems, rendering them forever allergic to meat.

When bitten by a tick carrying Alpha-Gal, the body's first response is to develop an antibody. Once this happens, every time you consume the sugar molecule, which is present in red meat, your immune system will attempt to fight it off, triggering an allergic reaction.

Symptoms of Alpha-Gal allergy syndrome include hives, shortness of breath, stomach cramps and in more severe cases difficulty in breathing and fainting. In the rarest of cases, it can even cause death.The tick traditionally makes its home in the south-eastern US states, however recently cases have popped up elsewhere, suggesting its habitat is growing.

Narjas zatat/the independent