2. ASCORBIC ACID

THE AGE OF DISCOVERY was fueled by molecules of the spice trade, but it was the lack of another, quite different molecule that almost ended it. Over 90 percent of his crew didn't survive Magellan's 1519–1522 circumnavigation of the world—in large part due to scurvy, a devastating disease caused by a deficiency of the ascorbic acid molecule, dietary vitamin C.

Exhaustion and weakness, swelling of the arms and legs, softening of the gums, excessive bruising, hemorrhaging from the nose and mouth, foul breath, diarrhea, muscle pain, loss of teeth, lung and kidney problems—the list of symptoms of scurvy is long and horrible. Death generally results from an acute infection such as pneumonia or some other respiratory ailment or, even in young people, from heart failure. One symptom, depression, occurs at an early stage, but whether it is an effect of the actual disease or a response to the other symptoms is not clear. After all, if you were constantly exhausted and had sores that and diarrhea, not be depressed.

Scurvy is a remains are said from ancient. scurvy is said to be a Viking warrior's disease, so the coast of Europe and Africa, where ships were supposed to make their way to America, probably had scurvy.

SCURVY AT SEA

In the fourteenth century, possible by the use of large, cargo ships, such as the caravels of the early Portuguese. These ships were not designed for long voyages in calm weather far from the days or weeks. Scurvy was seldom seen on ocean voyages in calm waters, but also reoccurring or more complicated
ASCORBIC ACID

had sores that did not heal, painful and bleeding gums, stinking breath, and diarrhea, and you knew that there was worse to come, would you not be depressed, too?

Scurvy is an ancient disease. Changes in bone structure in Neolithic remains are thought to be compatible with scurvy, and hieroglyphs from ancient Egypt have been interpreted as referring to it. The word scurvy is said to be derived from Norse, the language of the seafaring Viking warriors who, starting in the ninth century, raided the Atlantic coast of Europe from their northern homelands in Scandinavia. A lack of vitamin-rich fresh fruit and vegetables would have been common on board ships and in northern communities during winter. The Vikings supposedly made use of scurvy grass, a form of Arctic cress, on their way to America via Greenland. The first real descriptions of what was probably scurvy date from the Crusades in the thirteenth century.

SCURVY AT SEA

In the fourteenth and fifteenth centuries, as longer voyages were made possible by the development of more efficient sets of sails and fully rigged ships, scurvy became commonplace at sea. Oar-propelled galleys, such as those used by the Greeks and Romans, and the small sailing boats of Arab traders had stayed fairly close to the coast. These vessels were not seaworthy enough to withstand the rough waters and huge swells of the open ocean. Consequently, they would seldom venture far from the coast, and supplies could be replenished every few days or weeks. Access to fresh food on a regular basis meant that scurvy was seldom a major problem. But in the fifteenth century, long ocean voyages in large sailing ships heralded not only the Age of Discovery but also reliance on preserved food.

Bigger ships had to carry cargo and arms, a larger crew to handle the more complicated rigging and sails, and food and water for months at
sea. An increase in the number of decks and men and the amount of supplies inevitably translated into cramped sleeping and living conditions for the crew, poor ventilation, and a subsequent increase in infectious diseases and respiratory conditions. Consumption (tuberculosis) and the “bloody flux” (a pernicious form of diarrhea) were common as, no doubt, were body and head lice, scabies, and other contagious skin conditions.

The standard sailor's food did nothing to improve his health. Two major factors dictated the seafaring diet. Firstly, aboard wooden ships it was extremely difficult to keep anything, including food, dry and mold free. Water was absorbed through wooden hulls, as the only water-proofing material available was pitch, a dark-colored, sticky resin obtained as a by-product of charcoal manufacture, applied to the outside of the hull. The inside of the hull, particularly where ventilation was poor, would have been extremely humid. Many accounts of sailing journeys describe incessant dampness, as mold and mildew grew on clothing, on leather boots and belts, on bedding, and on books. The standard sailor's fare was salted beef or pork and ship's biscuits known as hardtack, a mixture of flour and water without salt that was baked rock hard and used as a substitute for bread. Hardtack had the desirable characteristic of being relatively immune to mildew. It was baked to such a degree of hardness that it remained edible for decades, but it was extremely difficult to bite into, especially for those whose gums were inflamed by the onset of scurvy. Typically, ship's biscuits were weevil infested, a circumstance that was actually welcomed by sailors as the weevil holes increased porosity and made the biscuits easier to break and chew.

The second factor governing diet on wooden ships was the fear of fire. Wooden construction and liberal use of highly combustible pitch meant that constant diligence was necessary to prevent fire at sea. For this reason the only fire permitted on board was in the galley and then only in relatively calm weather. At the first sign of foul weather, galley fires would be extinguished not possible for in water for the hou biscuits be made at stew or broth.

At the outset of a voyage, cheese, vinegar, and soon rancid, the butter cheeses hard, and then C, so signs of scurvy of port. Was it any wonder that the press-gangs wereSc!rvy's toll on the health of early voyages. By the 18th century, ships adrift at sea had to protect themselves against scurvy for centuries longer than all other causes: piracy, shipwrecks, as well as storms.

Astonishingly, pith or piece were known—the Chinese were gyf| The idea that fresh citrus fruits cured scurvy was, no doubt, contact with Chinese the Dutch and been the first fleet of the Elected oranges and lemons formed a small squadron of five or so. Lancaster, who carried the Dragon. Anyone who
Ascorbic Acid

Fires would be extinguished until the storm was over. Cooking was often not possible for days at a time. Salted meat could not be simmered in water for the hours necessary to reduce its saltiness; nor could ship’s biscuits be made at least somewhat palatable by dunking them in hot stew or broth.

At the outset of a voyage provisions would be taken on board: butter, cheese, vinegar, bread, dried peas, beer, and rum. The butter was soon rancid, the bread moldy; the dried peas weevil infested, the cheeses hard, and the beer sour. None of these items provided vitamin C, so signs of scurvy were often evident after as little as six weeks out of port. Was it any wonder that the navies of European countries had to resort to the press-gang as a means of manning their ships?

Scurvy’s toll on the lives and health of sailors is recorded in the logs of early voyages. By the time the Portuguese explorer Vasco da Gama sailed around the southern tip of Africa in 1497, one hundred of his 160-member crew had died from scurvy. Reports exist of the discovery of ships adrift at sea with entire crews dead from the disease. It is estimated that for centuries scurvy was responsible for more death at sea than all other causes; more than the combined total of naval battles, piracy, shipwrecks, and other illnesses.

Astonishingly, preventives and remedies for scurvy during these years were known—but largely ignored. As early as the fifth century, the Chinese were growing fresh ginger in pots on board their ships. The idea that fresh fruit and vegetables could alleviate symptoms of scurvy was, no doubt, available to other countries in Southeast Asia in contact with Chinese trading vessels. It would have been passed on to the Dutch and been reported by them to other Europeans as, by 1601, the first fleet of the English East India Company is known to have collected oranges and lemons at Madagascar on their way to the East. This small squadron of four ships was under the command of Captain James Lancaster, who carried bottled lemon juice with him on his flagship, the Dragon. Anyone who showed signs of scurvy was dosed with three tea-
spoons of lemon juice every morning. On arrival at the Cape of Good Hope, none of the men on board the Dragon was suffering from scurvy, but the toll on the other three ships was significant. Despite Lancaster’s instructions and example, nearly a quarter of the total crew of this expedition died from scurvy—and not one of these deaths was on his flagship.

Some sixty-five years earlier the crew members on French explorer Jacques Cartier’s second expedition to Newfoundland and Quebec were badly affected by a severe outbreak of scurvy, resulting in many deaths. An infusion of needles of the spruce tree, a remedy suggested by the local Indians, was tried with seemingly miraculous results. Almost overnight the symptoms were said to lessen and the disease rapidly disappeared. In 1593 Sir Richard Hawkins, an admiral of the British navy, claimed that within his own experience at least ten thousand men had died at sea from scurvy, but that lemon juice would have been an immediately effective cure.

There were even published accounts of successful treatments of scurvy. In 1617, John Woodall’s The Surgeon’s Mate described lemon juice as being prescribed for both cure and prevention. Eighty years later Dr. William Cockburn’s Sea Diseases, or the Treatise of their Nature, Cause and Cure recommended fresh fruits and vegetables. Other suggestions such as vinegar, salt water, cinnamon, and whey were quite useless and may have obscured the correct action.

It was not until the middle of the following century that the effectiveness of citrus juice was proven in the first controlled clinical studies of scurvy. Although the numbers involved were very small, the conclusion was obvious. In 1747, James Lind, a Scottish naval surgeon at sea in the Salisbury, chose twelve of the crew suffering from scurvy for his experiment. He selected men whose symptoms seemed as similar as possible. He had them all eat the same diet: not the standard salted meat and hardtack, which these patients would have found very difficult to chew, but sweetened gruel, mutton broth, boiled biscuits, barley, sago, rice, raisins, this carbohydrate quart of cider daily unfortunate pair r more were require two were fed a cor cream of tartar, an daily two oranges.

The results were today’s knowledge fruit were fit for dr. off their seawater, with lemons and o. Scurvy, but it was a compulsory issue o.

If an effective tre upon and used routi seems to have not l blamed scurvy on a fresh meat rather th was a logistical pro juice for weeks at a t serve lemon juice, b and perhaps not very amount in fruits and

Because of expen: the British admiral, ficient greens or citru space would have too l fruit was expensive, c ventive measure. Eco.
Ascorbic Acid

Good scurvy, scurvy’s ex- on his
sagor, rice, raisins, currants, and wine. Lind added various supplements to this carbohydrate-based regime. Two of the sailors each received a quart of cider daily. Two others were dosed with vinegar, and another unfortunate pair received diluted elixir of vitriol (or sulfuric acid). Two more were required to drink half a pint of seawater daily, and another two were fed a concoction of nutmeg, garlic, mustard seed, gum myrrh, cream of tartar, and barley water. The lucky remaining pair was issued daily two oranges and one lemon each.

The results were sudden and visible and what we would expect with today’s knowledge. Within six days the men who received the citrus fruit were fit for duty. Hopefully, the other ten sailors were then taken off their seawater, nutmeg, or sulfuric acid regimes and also supplied with lemons and oranges. Lind’s results were published in *A Treatise of Scurvy*, but it was another forty years before the British navy began the compulsory issue of lemon juice.

If an effective treatment for scurvy was known, why wasn’t it acted upon and used routinely? Sadly, the remedy for scurvy, though proven, seems to have not been recognized or believed. A widely held theory blamed scurvy on a diet of either too much salted meat or not enough fresh meat rather than a lack of fresh fruit and vegetables. Also, there was a logistical problem: it was difficult to keep fresh citrus fruit or juice for weeks at a time. Attempts were made to concentrate and preserve lemon juice, but such procedures were time consuming, costly, and perhaps not very effective, as we now know that vitamin C is easily destroyed by heat and light and that long-term storage reduces the amount in fruits and vegetables.

Because of expense and inconvenience, naval officers, physicians, the British admiralty, and shipowners could see no way of growing sufficient greens or citrus fruit on heavily manned vessels. Precious cargo space would have to be used for this purpose. Fresh or preserved citrus fruit was expensive, especially if it was to be allocated daily as a preventive measure. Economy and the profit margin ruled—although, in
hindsight, it does seem that this was a false economy. Ships had to be manned above capacity to allow for a 30, 40 or even 50 percent death rate from scurvy. Even without a high death rate, the effectiveness of a crew suffering from scurvy would have been remarkably low. And then there was the humane factor—rarely considered during these centuries.

Another element was the intransigence of the average crew. They were used to eating the standard ship’s fare, and although they complained about the monotonous diet of salt meat and ship’s biscuit when they were at sea, what they wanted in port was lots of fresh meat, fresh bread, cheese, butter, and good beer. Even if fresh fruit and vegetables were available, the majority of the crew would not have been interested in a quick stir-fry of tender crunchy greens. They wanted meat and more meat—boiled, stewed, or roasted. The officers, who generally came from a higher social class, where a wider and more varied diet was common, would have found eating fruit and vegetables in port to be normal and probably highly acceptable. It would not have been unusual for them to be interested in trying exotic new foodstuffs to be found in the locales where they made landfall. Tamarinds, limes, and other fruits high in vitamin C would have been used in the local cuisine that they, unlike the crew, might try. Scurvy was thus usually less of a problem among a ship’s officers.

Cook: Hundreds—Scurvy: Nil

James Cook of the British Royal Navy was the first ship’s captain to ensure that his crews remained scurvy free. Cook is sometimes associated with the discovery of antiscorbutics, as scurvy-curing foods are called, but his true achievement lay in the fact that he insisted on maintaining high levels of diet and hygiene aboard all his vessels. The result of his meticulous standards was an extraordinarily good level of health and a low mortality rate among his crew. Cook entered the navy at the relatively late age of twenty-seven, but his previous nine years of experience sailing as a midshipman and his intelligence, rapid promotion, and reputation as an officer who cared for his crew’s health likely helped to reduce the incidence of scurvy among his crews.
ence sailing as a merchant seaman mate in the North Sea and the Baltic, his intelligence, and his innate seamanship combined to ensure his rapid promotion within the naval ranks. His first experience with scurvy came aboard the *Pembroke*, in 1758, on his initial voyage across the Atlantic Ocean to Canada to challenge the French hold on the St. Lawrence River. Cook was alarmed by the devastation this common affliction caused and appalled that the deaths of so many crew, the dangerous reduction of working efficiency, and even actual loss of ships were generally accepted as inevitable.

His experience exploring and mapping around Nova Scotia, the Gulf of St. Lawrence, and Newfoundland and his accurate observations of the eclipse of the sun greatly impressed the Royal Society, a body founded in 1645 with the aim of “improving natural knowledge.” He was granted command of the ship *Endeavour* and instructed to explore and chart the southern oceans, to investigate new plants and animals, and to make astronomical observations of the transit of planets across the sun.

Less known but nonetheless compelling reasons for this voyage and for Cook’s subsequent later voyages were political. Taking possession in the name of Britain of already discovered lands; claiming of new lands still to be discovered, including Terra Australis Incognita, the great southern continent; and the hopes of finding a Northwest Passage were all on the minds of the admiralty. That Cook was able to complete so many of these objectives depended to a large degree on ascorbic acid.

Consider the scenario on June 10, 1770, when the *Endeavour* ran aground on coral of the Great Barrier Reef just south of present-day Cooktown, in northern Queensland, Australia. It was a near catastrophe. The ship had struck at high water; a resulting hole in the hull necessitated drastic measures. In order to lighten the ship, the entire crew heaved overboard everything that could be spared. For twenty-three hours straight they manned the pumps as seawater leaked inexorably into the hold, hauling desperately on cables and anchor in an attempt to plug the hole by fothering, a temporary method of mending a hole by drawing a heavy sail under the hull. Incredible effort, superb seamanship, and good
fortune prevailed. The ship eventually slid off the reef and was beached for repairs. It had been a very close call—one that an exhausted, scurvy-inflicted crew could not have summoned the energy to answer.

A healthy, well-functioning crew was essential for Cook to accomplish what he did on his voyages. This fact was recognized by the Royal Society when it awarded him its highest honor, the Copley gold medal, not for his navigational feats but for his demonstration that scurvy was not an inevitable companion on long ocean voyages. Cook’s methods were simple. He insisted on maintaining cleanliness throughout the ship, especially in the tight confines of the seamen’s quarters. All hands were required to wash their clothes regularly, to air and dry their bedding when the weather permitted, to fumigate between decks, and in general to live up to the meaning of the term *shipshape*. When it was not possible to obtain the fresh fruit and vegetables he thought necessary for a balanced diet, he required that his men eat the sauerkraut he had included in the ship’s provisions. Cook touched land at every possible opportunity to replenish stores and gather local grasses (celery grass, scurvy grass) or plants from which he brewed teas.

This diet was not at all popular with the crew, accustomed as they were to the standard seamen’s fare and reluctant to try anything new. But Cook was adamant. He and his officers also adhered to this diet, and it was by his example, authority, and determination that his regimen was followed. There is no record that Cook had anyone flogged for refusing to eat sauerkraut or celery grass, but the crew knew the captain would not hesitate to prescribe the lash for opposing his rules. Cook also made use of a more subtle approach. He records that a “Sour Krout” prepared from local plants was initially made available only to the officers; within a week the lower ranks were clamoring for their share.

Success no doubt helped convince Cook’s crew that their captain’s strange obsession with what they ate was worthwhile. Cook never lost a single man to scurvy. On his first voyage of almost three years, one-third of his crew died after contracting malaria or dysentery in Batavia (now Jakarta). His voyage from 1768 to 1771 but not to scurvy; badly affected severely reproach on the ascorbic acid of accomplish. Great Barrier Reefs charting of the Antarctic Circle.

**A Small M**

What is this sm the world? The *vital* (necessary) it was originally, gen atom). The ever identified.

This system c vitamin H are the
Ascorbic Acid

(now Jakarta) in the Dutch East Indies (now Indonesia). On his second voyage from 1772 to 1775, he lost one member of his crew to illness—but not to scurvy. Yet on that trip the crew of his companion vessel was badly affected by the problem. The commander, Tobias Furneaux, was severely reprimanded and instructed yet again by Cook on the need for preparation and administration of antiscorbutics. Thanks to vitamin C, the ascorbic acid molecule, Cook was able to compile an impressive list of accomplishments: the discovery of the Hawaiian Islands and the Great Barrier Reef, the first circumnavigation of New Zealand, the first charting of the coast of the Pacific Northwest, and first crossing of the Antarctic Circle.

A SMALL MOLECULE IN A BIG ROLE

What is this small compound that had such a big effect on the map of the world? The word vitamin comes from a contraction of two words, vital (necessary) and amine (a nitrogen-containing organic compound—it was originally thought that all vitamins contained at least one nitrogen atom). The C in vitamin C indicates that it was the third vitamin ever identified.

\[
\text{\begin{center}
\text{Structure of ascorbic acid (or vitamin C)}
\end{center}}
\]

This system of naming has numerous flaws. The B vitamins and vitamin H are the only ones that actually do contain nitrogen. The orig-
inal B vitamin was later discovered to consist of more than one compound, hence vitamin B₁, vitamin B₂, etc. Also, several supposedly different vitamins were found to be the same compound, and thus there is no vitamin F or vitamin G.

Among mammals, only primates, guinea pigs, and the Indian fruit bat require vitamin C in their diet. In all other vertebrates—the family dog or cat, for example—ascorbic acid is made in the liver from the simple sugar glucose by a series of four reactions, each catalyzed by an enzyme. Thus for these animals ascorbic acid is not a dietary necessity. Presumably, somewhere along the evolutionary path humans lost the ability to synthesize ascorbic acid from glucose, apparently by losing the genetic material that enabled us to make gulonolactone oxidase, the enzyme necessary for the final step in this sequence.

A similar set of reactions, in a somewhat different order, is the basis for the modern synthetic method (also from glucose) for the industrial preparation of ascorbic acid. The first step is an oxidation reaction, meaning that oxygen is added to a molecule, or hydrogen is removed, or possibly both. In the reverse process, known as reduction, either oxygen is removed from a molecule, or hydrogen is added, or again possibly both.

![Chemical structures](image)

\[ \text{Glucose} \xrightarrow{\text{oxidizing enzyme}} \text{Gluconic acid} \xrightarrow{\text{reducing enzyme}} \text{Gulonic acid} \]

The second step involves reduction at the opposite end of the glucose molecule from that of the first reaction, forming a compound known as gulonic acid. The next part of the sequence, the third step, involves gulonic acid forming a cyclic or ring molecule in the form of a lactone. A final ox ascorbic acid mole humans are missir

\[ \text{Gulonic acid} \]

The initial after vitamin C were u though ascorbic acid o separating it from are also present in fore, that the isola from plants but fr

In 1928, Albert working at Camb gram of crystalline part of a pair of en at only about 0.03 not initially recog isolated a new su part being the (tose) and the \text{ig} part structure. When S nose, was also reje viously did not sh name \text{hexuronic acid} accuate chemical
Ascorbic Acid

lactone. A final oxidation step then produces the double bond of the ascorbic acid molecule. It is the enzyme for this fourth and last step that humans are missing.

The initial attempts to isolate and identify the chemical structure of vitamin C were unsuccessful. One of the major problems is that although ascorbic acid is present in reasonable amounts in citrus juices, separating it from the many other sugars and sugar-like substances that are also present in these juices is very difficult. It's not surprising, therefore, that the isolation of the first pure sample of ascorbic acid was not from plants but from an animal source.

In 1928, Albert Szent-Györgyi, a Hungarian doctor and biochemist working at Cambridge University in England, extracted less than a gram of crystalline material from bovine adrenal cortex, the inner fatty part of a pair of endocrine glands situated near a cow's kidneys. Present at only about 0.03 percent by weight in his source, the compound was not initially recognized as vitamin C. Szent-Györgyi thought he had isolated a new sugar-like hormone and suggested the name ignose, the osae part being the ending used for names of sugars (like glucose and fructose) and the ig part signifying that he was ignorant of the substance's structure. When Szent-Györgyi's second suggestion for a name, Godnose, was also rejected by the editor of the Biochemical Journal (who obviously did not share his sense of humor), he settled for the more sedate name hexuronic acid. Szent-Györgyi's sample had been pure enough for accurate chemical analysis to show six carbon atoms in the formula,
NAPOLeON’S BUTTONS

C₆H₈O₆, hence the hex of hexuronic acid. Four years later it was shown that hexuronic acid and vitamin C were, as Szent-Györgyi had come to suspect, one and the same.

The next step in understanding ascorbic acid was to determine its structure, a task that today’s technology could accomplish relatively easily using very small amounts but was nearly impossible in the absence of large quantities in the 1930s. Once again Szent-Györgyi was in luck. He discovered that Hungarian paprika was particularly rich in vitamin C and, more important, was particularly lacking in other sugars that had made the compound’s isolation in fruit juice such a problem. After only one week’s work he had separated over a kilogram of pure vitamin C crystals, more than sufficient for his collaborator, Norman Haworth, professor of chemistry at the University of Birmingham, to begin the successful determination of the structure of what Szent-Györgyi and Haworth had now termed ascorbic acid. In 1937 the importance of this molecule was recognized by the scientific community. Szent-Györgyi was awarded the Nobel Prize for medicine for his work on vitamin C, and Haworth the Nobel Prize for chemistry.

Despite more than sixty years of further work, we are still not completely sure of all the roles that ascorbic acid plays in the body. It is vital for the production of collagen, the most abundant protein in the animal kingdom, found in connective tissues that bind and support other tissues. Lack of collagen, of course, explains some of the early symptoms of scurvy: the swelling of limbs, softening of gums, and loosening of teeth. As little as ten milligrams a day of ascorbic acid is said to be sufficient to keep the symptoms of scurvy at bay, although at that level subclinical scurvy (vitamin C deficiency at the cellular level but no gross symptoms) probably exists. Research in areas as varied as immunology, oncology, neurology, endocrinology, and nutrition is still discovering the involvement of ascorbic acid in many biochemical pathways.

Controversy as well as mystery has long surrounded this small molecule. The British navy delayed implementing James Lind’s recom-

 mendations by a scandal purportedly withheld it from its sailors weak and quadriplegic. Linus Pauli in chemistry for his work on the Nobel Peace Prize. In 1970 this weapon was valued in high doses of ascorbic acid and cancer. Despite the fact that it has not general...

The RDA (Recommended Dietary Allowance) for an adult is generally given as a small orange. The citric acid and some other vital physiological role of vitamin C is high. The highest RDA is recommended intake is often reduced. A daily dose of 1 gram to a saturation level is desirable. One should also consider the kidney. Megadoses is to prevent scurvy, however, to ensure that it is not a list of chronic conditions like the list of chronic conditions and kidney.

Research continues to ease states; bursitis, ulcers, obesity, os...
Ascorbic Acid

...mendations by a scandalous forty-two years. The East India Company purportedly withheld antiscorbutic foods on purpose in order to keep its sailors weak and controllable. At present there are debates on whether megadoses of vitamin C play a role in treatment of a variety of conditions. Linus Pauling was recognized in 1954 with the Nobel Prize in chemistry for his work on the chemical bond and again in 1962 with the Nobel Peace Prize for his activities opposing the testing of nuclear weapons. In 1970 this double Nobel laureate released the first of a number of publications on the role of vitamin C in medicine, recommending high doses of ascorbic acid for the prevention and cure of colds, flu, and cancer. Despite his eminence as a scientist, the medical establishment has not generally accepted Pauling’s views.

The RDA (Recommended Daily Allowance) of vitamin C for an adult is generally given as sixty milligrams per day, about that found in a small orange. The RDA has varied over time and in different countries, perhaps indicating our lack of understanding of the complete physiological role of this not-so-simple molecule. It is agreed that a higher RDA is necessary during pregnancy and breast-feeding. The highest RDA is recommended for older people, a time when vitamin C intake is often reduced through poor diet or lack of interest in cooking and eating. Scurvy today is not unknown among the elderly.

A daily dose of 150 milligrams of ascorbic acid generally corresponds to a saturation level, and further intake does little to increase the ascorbic acid content of blood plasma. As excess vitamin C is eliminated through the kidneys, it has been claimed that the only good done by megadoses is to provide profits for pharmaceutical companies. It does seem, however, that higher doses may be necessary under circumstances such as infection, fever, wound recovery, diarrhea, and a long list of chronic conditions.

Research continues into the role of vitamin C in more than forty disease states; bursitis, gout, Crohn’s disease, multiple sclerosis, gastric ulcers, obesity, osteoarthritis, Herpes simplex infections, Parkinson’s,
anemia, coronary heart disease, autoimmune diseases, miscarriages, rheumatic fever, cataracts, diabetes, alcoholism, schizophrenia, depression, Alzheimer's, infertility, cold, flu, and cancer, to name just some of them. When you look at this list, you may see why this molecule has sometimes been described as "youth in a bottle," although research results do not as yet support all the miracles that have been claimed.

Over fifty thousand tons of ascorbic acid are manufactured annually. Produced industrially from glucose, synthetic vitamin C is absolutely identical in every way to its natural counterpart. There is no physical or chemical difference between natural and synthetic ascorbic acid, so there is no reason to buy an expensive version marketed as "natural vitamin C, gently extracted from the pure rose hips of the rare Rosa macrophylla, grown on the pristine slopes of the lower Himalayas." Even if the product did originate at this source, if it is vitamin C, it is exactly the same as vitamin C that has been manufactured by the ton from glucose.

This is not to say that manufactured vitamin pills can replace the natural vitamins in foods. Swallowing a seventy-milligram ascorbic acid pill may not produce quite the same benefits as the seventy milligrams of vitamin C obtained from eating an average-sized orange. Other substances found in fruits and vegetables, such as those responsible for their bright colors, may help the absorption of vitamin C or in some way, as yet unknown, enhance its effect.

The main commercial use of vitamin C today is as a food preservative, where it acts as an antioxidant and an antimicrobial agent. In recent years food preservatives have come to be seen as bad. "Preservative free" is shouted from many a food package. Yet without preservatives much of our food supply would taste bad, smell bad, be inedible, or even kill us. The loss of chemical preservatives would be as great a disaster to our food supply as would the cessation of refrigeration and freezing.

It is possible to safely preserve fruit in the canning process at the temperature of boiling water, as fruit is usually acidic enough to prevent the growth of the content vegetables. To kill this con home canning of fruits increases acidity and food poisoning res Clostridium botulinum toxin it produces though only if eaten the skin interrupt n is a temporary era treatment.

Although chemi has created the moium botulinum, is the deadly than dioxin toxin A, the lethal c LD_{50} is 8 x 10^{-8} mg toxin A per kilogram the LD_{50} is 3 x 10^{-2} weight. It has bee could kill 100 millic think our attitudes
The growth of the deadly microbe *Clostridium botulinum*. Lower-acid-content vegetables and meats must be processed at higher temperatures to kill this common microorganism. Ascorbic acid is often used in home canning of fruit as an antioxidant to prevent browning. It also increases acidity and protects against botulism, the name given to the food poisoning resulting from the toxin produced by the microbe. *Clostridium botulinum* does not survive inside the human body. It is the toxin it produces in improperly canned food that is dangerous, although only if eaten. Tiny amounts of the purified toxin injected under the skin interrupt nerve pulses and induce muscle paralysis. The result is a temporary erasing of wrinkles—the increasingly popular Botox treatment.

Although chemists have synthesized many toxic chemicals, nature has created the most deadly. Botulinum toxin A, produced by *Clostridium botulinum*, is the most lethal poison known, one million times more deadly than dioxin, the most lethal man-made poison. For botulinum toxin A, the lethal dose that will kill 50 percent of a test population (the LD$_{50}$) is $5 \times 10^{-8}$ mg per kg. A mere 0.00000003 milligrams of botulinum toxin A per kilogram of body weight of the subject is lethal. For dioxin, the LD$_{50}$ is $3 \times 10^{-2}$ mg per kg, or 0.03 milligrams per kilogram of body weight. It has been estimated that one ounce of botulinum toxin A could kill 100 million people. These numbers should surely make us rethink our attitudes toward the perceived evils of preservatives.

**Scurvy on Ice**

Even in the early twentieth century a few Antarctic explorers still supported theories that putrefaction of preserved food, acid intoxication of the blood, and bacterial infections were the cause of scurvy. Despite the fact that compulsory lemon juice had virtually eliminated scurvy from the British navy in the early 1800s, despite observations that Eskimos in the polar regions who ate the vitamin C-rich fresh meat,
Napoleon’s Buttons

brain, heart, and kidneys of seals never suffered from scurvy, and despite the experience of numerous explorers whose antiscorbutic precautions included as much fresh food as possible in the diet, the British naval commander Robert Falcon Scott persisted in his belief that scurvy was caused by tainted meat. The Norwegian explorer Roald Amundsen, on the other hand, took the threat of scurvy seriously and based the diet for his successful South Pole expedition on fresh seal and dog meat. His 1911 return journey to the pole, some fourteen hundred miles, was accomplished without sickness or accident. Scott’s men were not so fortunate. Their return journey, after reaching the South Pole in January 1912, was slowed by what is now thought to be the Antarctic’s worst weather in years. Symptoms of scurvy, brought on by several months on a diet devoid of fresh food and vitamin C, may have greatly hampered their efforts. Only eleven miles from a food and fuel depot they found themselves too exhausted to continue. For Commander Scott and his companions, just a few milligrams of ascorbic acid might have changed their world.

Had the value of ascorbic acid been recognized earlier, the world today might be a very different place. With a healthy crew Magellan might not have bothered to stop in the Philippines. He could have gone on to corner the Spice Islands clove market for Spain, sail triumphantly upriver to Seville, and enjoy the honors due to the first circumnavigator of the globe. A Spanish monopoly of the clove and nutmeg markets might have thwarted the establishment of the Dutch East India Company—and changed modern-day Indonesia. If the Portuguese, the first European explorers to venture these long distances, had understood the secret of ascorbic acid, they might have explored the Pacific Ocean centuries before James Cook. Portuguese might now be the language spoken in Fiji and Hawaii, which might have joined Brazil as colonies in a far-flung Portuguese Empire. Maybe the great Dutch navigator Abel
Janszoon Tasman, with the knowledge of how to prevent scurvy on his voyages of 1642 and 1644, would have landed on and formally laid claim to the lands known as New Holland (Australia) and Staten Land (New Zealand). The British, coming later to the South Pacific, would have been left with a much smaller empire and far less influence in the world, even to this day. Such speculation leads us to conclude that ascorbic acid deserves a prominent place in the history—and geography—of the world.