Our Astronomical Column.

CONJUNCTION OF MARS WITH SPICA.—Interesting, though not extremely close, approaches of Mars to the bright star Spica Virginis will occur on May 22, when Mars will be situated $2\frac{1}{2}$ degrees north of the star. On that night the planet will pass the meridian at 9.21 G.M.T. at an altitude of about 30 degrees. On succeeding nights Mars will be observed to the N.N.W. of the star, but on June 2 will become stationary, and thereafter move slowly eastwards. On June 12 he will again be in conjunction with Spica Virginis, and about $1^{\circ}37'$ N. of the star. Mars will cross the S. meridian 10 minutes before sunset on the latter night, and a good view will not be obtainable of the planet and star until 9 p.m. G.M.T. and afterwards. Mars will be much the brighter of the pair, and visible at an earlier time than the star. The two conjunctions will form attractive and striking configurations.

THE DUPLICITY OF γ GEMINORUM.—There is an article on this star by Dr. Bernewitz in *Astr. Nach.*, 5041. The orbit as a spectroscopic binary was investigated in the Publications of Ottawa Observatory (vol. iv., No. 19). The period is 9.6 years, and the value of $a \sin i$ is 1,400,000,000 km. This large value suggested that it might not be impossible to detect the duplicity visually. It has been examined with the 65-cm. refractor at Berlin-Babelsberg Observatory by Dr. Bernewitz, Dr. Bottlinger, Prof. Guthnick, and Mr. F. Pavel. All agree that the image is distinctly elongated. Neighbouring stars of similar magnitude appeared perfectly round, so that it is concluded that the effect is not instrumental. On examining

Geminorum through increasing thicknesses of a dark wedge it was found that before it disappeared it became round; they conclude from this that the companion is about 1 magnitude fainter than the primary. This difference removes uncertainty as to the quadrant. Dr. Bernewitz and Mr. Pavel each measured the pair on five nights, and their respective results are:

Date	P.A.	Distance.
1920-208	116.2	0.14
1920-205	124.3	0.16

They state that the spectroscopic results indicate that the star is now near elongation. If measures can be obtained over a sufficient arc of the orbit, it will be possible to deduce the parallax and mass. The spectral type is B5, so that a mass-determination would be of particular interest.

KODAIKANAL OBSERVATIONS OF PROMINENCES.—Vol. i., part 2, of the Memoirs of Kodaikanal Observatory has lately been distributed. It contains a full description, with numerous photographs, of the prominence observations made by Mr. and Mrs. Evershed, and a discussion of their distribution and motion. Their preponderance at the sun's eastern limb, which many observers have noticed, is difficult to explain except as an earth effect. It will be remembered that Mr. Evershed has recently noticed another sign of an earth effect in the distribution of line-of-sight velocities in the photosphere.

It is pointed out that besides the principal prominence zones, which coincide with those of sunspots, there are also high-latitude zones. The prominences in these are less active than the equatorial ones; they frequently appear as pyramids, or rows of round patches. Their wave of activity begins in latitude 50° , soon after sunspot maximum; it travels poleward, reaching the pole about the next maximum and dying out there. It is suggested that the change in the corona round the poles, which takes place in the

sunspot cycle, may be connected with this prominence fluctuation.

The rotation of the prominences has been studied at Kodaikanal; it is found to be more rapid than that of the photosphere. Line-of-sight velocities and disc observations of long-lived prominences agree in supporting this. It is concluded that the prominences are so tenuous that the free path of the atoms is infinite. Their luminosity "is due to the internal energy of the atoms, perhaps derived mainly from absorption of the intense solar radiation."

Leonardo da Vinci.¹

By EDWARD McCURDY.

WITH the list of war inventions may be numbered Leonardo's researches in aviation. He pursued this subject for many years. His studies range from the consideration of the primary causes of flight in birds and other winged creatures to the invention of a screw propeller and the consideration of its applicability to aerial navigation. He also made an actual attempt. Jerome Cardan, the physician who made a horoscope for Edward VI., in his work "De Subtilitate" refers to an unsuccessful attempt at flight made by Leonardo da Vinci, and adds somewhat dryly, "He was a great painter." A sentence on the cover of Leonardo's manuscript, "Sul Volo degli Uccelli," written in 1505, has been interpreted as referring to this attempt. "The great bird," it runs, "will take its first flight upon the back of the great swan, filling the whole world with amazement, and filling all records with its fame; and it will bring eternal glory to the nest where it was born."

This enigmatic utterance may be somewhat more comprehensible if it is remembered that *cecero* is the Italian word for swan, and "the back of the great swan" may therefore be interpreted as a reference to Monte Ceceri, a hill to the south-west of Fiesole, from which it is believed the flight took place.

From the meagre records of the attempt we pass to researches in theory and construction.

The material falls naturally into two groups, the first being a series of investigations of the laws which govern the power of flight as manifested in Nature by birds and other winged creatures, the second consisting of deductions from these principles in the construction of a mechanism which should be capable of sustaining and being worked by man. The interdependence of the two parts of the inquiry is stated with great succinctness in a passage in the *Codice Atlantico*:

"A bird is an instrument working according to mathematical law, which instrument it is within the capacity of man to reproduce with all its movements, but not with a corresponding degree of strength, though it is deficient only in the power of maintaining equilibrium. We may therefore say that such an instrument constructed by man is lacking in nothing except the life of the bird, and this life must needs be supplied from that of man.

"The life which resides in the bird's members will, without doubt, better conform to their needs than will that of man, which is separated from them, and especially in the almost imperceptible movements which preserve equilibrium.

"But since we see that the bird is equipped for many obvious varieties of movements, we are able from this experience to deduce that the most rudimentary of these movements will be capable of being comprehended by man's understanding; and that he will to a great extent be able to provide against the

¹ From a discourse delivered at the Royal Institution on Friday, March 19. Continued from p. 309.

destruction of that instrument of which he has himself become the living principle and the propeller."

In the analogy thus drawn from Nature to the problem before him, Leonardo has anticipated the attitude of modern research.

In his construction of the instrument he finally attempted to combine the type of the lark soaring with its wings open with that of the bat as it descends. He does this by the introduction of *sportelli* (trap-doors or shutters) in the surface of the wings, whereby, as he says, "the wing is full of holes as it rises and closes up when it falls." The shutters should have rims of cane and be covered with starched taffeta to render them airtight. Perhaps it was after the Monte Ceceri attempt that he wrote on a page of MS. B of the Paris manuscripts, "Try the actual instrument in the water, so that if you fall you will not do yourself any harm." It may also have been the failure of this attempt that caused him to search for a fresh source of motive power to take the place of that exerted by the muscles of a man. On 83 verso, MS. B of the Paris manuscripts, there is a drawing of a large screw constructed to revolve round a vertical axis, and a note explains its intended use: "If this instrument made with a screw is well made—that is to say, made of linen of which the pores are stopped up with starch—and is turned swiftly, the said screw will make its spiral in the air, and it will rise high."

Leonardo adds that a small model may be made of cardboard, with the axis formed of fine steel wire bent by force, and that this when released will turn the screw. To his drawing of this instrument the architect Luca Beltrami has—to me, as it seems, justly—applied the word "aeroplane."

Another page in the Codice Atlantico (311 v. d.) of unique interest contains three studies of artificial wings, a name, and a note that the machine is to be made, not with *sportelli*—that is, shutters—but united. The natural interpretation is that the note refers to a commission for the construction of a machine for flight, with regard to which the patron, Gian Antonio de Mariolo, has expressed a desire that the wings should be such that no wind would be able to pass through them as it would if they had shutters, i.e. should be like the wings of the bat.

Leonardo's researches in natural and applied science cover so wide a field, and specialisation in these days has so divided knowledge into watertight compartments, that properly to gauge the value of his contributions to scientific research would require a combination of many trained intelligences. But it is not possible to devote a number of years to the close study of all that concerns Leonardo without becoming imbued with the conviction of the complete oneness of his work and method. The dominant purpose which animates him, whatever the nature of the problem, is to investigate, to examine, and to define primary causes. His pen reinforces his practice. "Nature," he says, "is constrained by the order of her own law, which lives and works within her." Again, "There is no result in Nature without a cause; understand the cause, and you will have no need of the experiment"; and "Nature is full of infinite causes which were never set forth in experience."

With Leonardo the latter end of this search forgot the beginning. His intellectual curiosity into the origins and causes of all created things is revealed in infinite variety in the thousands of pages of his manuscripts, compact, as has been said, "of observation, of prophecy, of achievement," and in his triple legacy forming a record probably unequalled, certainly unsurpassed, by that of any other man in the history of the world. For consider what he was Painter,

sculptor, engineer, architect—all these to the wonder of his contemporaries. His manuscripts reveal that he was no less distinguished as physicist, biologist, and philosopher. But in the field of science he was essentially a forerunner. The results that he achieved must be reckoned as small compared with his grasp of basic principles, with the vistas that he opened up, and with the unerring instinct which he displayed in choosing the true method of investigation.

All Leonardo's writings connected with science seem, as it were, fragments of a larger purpose, charted, defined, explored, but never fulfilled, of which his researches in anatomy, zoology, physiology, embryology, and biology are the allied and component parts. Discerning the essential unity of man and the animals—"because," as he says, "all land animals have similar members—that is to say, muscles, nerves, and bones—and these members do not vary at all except in length and thickness" (MS. G, 5 verso)—he may be said to have founded comparative anatomy. Drawings now at Windsor show the gradations of the human type merging into that of various animals. Leonardo tracks the mystery of life from the conception and the foetus through growth to maturity, and so to the gradual wasting of the tendons and all the physical phenomena of death.

"I have dissected," he says, "more than ten human bodies, destroying all the various members, and removing even the very smallest particles of the flesh which surrounded these veins without causing any effusion of blood other than the imperceptible bleeding of the capillary veins. And, as one single body did not suffice for so long a time, it was necessary to proceed by stages with so many bodies as would render my knowledge complete; and this I repeated twice over in order to discover the differences."

The drawings made in the course of these investigations, now in the Royal Collection at Windsor, were examined in the time of George III. by the famous surgeon William Hunter, who, approaching them with natural professional distrust, thus made the *amende honorable* :—

"I expected," he says, "to see little more than such designs in anatomy as might be useful to a painter in his own profession. But I saw, and indeed with astonishment, that Leonardo had been a general and deep student. When I consider what pains he has taken upon every part of the body, the superiority of his universal genius, his particular excellence in mechanics and hydraulics, and the attention with which such a man would examine and see objects which he has to draw, I am fully persuaded that Leonardo was the best anatomist at that time in the world." Although he does not fully explain its mechanism, he evidently knew of the circulation of the blood a hundred years before Harvey gave the knowledge to the world. "The heart," he wrote, "is a muscle of great strength; the blood which returns when the heart opens again is not the same as that which closes the valve."

The depth and variety of his researches in other branches of natural science may be inferred from the citation of a few instances in which he anticipated the results of investigations associated with other names. Either before, or at latest during such time as Copernicus was laying the foundations of his heliocentric theory by study at Bologna and Padua—a theory afterwards brought to completion and published in his work, "*De Revolutionibus Orbium Cœlestium*," in 1543—Leonardo had enunciated the ruling principle of it in a line in the manuscripts now at Windsor, "Il sole non si muove" ("The sun does not move").

A hundred years before Maestlin, who is credited with the discovery, he had defined the obscure light of

the unilluminated part of the moon as due to reflection from the earth's surface.

In the search for hidden laws and causes the scientific problem followed hard upon the artistic problem. The study of perspective led to that of light and shade, and so of optics—the study of the structure and functions of the eye, as being the instrument by which light and shade are perceived. He made a model of its parts, and showed how an image is formed on the retina, thus refuting the currently accepted belief of the eye throwing out rays which touch the object it desires to examine. He described also the principle of the *camera obscura* ninety years before Porta developed the idea in practice.

In mechanics he enunciated the theory of inertia, afterwards demonstrated by Galileo, and relegated the theory of perpetual motion then current to the same category as astrology and necromancy. He refound the wisdom of Archimedes, and demonstrated his theory of oblique forces applied to the arm of the lever, afterwards associated with the name of Galileo. Following on Archimedes's conception of the pressure of fluids, he showed—a century and a half before Pascal—that liquids stand at the same level in communicating vessels, while if the two arms are filled by different liquids the heights will vary inversely as their densities.

Leonardo is at once artist and man of science in his treatment of, and interest in, water. He studies its properties and power of movement under conditions varying from the action of the tides of the ocean to the laws which regulate the movement of water in siphons—a subject on which he notes his intention of writing a treatise. He follows its transformation into vapour, rain, dew, snow, and ice. It winds mysteriously in wonder-working coils through the landscape backgrounds of his pictures. He traces the infinite shapes it assumes, falling in violence of movement in spirals and eddies, circling like the loop of a swallow's flight, something of the artist's sheer delight in the creation of beauty of form mingling with the purpose of the man of science to wrest from this variety its underlying principle. Or again, as engineer he harnesses its power, studying to divert its channels either in menace of war or for purposes of commerce or irrigation.

In considering a geological problem his method is entirely deductive. "Since," as he says, "things are far more ancient than letters," he turns from authority to the testimony of things themselves. "Why," he asks, "do we find the bones of great fishes and oysters and corals and various other shells and sea-shells on the high summits of mountains by the sea just as we find them in low seas?" The fact that the cockles were living at the time when they became embedded in the strata—this being evident from the shells being found in a row in pairs, while in other places the dead are found separated from their shells and all cast up together by the waves—is cited as proof that water formerly covered parts of the earth which are now far above the level of the sea, and that this condition continued for a period of more than the forty days of the Deluge, because, as the cockle travels along a furrow at the rate of three or four braccia daily, it could not in forty days have proceeded from the Adriatic to Monferrato in Lombardy, a distance of 250 miles. By an investigation of the cuttings formed by the Arno in the successive strata of which the shells are found, he shows the gradual changes in the crust of the earth, and, following on the track of this knowledge, he essays the construction of the map of Italy in days remote beyond record, but of which the earth remains a living witness.

His special interest in botanical study may be traced

back to the earliest period of his artistic work. Vasari tells of a cartoon, intended for tapestry, of the sin of Adam and Eve in Paradise, where was a meadow with innumerable plants and animals, "of which in truth one could say that for diligence and truth to Nature divine wit could not make the like." He mentions a fig-tree as of special excellence for the foreshortening of the leaves and the disposition of the branches, and also a palm in which the roundness of the fan-like leaves was shown with marvellous art. His description suggests minute attention to detail on the part of the artist based upon a profound study of Nature, and these are the characteristics which find expression in Leonardo's many exquisite studies of plants and flowers, and in the treatment of the herbage in the Virgin of the Rocks in the Louvre. His study of botany was in inception an integral part of his treatise on painting, botany being as necessary as anatomy, in order that the painter might have the requisite knowledge of form and structure. But here also the artist's power of observation of the varied beauty of earth's raiment of plants and flowers is merged imperceptibly in the mood of the man of science who saw in Nature not only form and colour, but, above all, light, which St. Augustine called "the queen of colours," and uses Nature's profusion as a background whereon to study the incidence of light and shade.

Leonardo's researches in structure are so exact and so scientific in method as to anticipate the results of subsequent inquiry, as, for instance, in the knowledge his writings reveal of phyllotaxis—the law of quincuncial arrangement of the leaves on the stem—promulgated in 1658 by Sir Thomas Browne in his "Garden of Cyrus." In like manner the discovery that the age of a tree may be told from the number of concentric rings visible in a section of its trunk, with which more than a century later the names of Nathaniel Grew and Marcello Malpighi are associated, is contained in a passage in Leonardo's "Treatise on Painting" (Ludvig, 829). Leonardo also states in the same passage that these rings vary in thickness according to the greater or less amount of humidity of each year.

I have attempted here to summarise a few of the results attained in the course of this investigation. The breadth and variety of their scope may serve to recall the remark of Francis I., who is recorded by Benvenuto Cellini to have said that "he did not believe that any other man had come into the world who had attained so great knowledge as Leonardo."

Aeronautical Research.

THE announcement by the Air Ministry of the future arrangements for aeronautical research and education marks an important stage in the history of the subject. The course followed was indicated in a White Paper, noticed in NATURE of March 4, p. 14, containing the report of a Committee on Education and Research in Aeronautics. The chairman of that Committee, Sir Richard Glazebrook, is now head of the new Aeronautical Research Committee and Zaharoff professor at London University. He was for twelve years chairman of the late Advisory Committee for Aeronautics under the presidency of the late Lord Rayleigh, and it may fairly be claimed that the new advance in the direction of the co-ordination of research in a large subject is a consequence of the success of the work of the earlier body. The Advisory Committee for Aeronautics had the assistance of such eminent men of science as Sir Horace Darwin, Sir Joseph Petavel, Sir Dugald Clerk,