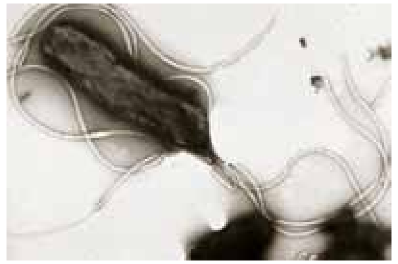
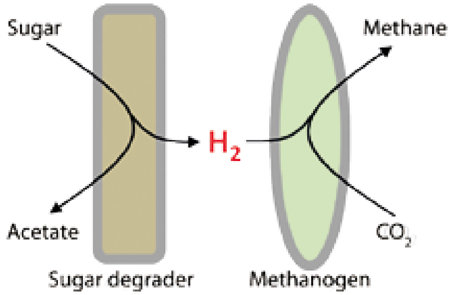


Helicobacter pylori.



Syntrophy (eating together) refers to a relationship in which both partners depend on each other for energetic reasons. Together they carry out a fermentation process that neither one could run on its own. During the degradation of complex organic material into methane, hydrogen is the key molecule that enables syntrophy; a phenomenon also known as "interspecies hydrogen transfer".

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Hydrogen, the ideal biofuel?

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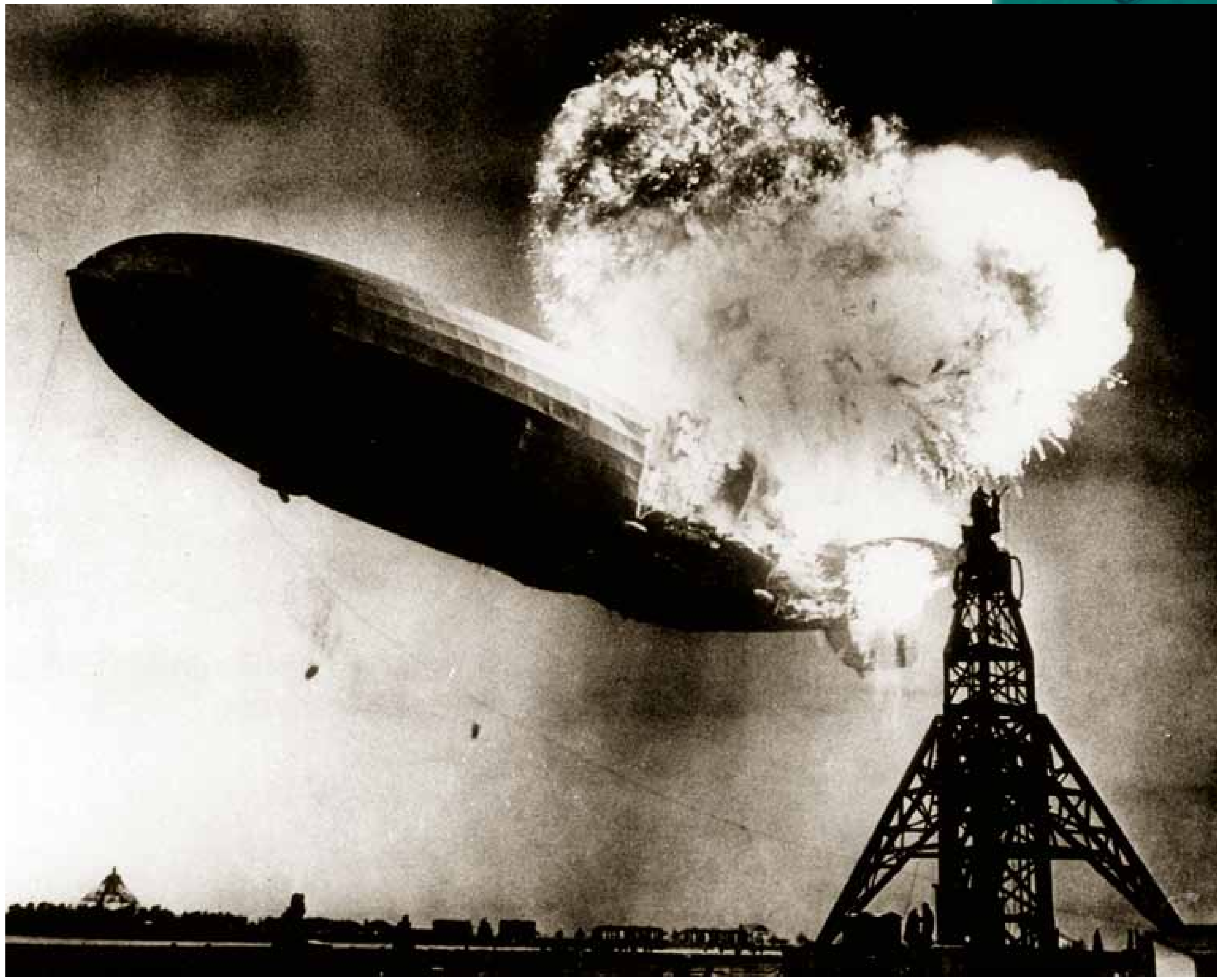
Atomic hydrogen (H) is the most abundant element in the universe. It is the first element in the periodic table, consisting of only one proton and one electron. Virtually every material in our daily lives, from plastics to wood to our own bodies, consists of hydrogen atoms combined with other elements. However, when two hydrogen atoms combine, they generate molecular hydrogen (H_2) which exists under ambient conditions as a gas. Hydrogen gas is the lightest of all gases and for that reason it has been used to lift balloons and zeppelins such as the famous Hindenburg, the largest zeppelin ever to fly. However, the Hindenburg came to an unfortunate end in 1937 because of another feature of hydrogen gas, its flammability. The airship exploded when the hydrogen gas it contained caught fire. When hydrogen gas burns, a huge amount of energy is released. On a weight basis, hydrogen gas can produce more energy than gasoline or diesel.

"Knallgas" bacteria

Microbes can obtain their energy for growth in very different ways and have evolved to exploit all possible energy sources, including organic molecules (e.g. sugars, proteins, fats) and inorganic molecules (e.g. iron, sulphur, ammonia) as well as sunlight. The energy stored in H_2 is also used by specific microbes. Like us, many bacteria use oxygen (O_2) from the air for aerobic respiration. Some bacteria can combine O_2 with H_2 to produce water and energy. These aerobic microbes are called "Knallgas" bacteria (*knall* means *bang* in German and Scandinavian languages, referring to the loud explosion that may occur when H_2 reacts with O_2). Many different microorganisms use this reaction for growth including human pathogens such as *Helicobacter pylori*, which causes gastritis and stomach cancer, and thermophiles such as *Hydrogenobacter thermophiles* that live in hot volcanic pools. In addition to the aerobes, there are also anaerobic bacteria that cannot use O_2 but still use H_2. They use reactions with compounds such as sulphur or iron. A special group of H_2-utilizing anaerobes are the methanogens. These bacteria grow in the absence of oxygen and use H_2 to convert carbon dioxide (CO_2) into methane (CH_4).

Microbes that produce hydrogen

In addition to the microorganisms mentioned above, there are other types of microbes that can produce hydrogen. It is often a product of anaerobic fermentation, a process in which H_2 is produced from sugars or proteins. In some cases, the growth of the microorganism is inhibited by the high levels of hydrogen produced, so these bacteria depend on other bacteria to consume it. The relationship between the hydrogen-producers and hydrogen-consumers where there is mutual benefit is known as syntrophy.



The Hindenburg caught fire and was completely destroyed within 37 seconds.

Microbial hydrogen production appears to be easier at higher temperatures. Some species of the genera *Thermococcus* and *Pyrococcus*, which grow at temperatures up to 100°C, are very efficient producers of hydrogen gas from certain sugars. They are quite restricted in their diet and for that reason are not suitable for H_2 biofuel production. Species from the genera *Caldicellulosiruptor* and *Thermotoga* grow optimally at 70 to 80°C and produce high concentrations of hydrogen. Moreover, these species can use