Greek wonder springs to life

Researchers have unravelled the marvels of a desktop cosmos from ancient times

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A shipwreck off the coast of Lebanon, discovered in year 1900, yielded a treasure of unparalleled ingenuity, dated to the second century BCE.

It was the Antikythera Mechanism, an artifact,42 m below water, off the Greek island of Antikythera along with others. The German philologist Albert Rehm identified the corroded object as an astronomical calculation machine, but nothing more could be made out. Till, between the 1950s and 1970, science historian Derek de Solla Price used X-ray and gamma ray radiography to identify the article as a complex, gear driven, astronomical calendar!

The modest, "dictionary size" object contains 30 different gears wheels, in bronze, and a mechanism that interconnects them, to display the positions of the Sun and Moon, following the then known cycle -- the Metonic cycle, a pattern of phases of the Moon, which repeats after nearly 19 years. And then the Callippic cycle, which is four Metonic cycles, less a day, to keep the Moon phases in step with the apparent movement of the Sun. With an input of past or future dates, turning a crank could calculate the positions of the Sun, Moon and the five planets then known, at different times. Even lunar and solar eclipses could be predicted, and that was using the Saros cycle, which describes the recurrence of eclipses, over a period of 6,585.3 days.

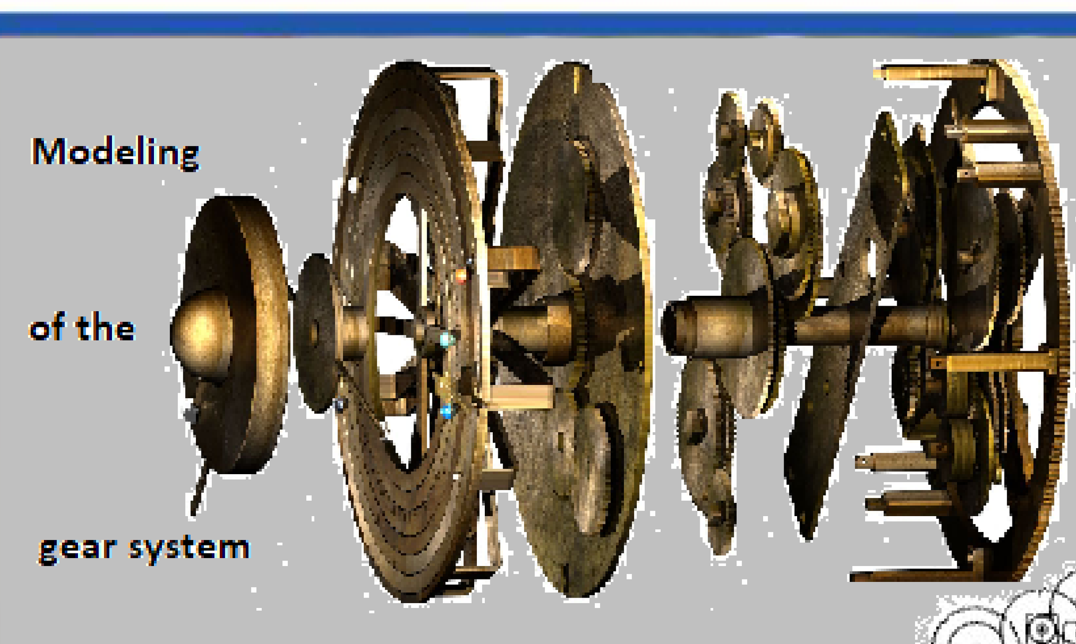
What lay behind the mechanism, however, remained unclear. Till, in 2006, microfocus X Ray tomography – building a 3-D image of the object followed by "slice by slice" analysis of scans, partly revealed the structure of the corroded and rust-covered mechanism. It also uncovered inscriptions, thousands of characters of text, that pointed to the motions of the Sun, Moon and planets, and how they were displayed by the mechanism. The detailing of the things the device could do provoked ideas about how it may work. But the internals or working of the device could not be meaningfully picturised.

Tony Freeth, David Higgon, Aris Dacanalis, Lindsay MacDonald, Myrto Georgakopoulou and Adam Wojcik, from University College London and Doha, and the Cyprus Institute at Nicosia, describe in the journal, *Scientific Reports*, how they grappled with all the data, at the level of astronomy understood in ancient Babylon and available to the Greeks, to finally work out how the ingenious contraption could display the movements of all five planets. "Our challenge was to create a new model to match all the surviving evidence. Features on the Main Drive Wheel indicate that it calculated planetary motions with a complex epicyclic system (gears mounted on other gears), but its design remained a mystery," the paper says.

How they went about it is no less than mathematical detective work, to fill in details of a complex, but unknown scheme of clockwork, based on bits and pieces of information. A useful lead, the paper says, came from the inscriptions in the "back front covers" of the device. The back cover described the front face as a system of rings representing the Sun and the planets, while the front cover listed out the rhythmic patterns of the movements of the planets (and the moon) and the Sun, and the periodic cycles the planets followed.

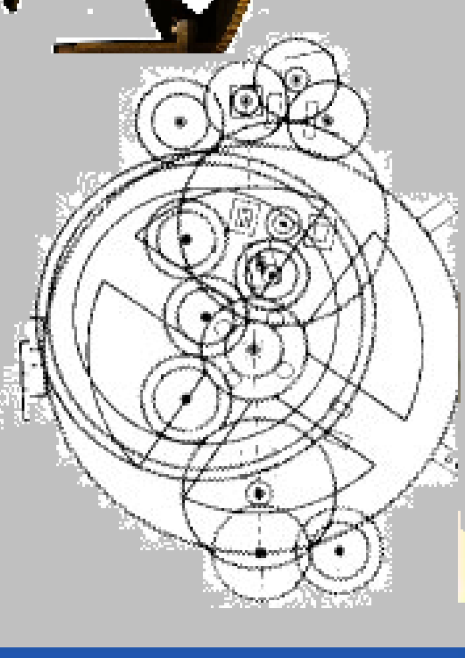
The paper considers that relative periods could be expressed by pairs of gears, which had numbers of teeth in the correct ratio. It surveys the theories and conjectures of the time to explain how periods moved, sometimes forward, sometimes backwards, as seen from Earth. As the Greeks believed the Earth to be the centre of the system, the movements were complex, described in terms of epicycles, or turning circles that moved around a larger circle. What the system of gears could model such motion? Finally, a step was taken forward, the paper says, when "surprisingly complex periods for the planets Venus and Saturn" were observed in the X-Ray imaging. If how those were worked out could be understood, could the team do the same for the other planets?

Tony Freeth mathematician | David Higgon horologist | Aris Dacanalis physicist | Lindsay MacDonald imaging expert | Myrto Georgakopoulou archeometallist | Adam Wojcik materials scientist



Common factors in ratios of cycles helped economise the number of gears wheels used

Planet	Cycles	Factors
MERCURY	1513	17 x 89
VENUS	289	17^2
MARS	133	7 x 19
JUPITER	315	3^2 x 5 x 7
SATURN	427	7 x 61



Where did it go?

If Greece had such ability so early, why did the industrial revolution have to wait so long? It seems that the device found in 1901 was not the only one of its kind. Cicero has spoken of a similar device built by Archimedes in the third century BCE and another one by Posidonius (second and first century BCE).

The technology appears to have been communicated via the Arab world, as suggested by a device dated in the sixth century, and Islamic calendar computers of the 13th century. Much of modern technology has its roots in the mechanical toys of the 18th century and the earlier tradition of clock working. And clock working too, like many things of our world, has Greek origins!

A known feature in the case of Venus was that the planet went through five cycles of movement every eight solar years. While this could be readily represented as a gear ratio, the ratio itself was approximate. The Babylonians had worked out a better ratio, at 720 cycles in 1,151 years, but this ratio was not practical, as 1,151 teeth were too many for a gear to have. "Then came a notable discovery in 2016," the paper says, of the numbers, 462 and 442, in respect of Venus and Saturn. In place of 720/1,151, the number 462 yields a ratio, 289/462, which is very nearly the same as 720/1,151. And there is a similar ratio, 427/442, for Saturn. And, significantly, those numbers, unlike 1,151, which is a prime, have whole number factors. The number 289 is nothing but 17x17, while 462 is 2x3x7x11. And in the case of Saturn, 427 = 7x61 and 442 = 2x13x17.

As for how the numbers, 462 and 442 had been arrived at, the paper finds that it was by a method called the Parmenedes Proposition. It is a mathematical device to improve an approximate ratio. To find the ratio – 22/7, for the value of pi, for instance, we could start from the knowledge that the ratio is more than 20/7 but is less than 23/6. Then, we add the numerators and denominators like this, (20+23)/ (7+6) which is 43/13, or 3.3. As we know that this is still too high, we can repeat the process, as (2x20+43)/2x7+13), which is 83/27, or 3.07, which is closer to 22/7.

The paper shows how this method could yield the numbers for Venus and Saturn, and an adaptation to provide possible ratios for the remaining planets. While the ratios are accurate and practical, they are chosen to have a feature of economy – ratios for Mercury, Mars and Jupiter are seen to include factors, like 7 and 17– allowing a 51-tooth gear to work for both Venus and Mercury, and a 56-tooth gear for the remaining planets and the Sun.

The line of thinking shows the way to an optimum gear design, which corresponds to the holes and posts, for spindles or gears, and what could be a reconstruction of the ancient marvel! The complexity suggests that Greek technology was far more advanced than previously thought. The precision has been compared to that of 18th century watchmakers. The design is astonishing. No other civilisation is known to have created anything as complicated for another thousand years.

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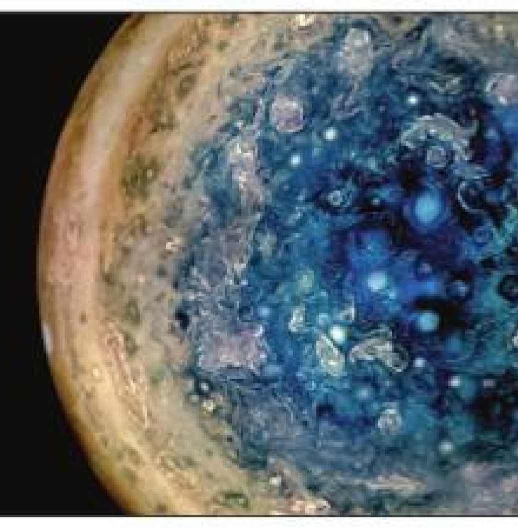
PLUS POINTS

Aurora storms



Scientists have been able to analyse the origins of Jupiter's incredible aurora dawn storms for the first time.

Originally discovered in 1994, the beautiful blue ring above the gas giant's north and south poles are formed on the nightside of the planet. As it rotates, and dawn breaks on the planet, the auroral features become more luminous.

It is estimated that between hundreds and thousands of gigawatts of ultraviolet light are beamed into space from the planet, 10 times greater than that of a typical aurora.

Despite the huge amounts of energy that were given out, the aurora has been hidden from scientists' view. This is because, prior to Nasa's Juno mission that was launched in 2016, the view had only been visible from the dayside – hiding everything that happened on the nightside of the planet.

"Observing Jupiter's aurora from Earth does not allow you to see beyond the limb, into the nightside of Jupiter's poles. Explorations by other spacecraft -- Voyager, Galileo, Cassini – happened from relatively large distances and did not fly over the poles, so they could not see the complete picture," Bertrand Bonfond, a researcher from the University of Liège in Belgium, explained.

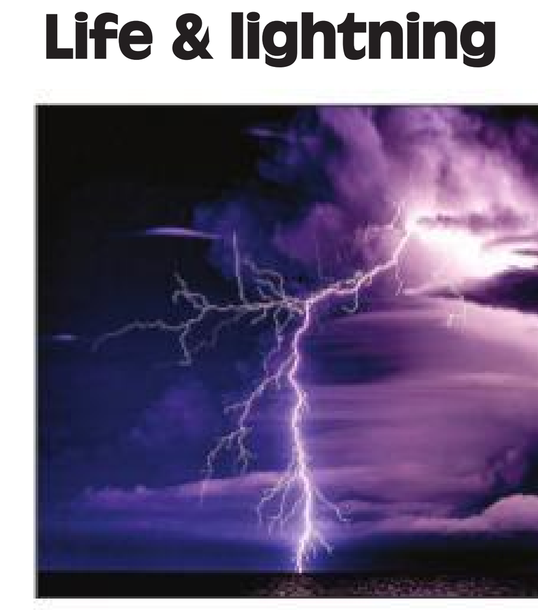
"That's why the Juno data is a real game changer, allowing us a better understanding of what is happening on the nightside, where the dawn storms are born."

The storms on Jupiter are very similar to a kind of aurora found on Earth, known as substorms. These are caused by short disturbances in the Earth's magnetosphere, which is controlled by our planet's magnetic field, where energy is released high into the planet's ionosphere.

Yet this similarity is peculiar, because the magnetospheres of Jupiter and Earth contrast vastly. On Earth, the magnetosphere is subject to the whims of the solar winds – charged particles that bombard the Earth from the Sun; on Jupiter, by contrast, it is particles from its volcanic moon Io that get ionised and trapped around the gas giant via magnetism that make up its magnetosphere.

–THE INDEPENDENT

Life & lightning



Lightning strikes may have supplied primordial Earth with enough phosphorus to support the emergence of life, according to new research published last week that offered an alternative explanation as to how living organisms were born.

Phosphorus is a vital building block of life as we know it, forming basic cell structures and the double helix shape of DNA and RNA. Billions of years ago on early Earth, most of the available phosphorus was locked away in insoluble minerals. However, one mineral, schreibersite, is highly reactive and produces phosphorus capable of forming organic molecules. Since most schreibersite on Earth comes from meteorites, the emergence of life here has long been thought to be tied to the arrival of extra-terrestrial rocks. But schreibersite is also contained within the glass-like rock formed by lightning strikes in some types of clay-rich soils.

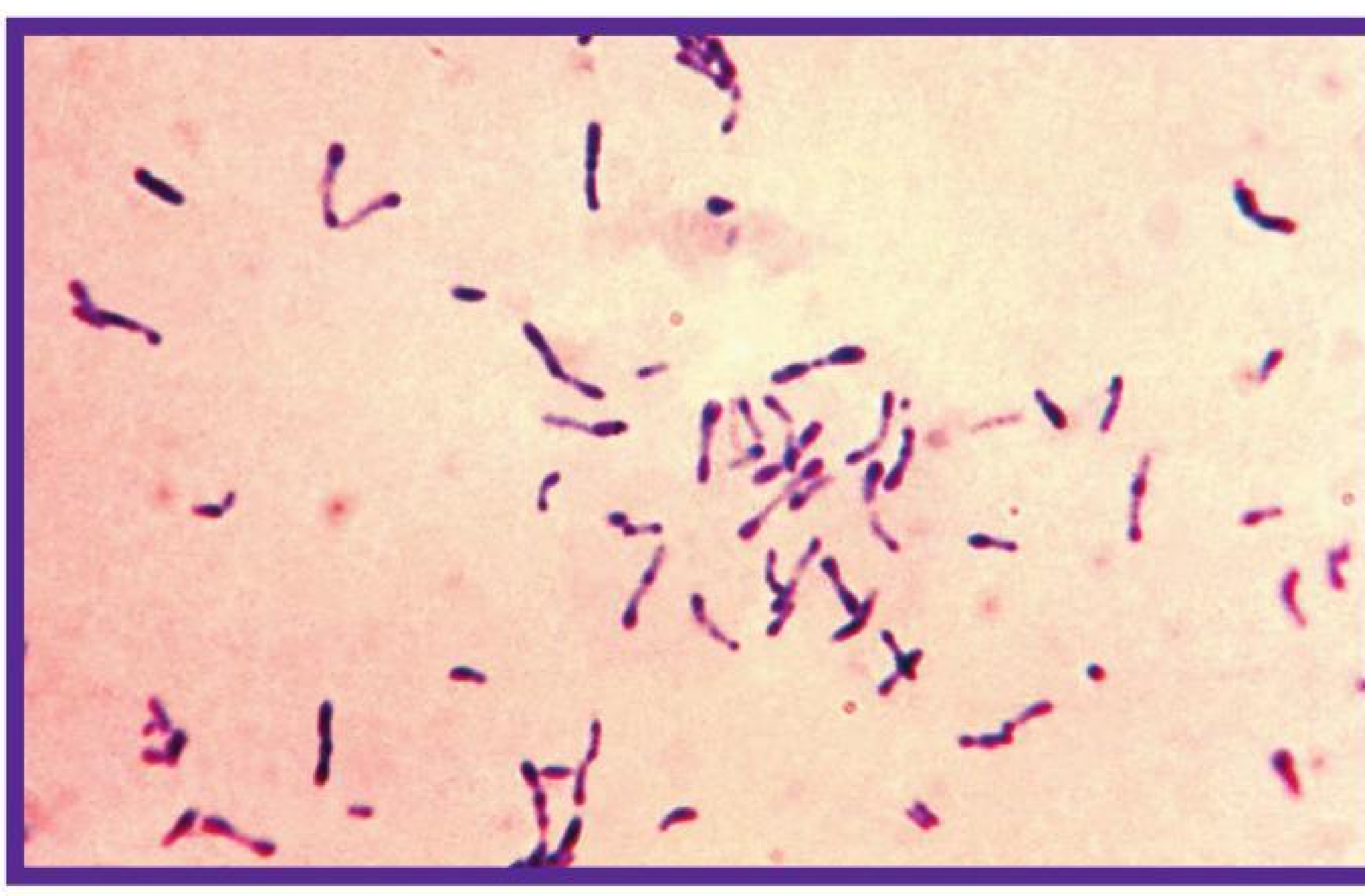
Researchers in the US and UK used state of the art image techniques to analyse the amount of the phosphorus-giving mineral formed in each lightning strike. Writing in the journal *Nature Communications*, lead study author Benjamin Hess from Yale's department of earth and planetary sciences and his colleagues estimated that lightning strikes could have produced between 110 and 11,000 kilogrammes of phosphorus a year. Using simulations of the climate on early Earth, they said that while meteor strikes began to decline after the Moon was formed 4.5 billion years ago, lightning strikes surpassed space rocks for phosphorus production around 3.5 billion years ago. That timing coincides with the origin of life.

Hess said that the research didn't entirely discount meteorites as another source of life-giving phosphorus.

–THE STRAITS TIMES/ANN

LOWDOWN ON DIPHTHERIA

Here's how the extremely infectious disease spreads



TAPAN KUMAR MAITRA

Extensive clinical, pathoanatomical, epidemiological and experimental investigations preceded the discovery of the agent responsible for diphtheria. They paved the way for the discovery of the organism (Edwin Klebs, 1883), its isolation in pure culture (Friedrich Loeffler, 1884), separation of the toxin (Émile Roux and Alexandre Yersin, 1888), antitoxin (Emil von Behring and Shibasaburo Kitasato, 1890) and diphtheria toxoid (Gaston Ramon, 1923).

Corynebacterium diphtheriae is a straight or slightly curved rod, one to eight mcm in length and 0.3-0.8 mcm in breadth. The organism is pleomorphous and stains more intensely at its ends, which contain volutin granules. *C. diphtheriae* frequently display terminal clubshaped swellings. Branched forms as well as short, almost coccal, forms sometimes occur. In smears the organisms are arranged at an angle and resemble spreadout lingers.

The causative agent of diphtheria is an aerobe or a facultative aerobe. The optimal temperature for growth is 37 °C and the organism does not grow at temperatures below 15 and above 40 °C. The pH of medium is 7.2-7.6. The organism grows readily on media which contain protein (coagulated serum, blood agar, and serum agar) and on sugar broth. On Roux's (coagulated horse serum) and Loeffler's (three parts of ox serum and one part of sugar broth) media the organisms produced growth in 16-18 hours. The growth resembles shagreen leather, and the colonies do not merge together.

In broth cultures *C. diphtheriae* produce potent exotoxins (histotoxin, dermonecrotoxin and haemolysin). The toxigenicity of the organisms is linked with lysogeny (the presence of moderate phagesprophages in the toxigenic strains). The classical international standard strain, Park-Williams eight exotoxin-producing strain, is also lysogenic and has retained the property of toxin production for over 85 years. The genetic determinants of toxigenicity are in the genome of the prophage, which is integrated with the *C. diphtheriae* nucleoid. The diphtheria exotoxin is a complex of more than 20 antigens. It has been obtained in a crystalline form.

The toxigenic strains of *C. diphtheriae* are characterised by marked dehydrogenase activity, while the non-toxigenic strains do not possess such activity. The diphtheria toxin is unstable, and is destroyed easily by exposure to heat, light and oxygen of the air, but is relatively resistant to supersonic vibrations. The toxin is transformed into the toxoid by mixture with 0.3-0.4 per cent formalin and maintenance at 38-40 °C for a period of three or four weeks. The toxoid is more resistant to physical and chemical factors than the toxin.

The genus Corynebacterium comprises a species pathogenic for human beings and several species, which are non-pathogenic for man and conditionally designated as diphtheroids. The majority of diphtheroids occurs in the external environment (water, soil and air) while some are present as commensals in the human body.

C. diphtheriae are relatively resistant to harmful environmental factor. They survive for one year on coagulated serum, for two months at room temperature, and for several days on children's toys. Corynebacteria remain viable in the membranes of diphtheria patients for long periods, particularly when the membranes are not exposed to light. The organisms are killed by a temperature of 60 °C and by a one per cent phenol solution in 10 minutes.

Animals do not naturally acquire diphtheria. Although virulent diphtheria organisms were found to be present in horses, cows and dogs, the epidemiological significance of animals in diphtheria is negligible.

Patients suffering from the disease and carriers are the sources of infection in diphtheria. The disease is transmitted by an airdroplet route, and sometimes with dust particles. Transmission by various objects (toys, dishes, books, towels, handker-chiefs, etc) and foodstuffs (milk, cold dishes, etc) contaminated with *C. diphtheriae* are also possible. It is most prevalent in autumn. That is because children crowd more in the autumn months and body resistance is reduced by a drop in temperature.

C. diphtheriae penetrates into the blood and tissues of sick humans and infected animals. The diffusion factor due to which these organisms are capable of invasion is formed of a complex of K-antigen and lipids of the wall of bacterial cells. Clinical studies and experiments on animals have provided evidence of the influence of pathogenic staphylococci and streptococci on the development of diphtheria, the infection becoming more severe in the presence of the organisms. Hypersensitivity to *C. diphtheriae* and to the products of their metabolism is of definite significance in the pathogenesis of diphtheria.

In humans, membranes containing a large number of *C. diphtheriae* and other bacteria are formed at the site of entry of the causative agent (pharynx, nose, trachea, eye conjunctiva, skin, vulva, vagina and wounds). The toxin produces diphtherial inflammation and necrosis in the mucous membranes or skin. On being absorbed, the toxin affects the nerve cells, cardiac muscle, and parenchymatous organs and causes severe toxaemia. Deep changes take place in the cardiac muscle, vessels, adrenals, and in the central and peripheral nervous systems.

According to the site of the lesion, faucial diphtheria and diphtheritic croup occur most frequently, and nasal diphtheria somewhat less frequently. The incidence of diphtheria of the eyes, ears, genital organs, and skin is relatively rare. Facial diphtheria constitutes more than 90 per cent of all the diphtherial cases, and nasal diphtheria takes the second place.

Immunity following diphtheria depends mainly on the antitoxin content in the blood. However, a definite role of the antibacterial component, associated with phagocytosis and the presence of opsonins, agglutinins, precipitins, and complement-fixing substances cannot be ruled out. Therefore, immunity produced by diphtheria is anti-infectious (anti-toxic and antibacterial) in character.

According to the physician's prescriptions, patients are given antitoxin in doses ranging from 5,000 to 15,000 units in mildly severe cases, and from 30,000 to 50,000 units in severe cases of the disease. Penicillin, streptomycin, tetracycline, erythromycin, sulphonamides and cardiac drugs are also employed. Diphtheria toxoid is recommended in definite doses for improving the immunobiological state of the body, or for stimulating antitoxin production. Carriers are treated with antibiotics. Tetracycline, erythromycin, and oxytetracycline in combination with vitamin C are very effective.

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