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La Biennale di Venezia
53. Esposizione Internazionale d'Arte
7 June to 22 November, 2009

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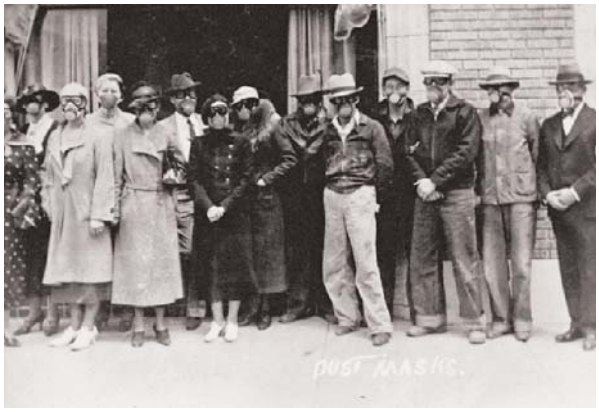

Citizens of Liberal, Kansas,
in front of the Red Cross building
wearing dust masks to protect their lungs
from blowing dust, 1935
KansasMemory.org, Kansas State Historical Society

Corn Bomb: A Short History of Nitrogen 1660–2008

Professor Michael A. Morris (Dept. of Chemistry, University College Cork, and CRANN, Trinity College Dublin) and John Gerrard

1660
World population stands at circa 500 million.

1660
Robert Boyle, an Irish scientist and one of the founders of modern chemistry, is the first to suggest that air is composed of tiny 'corpuscles' or molecules. A keen alchemist, Boyle spent many years trying to turn iron into gold.

1675
John Evelyn, an English writer, gardener and diarist, suggests that rainwater is not pure but instead impregnated with a beneficial substance which he names 'celestial nitre'.

1772
Elemental Nitrogen is isolated by the Scottish chemist and physician Daniel Rutherford but remains unnamed.

1770
World population stands at circa 900 million.

1773
Carl Wilhelm Scheele, an apprentice apothecary from Sweden with no formal education, discovers 'fire air' (oxygen), an 'air' that supports combustion. He produces

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it by reacting aqua fortis (nitric acid) with potash to produce a colourless gas. He also demonstrates that 'common air' consists of 'fire air' and a second component that does not support combustion and causes asphyxiation in animals. This he describes as 'foul air'.

1774
Joseph Priestley, a Unitarian Church Minister and radical social reformer who went on to become one of the greatest chemists of his generation, shows that 'fire air' (oxygen) could support life up to five times better than normal air. He travels to Paris to visit the chemist Antoine Lavoisier, who the following year discovers and formally names oxygen.

1780
The onset of the Industrial Revolution in the United Kingdom creates a need for large quantities of chemicals in the form of soaps, bleaches, acid and dyes for use in the production of textiles.

1790
Nitrogen is formally named in Jean Antoine Chaptal's *Éléments de chimie*. His choice of 'nitrogène' combines the Greek word νιτρον *[nitron]* = sodium carbonate, saltpetre and French word gène from Greek γεινομαι (geinomai) = to engender, bring forth. It is also referred to as *Phlogisticated Air* by Priestley and *Azote* (or 'lifeless') by Lavoisier.

1800
Amount of arable land needed to feed one person for one year: 60 acres.

1827
The role of soluble forms of nitrogen in crop cultivation is outlined in the groundbreaking work of Justus von Liebig, known as the father of the fertiliser industry. He recognises that nitrogen is needed in a fixed form.

Note
The earth's atmosphere is 80% nitrogen, but this nitrogen is non-reactive. Each nitrogen atom is tightly bound to another (N_2). They must be split and 'fixed' to other atoms to form nitrogen compounds: either with oxygen (to form nitrates) or hydrogen (to form ammonia and other amines). Nitrogen is fixed naturally by bacteria that live in the roots of leguminous plants (clover, peas, beans and alfalfa), or by lightning strikes during which nitrogen bonds are broken in the air and bound to oxygen.

1846
The modern history of petroleum begins with the discovery of the process of refining kerosene from coal by Nova Scotian physicist and geologist Abraham Pineo Gesner. In 1852 the Polish pharmacist Łukasiewicz improves Gesner's method by developing a means to refine kerosene from the more readily available 'rock oil' (*petr-oleum*) seeps. In 1853 the first rock oil mine is built in Bóbrka, near Krosno in western Poland.

1847
John Hutchinson, a 22-year old chemist and industrialist, recognises the importance of scale to economy in the chemical industry and acknowledges that chemicals are needed for domestic as well as industrial use. He opens a factory in northwest England (a region with salt deposits and a sophisticated canal network), and recruits three established chemists: Ludwig Mond, John Brunner and J.W. Towers.

1850
World population stands at circa 1,200 million. Widespead farming on the Great Plains of the United States begins. The advances of the Industrial Revolution and the onset of commercialisation, augmented by a new understanding of the relationship between crop yield and nitrogen and the need to avoid soil depletion, radically changes farming practices across

the world. With arable land under significant pressure to feed an increasing population, crop rotation between crops and leguminous plants as well as the use of manure, guano and mineral nitrates to increase production become commonplace.

1854
Benjamin Silliman, a professor at Yale University, is the first to fractionate petroleum by distillation. His discoveries rapidly spread around the world. In 1861 Meerzoeff built the first Russian refinery in the mature oil fields at Baku. Within a short space of time the area was producing almost 90% of the world's oil.

1859
Former railwayman Edwin Laurentine "Colonel" Drake drills the world's first successful oil well in Titusville, Pennsylvania.
2,000 barrels of oil are produced this year in the United States.

1862
The Morrill Act is passed in the United States to establish State Agricultural Experiment Stations to develop modern techniques in animal husbandry.

1865
California's first productive well is drilled by the Union Matolle Company in the state's Central Valley.

1866-77
A cattle boom accelerates inhabitation of the Great Plains, leading to a series of land-related disputes between farmers and ranchers.

1869
4,215,000 barrels of oil are produced in the United States.

1876
German inventor Nikolaus Otto, working with Gottlieb Daimler and Wilhelm Maybach, develops the first four-stroke piston cycle internal combustion engine.

1879
Karl Benz is granted a patent for his two-stroke gas engine, based on the same technology as Otto's. A short time later, Benz designs and builds his own four-stroke engine. He develops his first automobile in 1885 and patents it in 1886. Soon afterwards it becomes the first automobile in production.

1879-1883
The importance of mineral fertilizers in crop production leads to dramatic increases in fixed nitrogen prices. Its sourcing becomes a major political concern. India, Norway and Egypt each discover resources of various nitrate-containing minerals, but by far the largest are found in South America. Among them is a 220-mile-long deposit of guano (fixed nitrogen laid down in the excrement of birds over millions of years) and saltpetre (potassium nitrate). The value of the mineral rights within this field is a direct cause of the War of the Pacific (1879-1883, also known as the War of Saltpetre) between Chile, Peru and Bolivia. The government of the United Kingdom sponsors Chile with financial support and arms on the condition of guaranteed exploitation contracts. Following the war's conclusion Chile establishes itself as the world's largest supplier of nitrates. Companies from the United Kingdom soon own 70% of the Chilean nitrate industry.

1892
John Froelich develops the first successful gasoline-powered tractor, a machine that will ultimately welcome in the twentieth century and usher out the use of animal power. His company is later purchased by Deere & Company and becomes the John Deere Tractor Company.

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1893
Patillo Higgins, a Texan businessman and self-taught geologist, founds the Gladys City Oil, Gas, and Manufacturing Company in the belief that modern industry will soon switch from coal to oil.

1898
Chile builds a vibrant economy on guano and saltpetre sales, accounting for around half of its GNP. Exports of copper provide an additional quarter. Over-reliance on these products quickly becomes a major problem. Original forecasts that the nitrate fields would last for 100 years or more appear optimistic as global demand for fertilizer begins outstripping supply. Sir William Crookes, a chemist and senior British government official, delivers a lecture titled "The Wheat Problem." It proposes that the world might face starvation if nitrate sources run out (a situation he forecasted would occur in 1921).

1899
Average annual consumption of commercial fertilizer in the United States: 1,845,900 tonnes.

1900
90% of the United States population lives on farms.

1900
Although Crookes' warnings regarding the diminishing resources of natural nitrate are initially ignored, the potential impact of a shortage becomes glaringly apparent within a few months. The expectation of war in Europe and the consequent stockpiling of explosives contributes to a steep rise in the demand for and price of fertilizer. Further pressure comes from the food industry, with crop yield in Europe having doubled over the course of the last century to feed rapidly-expanding populations. Nitrogen is available in Europe, but only in the atmosphere. At this point, neither plants nor humans can make use of it because a technically feasible method of fixing it in chemical compounds has not yet been discovered.

Note
The growing demand for nitrate, in part to produce explosives during the First World War, eventually caused the collapse of the Chilean nitrate market and the departure of large numbers of British extraction companies. The Chilean economy did not regain stability until the late twentieth century.

The demand for clean ammonia for use in the production of explosives and fertilizer led to the small-scale development of two processes:
1. The arc process
($N_2 + O_2 \rightarrow 2NO$ $NO + ½\ O_2 \rightarrow NO_2$)
which took place at temperatures greater than 1200°C
This was energy-inefficient and 1 tonne of fixed N_2 equivalent to 1500 kWh.
2. Cyanamide process:
$CaO + C \rightarrow CaC$ $CaC + N_2 \rightarrow CaCN_2$
at temperatures greater than 1000°C
$CaCN_2 + H_2O \rightarrow CaCO_3 + NH_3$
Although more efficient, the process was not as easy to operate or as safe.

1900
World population stands at circa 1,600 million.
Amount of arable land needed to feed one person for one year: circa 5 acres.
German funding for research into synthetic munitions-grade nitrate begins.

1901
On January 10, the first major oil well is discovered in Texas. A 'gusher' in Spindletop, near Beaumont, rises to a height of more than 150 feet (50 metres). Called "Lucas 1," it flows for nine days before it can be capped. It begins delivering oil at an initial rate of close to 100,000 barrels per day, greater than all the

other wells in the United States combined.

1905
The German chemist Professor Fritz Haber, then just 36 years old, publishes '*Thermodynamik technischer Gasreaktionen*' (The Thermodynamics of Technical Gas Reactions) in which he details the iron-catalysed reaction of hydrogen and nitrogen to create ammonia at temperatures below 1000°C. Soon afterwards $N_2 + H_2 \rightarrow NH_3$ is patented as the 'Haber Process'. At this time Germany is still 95% reliant on Chilean nitrate.

1906
126,493,936 barrels of oil are produced in the United States.

1909
A dryland farming boom begins on the Great Plains with the arrival of itinerant, seasonal 'suitcase farmers', mining the land for valuable wheat crops but typically resident elsewhere. It will reach its peak in the 1920s.

1910
Considerable work is required to make the Haber Process commercially viable. "*The interest of a wider circle*," Haber later stated, "*has its source in the recognition that ammonia synthesis on a large scale represents a useful way to satisfy an economic need. This practical usefulness was not the preconceived goal of my experiments. I was not in doubt that my laboratory work could furnish no more than a scientific statement of the foundations and a knowledge of the experimental equipment, and that much had to be added to this result in order to attain economic success on an industrial scale.*"

1910
BASF chemist Carl Bosch takes out patents on the use of high pressure and separation processes and moves the concept towards a manufacturing method. The reaction requires high temperatures (750°C) and pressures and is energy-intensive. Bosch and Haber develop a process to fix atmospheric nitrogen and produce synthetic ammonia.

1910
Large, open-geared gas tractors are used for the first time for farming in the United States.

1913
The world's first commercial ammonia synthesis plant to produce mineral fertilizer according to the Haber-Bosch Process opens in Oppau, Germany.
Worldwide production of synthetic nitrogen:
7 arc plants (20,000 tonnes of nitrogen a year), 15 cyanamide plants (66,000 tonnes of nitrogen a year), and 1 direct synthetic ammonia plant (Oppau, 7,000 tonnes of nitrogen a year). The ammonia produced is converted to nitrate for use as explosives or fertilizers.

1913
The United Kingdom government (with the help of spies) initiates its own synthetic ammonia programme. Despite recognising the importance of synthetic production, they fail to recreate Germany's success.

1914
The assassination on 28 June of Archduke Franz Ferdinand of Austria in Sarajevo leads to the outbreak of the First World War. The United Kingdom government, which has its own nitrate source in India, expects that war will last just six months due to German munitions shortages. In order to prevent German access, a blockade of Chilean nitrate begins. Despite early successes in defying the British Navy, German ships are soon confined to home defence. The further development of domestic synthetic production suggests that Germany's munitions supply would last until early 1916. A combination of the Haber-Bosch Process to produce ammonia, and the Ostwald Process to convert it into nitric acid and

nitrates, prolongs the war until 1918.

Note
All explosive production was based around nitrate e.g. gunpowder = nitrate + sulphur + sugar, TNT = $CH_3C_6H_2(NO)_3$, nitroglycerin = $CH_5(ONO_2)_3$

1915
Haber supervises the first gas attack in military history at Ypres, France, on April 22. Somewhere around 10,000 Allied troops are killed or incapacitated by chlorine on that single day. Poison gas remains a focus of Haber's work, and he leads the effort to develop and deploy mustard gas (dichlordiethylsulfide). Haber's wife Clara Immerwahr,in 1900 the first female student at the University of Breslau to receive a PhD, expresses her objections to the use of chemistry for making weapons. After attending a dinner on May 2 to celebrate her husband's appointment to Captain, Immerwahr shoots herself with his service revolver. The morning after her death, Haber leaves home to stage the first gas attack against the Russian army on the Eastern Front.

Note
In 1986 Fritz Haber (son of the chemist) and his second wife, Charlotte, published a book on the history of poison gas, *The Poisonous Cloud.*

1916
During the wartime boom in grain prices, petroleum-driven tractors remove 100 million acres of American midwest prairie grass cover to sow wheat. As a national defense measure to ensure the supply of nitrates used in the production of munitions, the United States Congress authorizes the construction of two nitrate-manufacturing plants and a dam for hydro-electric power. President Woodrow Wilson chooses Muscle Shoals, Alabama as the site for both the plants and the dam, the latter of which will later be named after him.

1918
Following the conclusion of hostilities, Haber is awarded the Nobel Prize. He is a controversial recipient, having been named but found not guilty of being a war criminal. Bosch, whom many think in fact made the greater contribution, would be awarded the same prize in 1931. It becomes apparent that the German technology for ammonia synthesis is key to continued industrial growth and increased food production. The United Kingdom government hires the company Brunner-Mond to spearhead its research effort. Some time later Aldous Huxley visits their recently-opened and technologically-advanced plant at Billingham, northeast England. The introduction to the most recent edition of Huxley's 1931 classic novel *Brave New World* states that the author was inspired to write the book (in which Mustapha Mond figures as a character) after this visit.

1920
World population stands at circa 1,900 million.

1922
The United States National Live Stock and Meat Board is founded.

1926
Muscle Shoals Fertilizer Company and the Muscle Shoals Power Distributing Company are created by a consortium of southern United States power companies to utilise wartime facilities for the production of fertilizer.

1926
A light tractor is successfully developed for use in farming in the United States.

1930s
An all-purpose, rubber-tired tractor with complementary machinery comes into wide use in the United States, particularly on the Great Plains.

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1931
A severe drought hits the midwestern and southern plains of the United States. Crops die and "black blizzards" (great walls of dust whipped up from over-plowed and over-grazed land) sweep through the region.

1933
Franklin Roosevelt takes office in the United States.

1934
An even more more serious drought, the worst in the history of the United States, affects more than 75 percent of the country. Dust storms spread across an area of 100 million acres (400,000 square kilometres), centered on the panhandles of Texas and Oklahoma, and adjacent parts of New Mexico, Colorado, and Kansas. This area becomes known as the 'Dust Bowl'.

1935
On April 14, now known as "Black Sunday," the worst storm of the Dust Bowl occurs. Travelling at a speed of sixty miles an hour, it causes massive damage. 850 million tonnes of topsoil are blown off the Southern Plains during the course of the year. Millions of acres of farmland become useless, and hundreds of thousands of people are forced to leave their homes. Many traveled to California and other states in search of more beneficial economic conditions. Owning no land, others traveled from farm to farm picking fruit and other crops at starvation wages.

1939
Rain finally comes in the autumn, bringing an end to the drought. The outbreak of the Second World War on September 1 contributes to a regeneration of the United States economy, dragging it out of the Depression. The plains once again become golden with wheat.

1950
World population stands at circa 2,500 million.

1960
11 million tonnes of nitrogen fertiliser are used worldwide.

1970
32 million tonnes of nitrogen fertiliser are used worldwide.

1970s
The first "dead zone" in the Gulf of Mexico is discovered. Nitrates leak into the Mississippi River from the fields of the midwestern United States, which in turn feeds directly into the gulf. Such zones, it is later understood, are caused by eutrophication – an increase of chemical nutrient compounds containing nitrogen or phosphorus within an ecosystem causing algal blooms which consume all available oxygen, thereby causing the death of all other organisms in
the area.

1980
World population stands at circa 4,400 million.
Average meat consumption in the United States stands at 45kg per person.

1980
61 million tonnes of nitrogen fertiliser are used worldwide.

1990
Iraq invades Kuwait, leading to the First Gulf War.
79 million tonnes of nitrogen fertiliser are used worldwide.
The amount of fixed nitrogen used in farming in the period 1980-1990 exceeds all previous use prior to 1980.
Somewhere between 50-60% of the global population now rely on fertilizer to eat. The nitrogen used in

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ammonia manufacture is derived exclusively from fossil fuels: as a consequence, the price of fertilizer has run parallel to that of oil for more than 70 years.

1995
The Oklahoma City bombing takes place on April 19, targeting the Alfred P. Murrah Federal Building, an office complex belonging to the United States government. The attack, using nitrogen fertiliser, claims the lives of 168 people and injures over 800 others.

1997
World population stands at circa 5,900 million.

2000
82 million tonnes of nitrogen fertiliser are used worldwide.

2001
A dead zone in the Black Sea, previously the largest in the world, is found to have largely disappeared between 1991 and 2001. Fertilisers have become too expensive to use following the collapse of the Soviet Union and the demise of centrally-planned economies within Eastern Europe. Fishing again becomes a major economic activity in the region.
September 11 attacks on the United States, leading to the Second Gulf War.

2004
The United Nations Environment Programme publishes its first Global Environment Outlook Year Book. It details the existence of 146 dead zones in the world's oceans where marine life cannot be supported due to depleted oxygen levels.

2007
Total meat production in the United States reaches 40.5 billion kg. Exports account for 2.5 billion kg, compared to just 0.1 billion kg in 1970. Department of Agriculture data reveals that world grain production has risen from 0.905 billion metric tonnes in 1965 to 2.091 billion metric tonnes in 2007 (an increase of 131%) while the total area of farmed land increased during the same period by only 4.1%. Nitrogen fertiliser is credited as the principle driver of this growth.

2008
World population stands at circa 6,770 million.
World consumption of oil per day stands at circa 80 million barrels.
180 million tonnes of nitrogen fertiliser are used worldwide.
Amount of arable land needed to feed one person for one year: circa 1.8 acres.
400 gallons of oil are required to feed each United States citizen per year.
2% of the United States population lives on farms.
The manufacture of nitrogen fertiliser accounts for 37% of total energy use in agriculture.
405 dead zones have been found in lakes, seas and oceans worldwide. The most notorious dead zone remains the 22,126 square kilometre (8,543mi^2) area in the Gulf of Mexico. Other major oxygen-starved areas can be found in the Baltic Sea, the Adriatic Sea, the Gulf of Thailand, the Yellow Sea, and Chesapeake Bay. In addition, nitrate concentrations in rivers in the northeastern United States and much of Europe have increased 10- to 15-fold in the last 100 years. Proceedings of the National Academy of Sciences published online warned of "mass extinction in the oceans with unknown ecological and evolutionary consequences."

July 31, 2008
The Washington Post carries a report on so-called 'jubilees' taking place on the Gulf Coast of the United States. Wayne Keller, director of the Grand Isle Port Commission, Louisiana, says that in recent years people all along the coast have used nets and poles to

catch fish and shrimp which appear to 'rush' towards the shoreline. Driven by vast walls of deoxygenated and deathly water, there is nowhere else for the creatures to go. Huge numbers of them are barbecued along the coast amid scenes of celebration.

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