

of the Persian horizontal windmill must remain for the present undetermined, but they seem likely to have had just as much to do with the Mongol-Tibetan wind-driven prayer-mechanisms as with the horizontal water-wheel or the toys of ancient Alexandria.

(m) THE PREHISTORY OF AERONAUTICAL ENGINEERING

In the foregoing section we have been concerned with wheels or rotors which, according to our terminology, might be called 'ex-aerial', that is to say, wheels or windmill sails so designed as to utilise the force of the winds for doing work. In earlier sections we also saw that 'ad-aerial' wheels or fans were known to ancient and medieval China, whether for use in winnowing, or for cooling palace halls in summer weather.^a Although these employments did not involve the motion of any vehicle, which is one of the greatest uses of ad-aerial rotors today, we shall shortly see, not only that some precursors of the aeroplane propeller existed in China, but that one of them played a cardinal part in the development of modern aerodynamic thinking. More, the rise of this new science in the 19th century depended fundamentally upon the study of an apparatus which had not been known in Europe before the 16th, and which was partly Chinese in origin, namely the kite. The kite's stretched fabric is of course not a shaped aerofoil like the aeroplane wing,^b but the most essential difference between them is the fact that the lift of the kite is provided by the fortuitous air-stream of the wind, while that of the aeroplane's wing is made mechanically by its propellers. Pilots of today who call aeroplanes 'kites' perhaps hardly realise how fitting historically is this slang term.^c

'Lieh Tzu could ride upon the wind. Cool and skilfully sailing, he would go on for fifteen days before returning. . . .'^d These words (from the Section on Taoism) we shall not have forgotten. They give us, indeed, just the proper starting-point for the present

in Mengerhausen & Mengerhausen (1); Forbes (19); Baroja (2). But the mills in the interior provinces, against which Don Quixote fought, resemble French tower-mills closely. In 1960 I had the opportunity of close examination of a number of the small Portuguese windmills, especially at São Braz de Alportel and Santiago de Cacem. I was struck by the fact that the sails used are true lateens, with a small luff edge; their bellying towards the leach gives the necessary helicoidal structure. The eight arms, connected at their periphery with rope or wire, are set staggered into the windshaft at four points.

^a Pp. 118, 134, 151 above.

^b At least not normally. Yet some Chinese kites were astonishingly made with cambered surfaces (see Fig. 705). Examples are figured by Chanute (1); Tissandier (5) and Gibbs-Smith (4), p. 36, but with no indication of date. It would be very interesting to know how far back in Chinese history this technique originated. Cf. Wei Yuan-Tai (1).

^c In the years before the First World War, some of the pioneers of flying, especially S. F. Cody, habitually used the term 'power-kite' for their experimental aeroplanes. In 1907 he fitted a 12-h.p. engine to one of his modified man-lifting kites (cf. p. 590 below), and flew it without a pilot. The Farman aeroplanes of 1910 were often called 'box-kite' aircraft, although by that time the cellular type of construction was being rapidly abandoned. It had been very prominent, however, in the Voisin-Farman biplanes of 1908, and the Voisin-Archdeacon float glider of 1905; in both these the main wings were divided into kite-like cells by vertical partitions, and there was a similar tail-unit aft. Cf. Gibbs-Smith (1), pp. 57, 73, and pls. VIII (e) and IX (d).

^d *Chuang Tzu*, ch. 1; cf. Vol. 2, p. 66 above.



Fig. 701. The myth and magic of flight, one of the innumerable Buddhist *apsaras* (angels) depicted in the fresco paintings of the Chhien-fo-tung cave-temples at Tunhuang. A representation of the Thang period (c. +8th century) from cave no. 44, copied by Shih Wei-Hsiang. Weightless, she strikes the *phi-pha* lute (cf. Vol. 4, pt. 1, p. 130) to celebrate the Buddha's enlightenment. When thus he attained to the definition of the Four Holy Truths and the Noble Eightfold Way,

'So glad the world was—though it wist not why—
That over desolate wastes went swooning songs
Of mirth, the voice of bodiless Prets and Bhuts
Foreseeing Buddh; and Devas in the air
Cried, 'It is finished, finished!' . . . (*Light of Asia*, p. 110).

review.^a For though the Taoists elevated the conception of 'making excursion on the winds' and 'riding on the immensity of the universe' to philosophical heights, the idea itself had grown out of that primitive Asian shamanism which was one of the roots of their school. As has been abundantly shown, both for the most characteristic forms in Central and Northern Asia,^b and for less typical varieties further afield,^c the shamanic rites of possession and ecstasy almost invariably involve an imagined journey through the skies or the heavens, an ascension, a magic flight.^d Hence the frequency of this theme among the poets of the Warring States and the Han.^e The obsession of flight is constantly found in Chinese Taoism; the *hsien*,¹ or perfected adepts and immortals, were represented in Han times as having feathers or dressed in feathers;^f emperors and alchemists alike ascended to the heavens when they died, as we see from innumerable Taoist biographies;^g and down to modern times a literary term for Taoist priests was *yü k'ho*²—'feathered guests'. The entry of Buddhism to China only intensified the traditions of flying beings, for the *gandharvas* and *apsaras* of Indian mythology,^h transformed outwardly by the Graeco-Bactrian focus through which they passed, winged their way to the east as the *fei thien*,³ where they gave rise, in the Wei frescoes of Tunhuang, to some of the most exquisite and beautiful representations in all Chinese art.ⁱ One sees them in nearly every cave at Chhien-fo-tung; an example is given in Fig. 701. Meanwhile at the other end of the Old World, a parallel line of development had produced the angels of Hebrew and Christian tradition, and presumably also the broomstick-riding witches of medieval legend.^j We may take it that

^a Reference may here be made to previous treatments of the Chinese contributions to the development of aeronautical science. The note of Giles (9) was superseded by the remarkable contribution of Laufer (4), whose main failing was a tendency to take the legendary material too seriously. Parallel accounts for the occident are those of Feldhaus (14) and Hennig (2). The history of aviation itself constitutes now a large literature, some helpful items in which will be cited later on, including the works of Brown (1); Hodgson (2) and Davy (1). Perhaps the most brilliant study available is that of Duhem (1, 2), but it ends at the time of Montgolfier. It is thus fortunately now complemented by the book of Gibbs-Smith (1), for whose researches we were happy to make available a copy of the present section in draft form; his excellent work carries on the epic mainly from Montgolfier's time. Henceforward the reader may find it advantageous to have at hand some fairly up-to-date introduction to aeronautical science, such as that of Surgeoner (1) or Sutton (1). Abundant illustrations in Dollfus & Bouché (1).

^b The most recent summary of the material is the interesting book of Eliade (3). For the Buriat Mongols, Tungus, Yakuts, Ostjaks, etc., see pp. 175, 211 ff.

^c Métraux, on the South American Indians (1).

^d Eliade (3), p. 415.

^e Instances will be given in a moment. Sometimes on a bronze mirror we see a pair of scholars riding through nothingness in an aerial car drawn by birds or dragons—as for example that figured by Bulling (8), pl. 66, and dated by her in the close neighbourhood of +70.

^f Cf. Vol. 2, p. 141 above. A typical story about feathered fairy girls who married mortal farmers occurs in the *Hsüan Chung Chi* (+6th century), *YHSF*, ch. 76, p. 8a.

^g Laufer (4), p. 27; de Harlez (4); L. Giles (6); Kaltenmark (2), pp. 15, 23, 125, 127.

^h Cf. Eliade (3), pp. 362 ff.

ⁱ The reader is referred to the excellent monograph of Nagahiro Toshio (1) on the subject.

^j Cf. Laufer (4), p. 9. The devils of Christendom, it seems, had membranous bat wings only from the mid +13th century onwards; earlier occidental representations give them the bird wings of fallen angels. Baltrušaitis (1), pp. 151 ff., has brought forward evidence suggesting that this development was due to Chinese influence. There are certainly close iconographic similarities between the flying devils of later Europe and the demons of earlier Taoist and Buddhist China.

the whole complex goes back to imaginations of winged and flying genii in ancient Mesopotamia and Egypt.^a Its only connection with the present discussion is that it put ideas into people's heads; ideas (for example) of aerial cars and their makers.

(1) LEGENDARY MATERIAL

Legends of self-propelled aerial cars, as opposed to flying vehicles drawn by winged animals and to unassisted personal flight in the style of Daedalus and Icarus, go back quite a long way in China, where they were associated with a mythical foreign person or people called Chi-Kung.¹ In the text of the *Shan Hai Ching* (Classic of the Mountains and Rivers), which may represent Early Han ideas, these people appear as three-eyed hermaphrodites, but there is no mention of their aircraft.^b This appears suddenly in the works of two +3rd century contemporaries, Chang Hua and Huangfu Mi. The former, in his *Po Wu Chih* (Record of the Investigation of Things), says:^c

The Chi-Kung people were good at making mechanical devices (*shih kang*²) for killing birds. They could also make aerial carriages (*fei chhe*³) which, with a fair wind, travelled great distances. In the time of the emperor Thang⁴,^d a westerly wind carried such a car as far as Yüchow, whereupon Thang had the car taken to pieces, not wishing his own people to see it. Ten years later there came an easterly wind (of sufficient strength), and then the car was reassembled and the visitors were sent back to their own country, which lies 40,000 *li* beyond the Jade Gate.^e

Exactly the same story occurs in the *Ti Wang Shih Chi* (Stories of the Ancient Monarchs) of Huangfu Mi, who took Chi Kung to be a person, however, rather than a people.^f It is then echoed time after time, e.g. in the +5th century by Shen Yo in his commentary on the Bamboo Books^g and in the +6th by *Chin Lou Tzu*^h and the *Shu I Chi*,ⁱ naturally with variations.^j Long before the Sung it had become a literary commonplace.

Some interest attaches to the iconographic tradition associated with the Chi-Kung story. The oldest picture we have of the flying car is in the rare encyclopaedia *I Yü Thu Chih* (Illustrated Record of Strange Countries), compiled some time after +1392 and printed in +1489.^k It shows a rectangular chariot with two occupants and one curious wheel (Fig. 702) which appears to be toothed. If Giles (9) and Laufer (4) were right in interpreting this wheel (from the general drawing of the picture) as

^a No doubt the psychologists have something to say of its origins.

^b Ch. 7, p. 3a.

^c Ch. 2, p. 1b, tr. Giles (9), mod. auct.

^d Legendary founder of the Shang dynasty, therefore mid -2nd millennium.

^e Yümen Kuan on the Old Silk Road.

^f A third early source is the *Chin Kua Ti Thu*,⁵ cited in *Yü Hai*, ch. 78, p. 20a.

^g *Chu Shu Chi Nien*, ch. 1, p. 21a.

^h Ch. 5, p. 22b.

ⁱ Ch. 2, p. 13b.

^j Also in the *Hsüan Chung Chi*, cit. *TPYL*, ch. 752, p. 3a (missed by Ma Kuo-Han).

^k See Moule (4); Sarton (1), vol. 3, p. 1627; cf. Vol. 3, p. 513.

¹ 奇肱

² 拭扛

³ 飛車

⁴ 湯

⁵ 括地圖



Fig. 702. The oldest printed picture of the aerial car of the mythical Chi-Kung people, a page from the *I Yü Thu Chih* encyclopaedia, c. +1430, first printed +1489. The inscription is approximately identical with the passage of the *Po Wu Chih* translated in the text. The one wheel visible appears to be toothed; did the artist think of it as facing the air like a vertical wind-wheel?

meant to be placed at right angles to the direction in which the car is flying through rolling clouds,^a then it adumbrates a propeller. If we knew only this picture^b such an identification would not perhaps be very convincing, but a variant occurs in some

^a From the direction of the flags it would perhaps seem more likely that the wheel was imagined as one of a pair of aerial cart- or paddle-wheels.

^b Which found its final form in the *Thu Shu Chi Chheng*, *Pien i tien*, ch. 45; thence copied by Duhem (2), fig. 2, and others. Here two wheels were drawn.

editions of the *Shan Hai Ching*^a which shows a clearly recognisable attempt by the artist to depict screw-bladed rotors (Fig. 703).^b We shall produce evidence a few pages further on that the possibilities of the helicopter top or 'Chinese top' for powered flight were appreciated as early as the +4th century, and it may be, therefore, that some of the medieval artists who depicted the car of Chi-Kung were able to imagine the applicability of such rotors to horizontal motion. It may, for instance, be significant that Thao Hung-Ching in the late +5th century refers to a 'wheeled flying car' (*fei lun chhê*¹) in which the Prince of the Eastern Sea (one of the Taoist hierarchy) made a round of visits.^c

Flying cars drawn by birds, griffons, or dragons were a separate tradition. It started in the Han^d and was strongly taken up by the Buddhists, several examples being present in the Tunhuang frescoes (Wei and Thang),^e cf. Fig. 704a. The theme is also Indian^f and may well be connected with the concept of 'vehicles of the Gods' in that mythology, Garuḍa and the like, as well as with the chariots of the solar and planetary spirits which appear in occidental mythology also, e.g. Phaethon. Again, its origins are probably in Babylonia, as the Etana myth suggests.^g

What began as mythology was naturally transmuted into poetry as time went by. In the Section on

^a Notably the *Shan Hai Ching Kuang Chu*² of +1667 edited by Wu Jen-Chhen.³ It has been reproduced by Bazin (1); Duhem (2) and others.

^b Other editions simply have an ordinary chariot with a dragon in an ox-yoke.

^c In *Chen Kao* (TT 1004).

^d Besides Bulling (8) just mentioned, Chavannes (9) reproduced a relief dated +87 (car with birds) and Harada & Komai (1) give a picture of a cloud chariot (*yün chhê*⁴) said to be by the Chin painter Ku Khai-Chih.⁵

^e Especially caves nos. 296-311, with an important picture in no. 305.

^f Laufer (4), pp. 44 ff.

^g Laufer (4), pp. 58 ff. It is a curious coincidence that just about the same time that Chang Hua and Huangfu Mi were writing about the aerial cars of the Chi-Kung people in China, the corpus of legends about Alexander the Great which bears the name of Pseudo-Callisthenes was coming to completion in Alexandria and Byzantium. One of the many features of technical interest in this 'Alexander-Romance', as it is called, is the story that the great king embarked upon an aerial ascent in a car drawn by two or more large birds or gryphons. After the +9th century the story became very popular in Western Europe and is often found on façades and misericords, as e.g. in the choir at Lincoln. For further information see Cary (1), pp. 9 ff., 38, 59, 134 ff. and 296 ff.; Millet (1); M. D. Anderson (1).



Fig. 703. Another pictorial version of the aerial car of the Chi-Kung people, from the *Shan Hai Ching Kuang Chu* (text of the -2nd century or earlier, +17th-century commentary). The inscription follows the *Shan Hai Ching* (ch. 7, pp. 3a ff.) fairly closely at first, saying: 'The people of the Chi-Kung country have each one arm and three eyes, and they are partly male and partly female. They are able to construct flying carriages which can follow the wind and travel great distances. Their land lies north of the I-Pei (country of the One-Armed Men). The skill of the Chi-Kung people is truly marvellous; by studying the winds they created and built flying wheels, with which they can ride along the paths of the whirlwinds. They visited us in the time of the emperor Thang.' The artist has here drawn the aerial car with two wheels, but both seem to be intended to represent screw-bladed rotors.

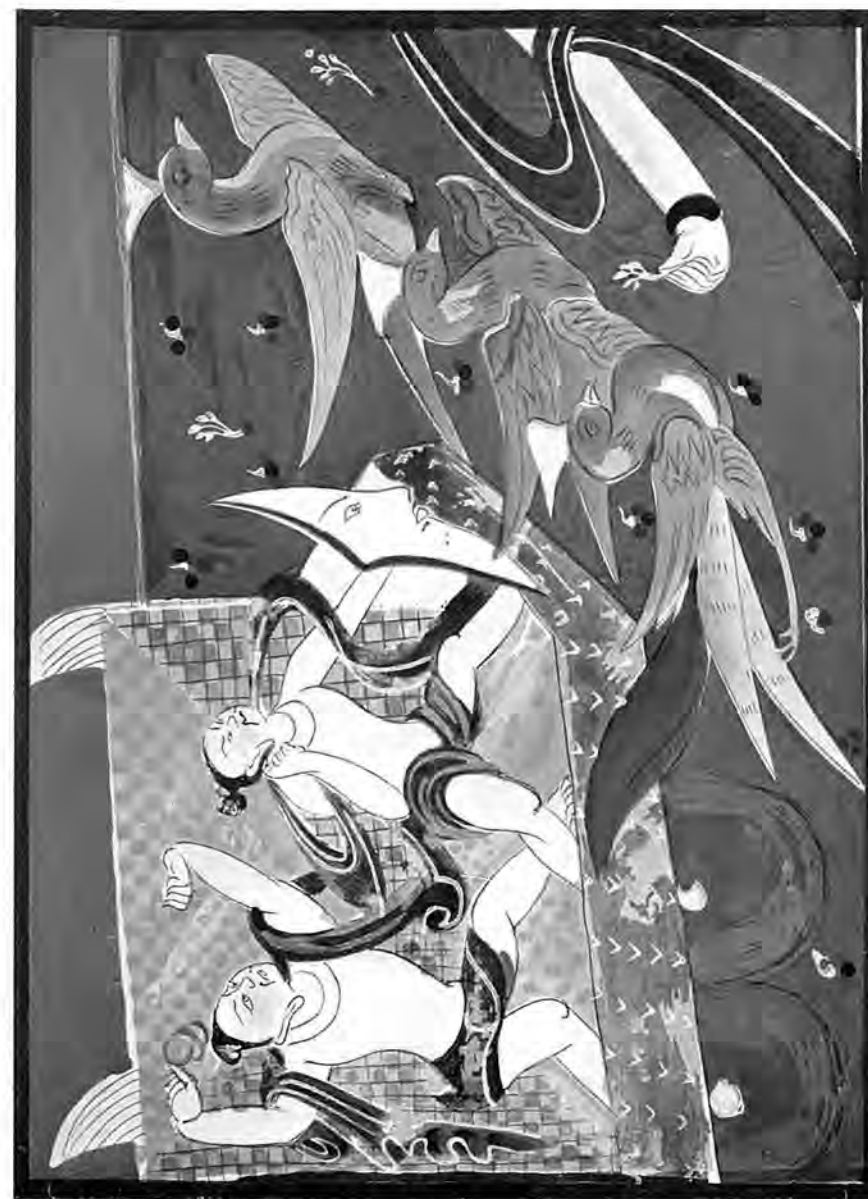


Fig. 704a. A bird-drawn flying car in the Chhien-fo-tung frescoes, Hsi and Ho as the charioteers of the sun (cf. Vol. 3, p. 188). Painting of the Western Wei period, c. +545, from cave no. 285, copied by Ho Hsi-Liang & Fan Wen-Tsao.



Fig. 704 b. Kite-flying at Haikuan (Allom & Wright).

astronomy^a we had occasion to refer to the accounts by numerous writers, ancient and modern, of imaginary flights through the sky to the moon or the sun. Lucian of Samosata (c. +160) is paralleled by Chang Hêng (+135), in his *Ssu Hsüan Fu*,^{1, b} and indeed by Chhü Yuan earlier in the great *Li Sao* (c. -295),^c though they are romantic while he is allegorical.

(2) THAUMATURGICAL ARTISANS

From the writers and artists we must now pass to the thaumaturgical artisans. In the end, someone actually does something. The invention of a wooden kite (*mu yuan*²) is ascribed in various ancient texts to Mo Ti³ (the founder of the Mohist school; d. -380),^d and to his contemporary Kungshu Phan,⁴ the famous engineer of the State of Lu.^e Whether it was in the shape of a bird is not clear. The character *yuan* continued to mean the bird which we call a kite (*Milvus lineatus* and related species),^f and when applied to the flying device was usually qualified by the adjectival word *chih*,⁵ paper. The *Han Fei Tzu* book, written about -255, says:^g

Mo Tzu made a wooden kite (*mu yuan*²) which took three years to complete. It could indeed fly, but after one day's trial it was wrecked. His disciples said 'What skill the Master has to be able to make a wooden kite fly!' But he answered 'It is not as clever as making a wooden ox-yoke peg (*i*⁶). They only use a short piece of wood, eight-tenths of a foot in length, costing less than a day's labour, yet it can pull 30 *tan*,^h travelling far, taking great strain, and lasting many years. Yet I have worked three years to make this kite which has been ruined after one day's use.' Hui Tzuⁱ heard of it and said: 'Mo Tzu is indeed ingenious, but perhaps he knows more about making yoke-pegs than about making wooden kites.'

This last remark may be taken as a hit at Mo Ti's utilitarianism. A closely similar passage occurs in the *Mo Tzu* book itself,^j where Kungshu Phan is said to have constructed a bird from bamboo and wood, which stayed aloft for three days without coming down. Mo Tzu then engages him in a similar conversation about utilitarianism. In later times everybody knew these stories, which are repeated in *Pao Phu Tzu*, where Ko Hung, talking (c. +300) of people who made artificial things as good as real ones, speaks of Kungshu Phan's kites swaying and somersaulting (*mu yuan chih phien fan*⁷);^k in the +6th-century *Shu I Chi* (with elaborations);^l in the +12th-century *Hsü Po Wu Chih*;^m and in the Ming *Hung Shu*⁸ (Book of the Wild Geese).ⁿ The third

^a Vol. 3, p. 440.^b CSHK (Hou Han sect.), ch. 52, p. 1 b, also *Wên Hsüan*, ch. 15, p. 1 a (tr. von Zach (6), vol. 1, p. 217).^c B. K. Lim (1), pp. 92 ff., better Hawkes (1), pp. 28 ff.^d Vol. 2, cf. pp. 165 ff. above.^e Cf. p. 43 above.^f R314.^g Ch. 11 (ch. 32), p. 2 a, tr. auct. adjuv. Liao Wên-Kuei (1), vol. 2, p. 34.^h A weight equivalent to nearly 2 tons. Cf. the parallel passage, p. 313 above.ⁱ The paradoxer, cf. Vol. 2, pp. 189 ff. above.^j Ch. 49, p. 9 b (tr. Mei Yi-Pao (1), p. 256). See p. 313.^k *Nei Phien*, ch. 8, p. 10 b.^l Ch. 2, p. 6 b.^m Ch. 10, p. 7 b.ⁿ By Liu Chung-Ta.⁹ Quoted in Wu Nan-Hsün (1), p. 168.¹ 思玄賦² 木鳶³ 墨翟⁴ 公輸般⁵ 紙⁶ 靦⁷ 木鳶之翻翻⁸ 鴻書⁹ 劉仲達

of these had no doubt that the devices of Mo Ti and Kungshu Phan were kites, such as were flown by Sung children; and the fourth repeats what was probably a tradition (though other statements of it have not come to hand) that Kungshu Phan flew wooden man-lifting kites over the city of Sung during a siege, either for observation or as vantage-points for archers. If this should be considered unlikely for the 4th century, we shall nevertheless see in a moment that the military use of kites goes back a long way in Chinese history.^a

It is interesting to find that Wang Chhung sought to discredit the traditions about Mo Ti and Kungshu Phan. About +83 the great sceptic wrote, in his *Lun Hêng*:^b

The books of the literati talk about the great skill of Kungshu Phan and Mo Ti, saying that they carved from wood kites which flew for three days without coming down. That they made wooden kites which would fly is quite possible but the report that these did not alight for three days must be exaggerated. If such a thing had the shape of a bird, how could it fly for three days without resting? If it could soar, why only for three days? It might indeed have been equipped with some mechanism by which it was set in motion and continued to fly, so that it did not descend; in this case the story should say that it flew continuously, not only for three days. There is another report, too, that Kungshu Phan lost his own mother because of his skill. He constructed for her a wooden chariot and horses with a wooden driver, and when it was ready and she had taken her place inside, it sped away and never returned; thus she was lost to him. Since the mechanism of the wooden kite was (presumably) equally well constructed, it also should have continued to fly without stopping. But if the mechanism would function but a short while, and therefore the kite could not keep flying for more than three days; so also the wooden carriage should have come to a stop on the road within three days' journey, instead of carrying the mother completely away. The two stories (in fact contradict each other and) must be wide of the truth.

Wang Chhung, therefore, though in captious mood, did not disbelieve in the possibility of artificial flight itself.

Another attempt at this seems to have been due to a younger contemporary of Wang Chhung, namely Chang Hêng the great astronomer and engineer (+78 to +139). The main information we have about it comes from a book called *Wên Shih Chuan*¹ (Records of the Scholars) by Chang Yin^{2, c}. The passage, quoted twice in the *Thai-Phing Yü Lan*,^d says that a wooden bird (*mu niao*³) was made, with wings and pinions (*yü ho*⁴), having in its belly a mechanism which enabled it to fly several *li* (*fu chung yü shih chi, nêng fei shu li*⁵). We are inclined to think that while the devices of Mo Ti and Kungshu Phan were kites, probably shaped roughly like birds, the invention of Chang Hêng could have involved the air-screw of the helicopter top, though the only motive power available to him for such a purpose would have been springs. We certainly need not take too seriously the statement about the distance flown. In Chang

^a And, more surprisingly, the use of man-lifting kites also.

^b Ch. 26, tr. Forke (4), vol. 1, p. 498; mod. Leslie et auct.

^c If he was the same Chang Yin who lived c. +170 to +190 his information would be rather likely to be accurate. But the book is not mentioned before the Sui bibliography.

^d Ch. 752, p. 26; ch. 914, p. 8a.

¹ 文士傳

² 張隱

³ 木鳥

⁴ 羽翮

⁵ 胸中有施機能飛數里

Hêng's own writings there are references to the machine. In his essay on the use of leisure in retirement (*Ying Hsien*¹),^a he says (+126):

Certain base scholars used to report evil of me to the emperor, but I decided not to worry about such affairs, or to learn their 'unique arts' (of civil service intrigue). Yet linked wheels may be made to turn of themselves, so that even an object of carved wood may be made to fly all alone in the air (*mu tiao yü nêng tu fei*²). With drooping feathers I have returned to my own home; why should I not adjust my mechanisms and put them in working order (so that I may fly still higher than before)?

Here then he seems to mention his own mechanical interests, using them as an analogy for his own situation out of office.^b

The chief Western parallel to all this is the 'flying dove' of Archytas of Tarentum, more or less of a Pythagorean,^c whose *floruit* was in the neighbourhood of -380, making him a contemporary of Mo Ti and Kungshu Phan. Unfortunately, there is little reference to his model aircraft earlier than Aulus Gellius (*fl.* +130 to +180), the contemporary of Chang Hêng and Chang Yin, who quotes from Favorinus of Arelates,^d an older man (*fl.* +150), the report that it flew by means of some expanding vapour contained within it.^e According to other accounts^f a weight and pulley were involved, and while the object could fly it could not rise again after falling. This might suggest that a launching mechanism was used, after which the model went forward in gliding flight assisted by whatever power-source is implied by the reference to compressed air or steam. The invention seems much more in the Alexandrian manner than of the time of Archytas, and it is distinctly curious, in view of the medieval expertise of China regarding gunpowder rockets,^g that the jet-propulsion principle seems to be hinted at in the Greek and not in the Chinese sources. All the great Alexandrian mechanicians, however, were concerned with pneumatic devices—Ctesibius with pumps,^h Heron with hydrostatic systems, organs, steam-jets and wind-power,ⁱ and

^a CSHK (Hou Han sect.), ch. 54, p. 8b; *Hou Han Shu*, ch. 89, p. 3b, with commentary; tr. auct.

^b Other references to flying birds of wood also occur in the same essay, p. 10a. It will be remembered that mention was made earlier of a lost writing of Chang Hêng's, the *Fei Niao Thu*,³ which can be dated at +114. In the Section on Geography (Vol. 3, pp. 538, 576) we considered the possibility that this work had something to do with map-making, though as the last character is uncertain, the real subject may have been calendrical science. A third possibility is that we should interpret the title 'Diagrams of the Mechanism of the Flying Bird'. As for the problem of what this was, the ornithopter type (flapping-wing aircraft) should not be forgotten. Leonardo's favourite obsession, it lasted as late as Lilienthal in the eighties of the last century, and many model forms of it have successfully flown (Gibbs-Smith (1), pp. 19, 21). But perhaps it will never be much use until the complexity of the wing-mechanisms approaches that of the wings of birds themselves (*ibid.* pp. 267 ff.).

^c On him in general see Freeman (1), p. 234; Sarton (1), vol. 1, p. 116; Neuburger (1), p. 231.

^d On him see B & M, p. 578.

^e *Noctes Atticae*, x, 12, ix ff. 'Nam et plerique nobilium Graecorum et Favorinus philosophus memoriarum veterum exsequeantissimus affirmatissime scripserunt, simulacrum columbae e ligno ab Archyta ratione quadam disciplinae mechanica factum volasse; ita erat scilicet libramentis suspensum et aura spiritus inclusa atque occulta concitum.'

^f Cf. Laufer (4), p. 64.

^g And even winged rockets, as we shall duly see in Sect. 30 below.

^h Cf., for example, Sarton (1), vol. 1, p. 184; Drachmann (2, 9).

ⁱ Sarton (1), vol. 1, p. 208; Drachmann (2, 9).

¹ 應閑

² 木雕猶能獨飛

³ 飛鳥圖

Ctesibius and Philon^a with catapults (ballistae) involving the use of compressed air.^b

Conceivably, therefore, the account in Aulus Gellius may refer to a light model with glider wings launched from an inclined platform by a weight, and containing a space with a narrow backward-pointing outlet, through which a jet of steam could issue, as in Heron's aeolipile.^c Alternatively the model was perhaps hung from a pole on a 'whirling arm' and driven round on the end of it.^d Thus if there is anything in these speculations, Mo Ti, Kungshu Phan and Chang Hêng may have experimented, before the +2nd century was out, with two of the great components of modern aeronautical science, the kite-wing and the air-screw;^e while Archytas or the Alexandrians may possibly have used the jet principle.

(3) THE KITE AND ITS ORIGINS

Let us now examine more closely the chief material basis for Chinese aeronautical stories, the kite of wood, bamboo, and paper. Its use in Asia would seem to be exceedingly old, since anthropologists have found it in a wide distribution radiating south and east of China through Indo-China, Indonesia, Melanesia and Polynesia (Chadwick, 1). In some parts of this area kite-flying was practised as a religious function connected with gods and mythical heroes. Often tabooed to women, the kite frequently carried, as in China, attachments such as strings or pipes to make musical or humming noises in the air.^f An important practical application was found for it in a method of fishing, to remove the hook and bait far from the sinister shadows of the boat and the fisherman.^g In China a game was played with kites.^h

As to the origin of the kite, Waley (15) suggested that perhaps it derived from an ancient Chinese method of shooting off an arrow with a line attached to it, so that both arrow and prey could be recovered by hauling it in—as represented in the character *i*^{1,1}. Raglan (1) declined to accept this for the reasons that kite-flying consists not in standing still and pulling a solid object towards one, but in towing it to start it from

^a Sarton (1), vol. 1, p. 195.

^b In the pneumatic catapult (*aerotonon*) the cord was attached to levers themselves fixed at right-angles to pistons fitting tightly into bronze cylinders. The act of stretching the cord compressed the air in the cylinders, and this, upon the pulling of the trigger mechanism, assured the return of the cord to its original position and the despatch of the arrow or other projectile. There is no evidence, however, that the machine was anything but a military curiosity, or even that it was ever built at all. Cf. Schramm (1); Beck (3); Neuburger (1), p. 224.

^c Duhem (1), p. 125, agrees with these general conclusions.

^d This suggestion is due to Mr Gibbs-Smith.

^e Allusion has been made already to the philosophical context and significance of their efforts at automation, cf. Vol. 2, pp. 53ff. Later Chinese work with flying models has been mentioned on p. 163 above.

^f See immediately below, p. 578.

^g This Indonesian-Melanesian device has been monographed by Balfour (2); Anell (1) and Plischke (1); see also Montandon (1), p. 244.

^h The cord near the kite being covered with crushed glass or porcelain glued on, the players seek to get their kites to windward of their rivals so that the cords are cut through, and the losing kite comes fluttering to earth. This is an autumn sport; Laufer (4), p. 32; Wei Yuan-Tai (1). Cf. Fig. 704b.

¹ We shall shortly find an unexpected, but more acceptable, function for this method in the history of technology, Sect. 28e below.

¹ 夷

the ground,^a while if a hunting method had been at the beginning of the story, the religious associations of the kite might be harder to explain. He himself suggested as the kite's ancestor the bull-roarer, which produces a loud humming noise on the end of the string with which it is whirled round, and still exists as an important ritual object in many primitive cultures. But the origin of the kite lies so far back in Asian history that all such theories can be but speculative.

Perhaps we have already seen an ancient Chinese representation of a kite without noticing it; on the —4th-century Hui-hsien bowl (Fig. 299 in Vol. 4, pt. 1, at the bottom on the left.)

We may well be prepared to regard the devices of Mo Ti and Kungshu Phan as the earliest references to kites, though Laufer was disinclined to do so. The scholars of the Sung, notably Kao Chhêng^b and Chou Ta-Kuan^c (+13th century), recorded a story that the Han general Han Hsin¹ (d. —196) flew a kite over a palace to measure the distance which his sappers would have to dig in order to make a tunnel through which the troops could enter. They used the expression 'paper kite' though paper was not available until three centuries after his time; moreover, the story has not been found so far in any contemporary source, but some foundation for it is by no means impossible. In the Thang book *Tu I Chih* we find the following:^d

In the Thai-Chhing reign-period (+547 to +549) of Liang Wu Ti, Hou Ching² rebelled, and besieged Thai-chhêng (Nanking), isolating it from loyal forces far and near. Chien Wên³ (i.e. Hsiao Kang,⁴ later emperor for one year, +550) and the crown prince (Hsiao) Ta-Chhi⁵ decided to use many kites (*fu yuan*⁶) flying in the sky to communicate knowledge of the emergency to the army leaders at a distance. The officers of Hou Ching told him that there was magic afoot, or that messages were being sent, and ordered archers to shoot at the kites. At first they all seemed to fall but then they changed into birds which flew away and disappeared.

This probably means that kites were used for signalling, and despatches sent out by carrier pigeons.^e Then in +781 a loyal general of the Thang, Chang Phei,⁷ besieged in Lin-ming, signalled with kites to inform his fellow commanders of his predicament, and the city was eventually relieved.^f Again in the +13th century kites were used in war between the Chin Tartars and the Mongols. At the famous siege of Khaifêng in +1232, when the army of the Jurchen Chin was shut up in their capital by Ögötai's forces,

The besieged sent up paper kites with writing on them, and when these came over the northern (i.e. the Mongol) lines, the strings were cut (so that they fell among) the Chin prisoners (there). (The messages) incited them (to revolt and escape). People who saw this said: 'Only a few days ago the Chin (commanders) were using red paper lanterns (for

^a Besides, the feathering of an arrow would be far too small to give it any lift. A Chinese farmer's hat on the end of a string would be a much more likely ancestor.

^b *Shih Wu Chi Yuan*, ch. 8, p. 27a.

^c *Chhêng Chai Tsa Chi*⁸ (c. +1295), a reference first noted by St Julien (4) and L. C. Anderson. Quoted *KCCY*, ch. 60, p. 8b.

^d Ch. 2, p. 4a; also quoted in *KCCY*. Tr. auct.

^e See below, Sect. 30.

^f Cf. *Chiu Thang Shu*, ch. 187B, p. 13a (biography).

¹ 韓信 ² 侯景 ³ 蕭文 ⁴ 蕭綱 ⁵ 大器 ⁶ 縛鸞

⁷ 張仝 ⁸ 誠齋雜記

signalling) and now they are making use of paper kites. If the generals think they can defeat the enemy by such methods they will find it very difficult.^a

Thus we have an early instance of a 'leaflet raid', for the messages were simply propaganda urging the captured Chin soldiers to rise and fight their way back to their own side.^b These examples may be enough to show the continual military uses which were found for kites in China, and this perhaps lends additional plausibility to the original association with Mo Ti, the interest of whose disciples in military technique has been emphasised more than once elsewhere in this book.^c

That kite-flying as a pastime also goes back a long way is evident too. One sees pictures of it in the Tunhuang frescoes from the Wei period onward.^d Literary descriptions occur in +10th-century books such as the *Tiao Chi Li Than*¹ (Talks at Fisherman's Rock),^e and frequently in the Sung and Ming.^f Though the practice of fitting Aeolian harps on kites may have started in the Thang or before, it is closely associated with the name of a famous maker of kites^g in the +10th century, Li Yeh.² Those of bamboo with one thin bamboo string are called *fêng chêng*,³ 'wind-psalteries', or *fêng chhin*,⁴ 'wind-zithers'; those with seven silk strings fixed across a gourd-shaped framework are called *yao chhin*,⁵ 'hawk-lutes'.^h Sung references to this practice are numerous.ⁱ In a cognate custom, whistles (*ko ling*⁶ or *shao tsu*⁷) of bamboo, gourd or horn, are fixed to the tail-feathers of pigeons.^j This is certain for the Sung period and not likely to have started later than the Thang.^k

^a *Chin Shih*, ch. 113, p. 18b, tr. auct.

^b The slightly modified quotation in the *Thung Chien Kang Mu*, pt. 3, ch. 19, p. 50a, b, was translated more than a century ago by St Julien for Reinaud & Favé (2), p. 288. Misunderstanding the nature of the writings carried by the kites, he supposed them to be magic charms, and added a patronising footnote about similar cases of Chinese credulity in the Opium Wars. But an independent and contemporary source, the *Kuei Chien Chih*, written in +1235 by Liu Chhi, which gives a fuller account (ch. 11, p. 4a), makes it quite clear that the messages called upon the prisoners to return, adding that they were all promised promotion if they got back, 'running between the arrows and the stones'. Thus once again Chinese common sense was turned by sinologists into non-sense. Feldhaus, for his part, (1), col. 654, confused two incidents of the siege, and placed lanterns and kites wrongly in the context of the Mongol hot-air balloon dragon-standards (cf. p. 597 below).

^c Above, Vol. 2, pp. 165 ff.; below, Sect. 30.

^d Notably in caves nos. 332 and 148, both Thang, the latter dated +698.

^e P. 38b.

^f See *Wu Tai Shih Chi*, ch. 30, p. 11b.

^g Moule (10), pp. 105, 111; cf. also the special article of Hsü Chia-Chen (1).

^h For example, *Tu Hsing Tsa Chih* (+1176), ch. 1, p. 9b, or a reference in a poem by Fan Chhêng-Ta c. +1180 (*Shih Hu Tzhu*, p. 13a). The *Wu Lin Chiu Shih* by Chou Mi (about +1270) lists Aeolian harps for kites as being on sale in Southern Sung Hangchow, and mentions the names of two men, Chou San⁸ and Lü Phien-Thou,⁹ who were renowned for making them (ch. 6, pp. 15b, 30b). They are also discussed in the Ming book *Hsin Chiu Lu*¹⁰ (Enquiries and Suggestions about Popular Customs) by Chhen I.¹¹ Cf. Wu Nan-Hsün (2), p. 168.

ⁱ Moule (10), p. 67. These can fill the air above a Chinese city with delicious sounds, as I know from personal experience, well remembering that strange sky-music which one used to hear in the lanes of the Kweichow town of Anshun—as well as other places in China. Cf. further Laufer (4), p. 72, (26); Bodde (12), p. 22; Wang Shih-Hsiang (1).

^k Moule's estimate of date was too cautious; he would have been delighted to find the pigeon-whistles on sale in his own Hangchow in the Southern Sung, for they are indeed listed (as *po-ko ling*¹²) among the special commodities in *Wu Lin Chiu Shih*, ch. 6, p. 15b.

¹ 釣機立談

² 李業

³ 風箏

⁴ 風琴

⁵ 鷗琴

⁶ 錢鈴

⁷ 哨子

⁸ 周三

⁹ 呂偏頭

¹⁰ 陶菊錄

¹¹ 陳沂

¹² 鵝鴿鈴

A kite is supported upon the wind by a combination of three forces: its weight, the resistance of the air, and the compensating tension of the string. According to the strength of the wind the kite moves in a great circle of which the string is the radius, rising when the wind freshens and falling to a vertical position in which it can no longer remain suspended when the wind falls. The operator can then, by holding the string taut and running, keep the kite airborne during the calm period by providing sufficient flow under its plane surfaces, just as the artificial airstream lifts the true powered aeroplane. In the 18th century, some of the greatest European mathematicians devoted attention to the theory of kites (e.g. Newton, Desaguliers, d'Alembert, Euler).^a But already, during the centuries of existence of the kite in China,

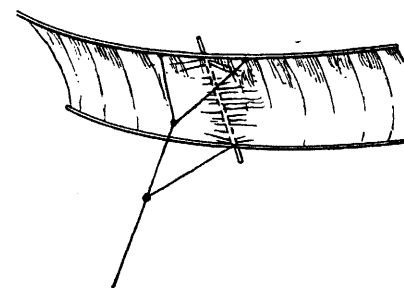


Fig. 705. Chinese cambered-wing kite (after Tissandier, 5).

several interesting refinements had been introduced, such as the addition of a second cord permitting the control of the angle of attack according to the wind strength.^b Surfaces were also (as we have seen) made concavo-convex,^c but unfortunately we do not yet know whether this practice began earlier than the end of the +18th century, at which time the first suggestions of curved aerofoils were made in Europe.^d Fig. 705 shows a typical Chinese cambered-wing kite. Here a point which should not be overlooked is the historical relation between the kite, the aeroplane and the sailing-carriage. The Chinese origin of the latter has already been described;^e and the kite might almost be considered as a detached sail of the sailing-carriage.^f At various times efforts were indeed made, not without success, to tow land-vehicles by means of kites, the most famous being that of Pocock in 1827.^g

^a Duhem (1), p. 199.

^b *Ibid.* p. 195.

^c See Chanute (1) and especially Tissandier (5) reproduced by Gibbs-Smith (4), fig. 11, p. 36. 'Monoplane' kites were generally not less than 3 ft. broad and often 11 ft. long. The two ends are often curved like plant leaves, and bird-shaped kites may have long rigid tails. Similar principles governed kite-making in Japan, to judge from the study of Tissandier (6). Cf. Wei Yuan-Tai (1); le Cornu (1); Needham (42).

^d See below, p. 581.

^e See above, p. 274.

^f Duhem (1), p. 180. Did not della Porta call it a 'flying sayle'?

^g *Ibid.* p. 193; Gibbs-Smith (1), pp. 12, 162. He had a successful run on the road between Bristol and Marlborough.

(4) THE HELICOPTER TOP; KO HUNG AND GEORGE CAYLEY ON THE
'HARD WIND' AND 'ROTARY WAFTS'

We now approach the most important part of this discourse, the examination of the role which ancient and medieval Chinese aeronautical devices played as part of the basis for the vast modern development of aerodynamics and aviation. That the kite was unknown in Europe until the end of the +16th century, when it was brought back by the early travellers, is well appreciated. 'It makes its début', said Laufer, 'as a Chinese contrivance, and not as a heritage of classical antiquity.'^a This does not mean that the kite was unknown in the Islamic world; it was probably not new there in the +9th century when Abū 'Uthmān al-Jāhiz described the flying of kites 'made of Chinese carton and paper' by boys.^b But in Europe the first description of kites occurs in Giambattista della Porta's *Magia Naturalis*^c of +1589. A few decades later they were employed in England for the letting off of fireworks in the air, as it is for this purpose that John Bate describes them in his *Mysteries of Nature and Art* (+1634).^d Athanasius Kircher, the Jesuit, whose relations with the China Jesuits were close, and who himself wrote on China, also refers to them in the *Ars Magna Lucis et Umbra* (+1646), and states that in his time kites were made in Rome of such dimensions that they were capable of lifting a man.

All this is highly relevant to the developments of the 19th century. The study of kites did indeed in due course confirm experimentally their capacity to carry human aeronauts aloft, but it was much more important in another way, because closely connected with the search for suitable glider and aeroplane wings. In 1804 Sir George Cayley constructed a successful model aircraft with plane (flat) kite wings and a tail rudder-elevator consisting of two plane kites intersecting at right angles.^e This was 'the first true aeroplane in history'.^f Plane surfaces attached to whirling arms were also used by him in the same year for his fundamental physical experiments on air-

^a (4), p. 37. So also Plischke (2) in a later careful re-examination of the matter.

^b In the Book of Animals (*Kitāb al-Ḥayawān*); Laufer (4), p. 37; Hitti (1), p. 382.

^c Bk. 20, ch. 10 (English ed. +1658, p. 409), a 'flying Sayle'. In the +16th-century descriptions it is not always easy to distinguish the true kite from the hot-air dragon-balloon which had been popular earlier (cf. p. 597 below), but Johann Schmidlap (+1560) and Johann Mathesius (+1562) were probably talking about the latter and not the former. Della Porta was quickly followed by Jacob Wecker (+1592) and Daniel Schwenker (+1636). The latter talks of whistles which could be fitted on the kite as well as fireworks, a distinctly Asian (if not specifically Chinese) trait.

^d Bate gives a picture of kite-flying, reproduced in Duhem (2), fig. 65; Gibbs-Smith (1), pl. 1 (a); but the first European illustration was that of Hellenius (+1618), in an engraving of Middelburg in Holland. As Plischke (2) points out, the fact that the kite appears first in Holland and England suggests that it was brought to Europe by Dutch or English merchants; if the transmission had been Portuguese we should expect it to have occurred half a century earlier. Neither della Porta nor Bate used the word 'kite', and Gibbs-Smith (1), p. 163, finds it 'inexplicable' that this should have been chosen out of all other possible bird names. But in fact the English name 'kite' is just a direct translation of the old Chinese term. The words used in other European languages, e.g. *Drache*, *cerf-volant*, etc., could also have been derived from the different animal forms so often given by the Chinese to their kites. Thus the terminology points rather clearly to China as the source of the transmission.

^e See Cayley (1), p. 26. For his biography (+1773 to 1857) see Hodgson (1, 3); Pritchard (1). He is not to be confused with the Cambridge mathematician, Arthur Cayley (1821-95).

^f Gibbs-Smith (1), pp. 10, 162, 190, and pl. 11 (b), (8); Needham (42).

resistance, angle of incidence, and other aerodynamic phenomena.^a But the study of the wings of birds had long been proceeding in parallel, and Cayley himself had realised as early as 1799 that 'to make a surface support a given weight by the application of power to the resistance of air' was the basic problem. Any aeroplane must have, he clearly saw, a main supporting wing,^b with a tail-unit to exercise control; this we know from a dated silver medallion engraved by him, and from contemporary drawings.^c His pioneer design, in which these features were incorporated, is regarded as 'the first illustration in history of an aeroplane of modern type'. Moreover, it embodied the discovery of the aerofoil.^d Although Cayley understood that a cambered wing gave better lift, he did not feel compelled to build it into his full-size machines, for in his model gliders he relied on the production of a curved surface by the airflow itself, acting as it did on his fabric wings which had spars only along the leading and trailing edges. But many of his drawings show the camber very clearly. Then, within fifty years, the conviction grew that one must imitate the cross-section of avian wings^e rather than the stretched paper of the kite, and double-surfaced wings with different upper and lower profiles were introduced.^f In this way streamlined sections were attained which combined the advantages of the convex upper surface with those of a nearly flat lower one, the former reducing air-pressure by accelerating the speed of flow and so creating an upward suction; the latter obviating concavity turbulence and compressing the air by decreasing its flow speed.^g In later years Cayley himself carried the aerofoil principle further in successful models (1818, 1849 and 1853) and full-scale passenger-carrying monoplane gliders (1849 and 1853), which however continued to show traces of the plane kite both in their wings and in their rudder-elevator tails.^h He had already for many years mastered lateral stability by means of the dihedral angle at which he set his wings, and longitudinal stability by means of the tail-plane which he fitted. The majority of those who experimented with model flying-machines in the second half of the century adopted curved aerofoil shapes of one kind or another for their wings.ⁱ

But still the paper bird of China had not exerted its full influence upon aeroplane

^a See Cayley (1), pp. 22 ff. and frontispiece.

^b That is to say, in ordinary speech, for a monoplane has strictly two wings, port and starboard, and a biplane two sets of wings.

^c Gibbs-Smith (1), pp. 10, 189, and title-page. In this Cayley had been preceded by certain imaginative writers, notably Restif de la Bretonne (+1781).

^d A key point here is whether Cayley or any of the other 18th- or 19th-century pioneers knew of the cambered wings of some of the Chinese kites. Kite-makers in China had doubtless been led to this development by their preoccupation with the imitation of animal, especially bird, forms (cf. Wei Yuan-Tai, 1), and not from formulated aerodynamic considerations. Yet the influence, could it be established, would be of great interest, and a search in the literature of early aviation, both manuscript and printed, might be very rewarding. There were many who experimented with large cambered-wing kites, e.g. Maillot (1).

^e Cf. Cayley (1), p. 52.

^f Henson (1842) seems to take the credit for this, followed by Pénaud (1876) and many others.

^g Cf. Surgeoner (1), vol. 1, pp. 32 ff.; Gibbs-Smith (1), pp. 256 ff., 263 ff. Here we have a nice illustration of the way in which the aeroplane wing embodies, in a very real sense, both the bird-wing and the paper-kite plane. The later developments are sketched in Brooks (1).

^h See Cayley (2, 3) and Gibbs-Smith (1), pp. 10, 190 ff. and pl. 11 (d). Cayley's actual design has now been discovered by Gibbs-Smith (6).

ⁱ E.g. Henson (1847), Wenham (1866) and Lilienthal (1891).

design, for in 1893 the Australian Lawrence Hargrave invented the box-kite for greater stability and lift,^a normally two cells connected by booms to form a tandem frame, and it was this which inspired most of the biplane builders of the first decade of the present century.^b Thus although the plane (flat) kite was not by any means the only influence on glider design, there was justification enough for the use of the term 'power-kite' for some of the aeroplanes of this period, and for its legacy in common speech today.^c Meanwhile from Cayley's time onwards the study of suitable power-sources was steadily progressing,^d so that at last the tow-rope and falling gradient could be replaced by energy generated within the aircraft itself. For this the invention of the air-screw or propeller was an absolute essential, and in a moment we must turn to consider what its origins were.

Before proceeding to this, however, let us leap backward in time some fifteen centuries, and pause to notice a very remarkable passage, on aerodynamics one might almost say, written by the great Taoist adept and alchemist Ko Hung about +320. This is what we find in the *Pao Phu Tzu*:^e

Someone asked the Master about the principles (*tao*¹) of mounting to dangerous heights and travelling into the vast inane. The Master said...^f 'Some have made flying cars (*fei chhê*²) with wood from the inner part of the jujube tree, using ox leather (straps) fastened to returning blades so as to set the machine in motion (*huan chien i yin chhi chi*³).^g Others have had the idea of making five snakes, six dragons and three oxen, to meet the "hard wind" (*kang (fêng')*⁴)^h and ride on it, not stopping until they have risen to a height of forty *li*.ⁱ That region is called Thai Chhing,⁵ (the purest of empty space). There the *chhi*⁶ is extremely hard, so much so that it can overcome (the strength of) human beings. As the Teacher^j says: "The kite (bird) flies higher and higher spirally, and then only needs to stretch its two wings, beating the air no more, in order to go forward by itself. This is because it starts gliding (lit. riding) on the 'hard wind' (*kang chhi*⁷). Take dragons, for example; when they first rise they go up using the clouds as steps, and after they have attained a height of forty *li* then they

^a Cf. Gibbs-Smith (1), pp. 30, 73, 162, 318 and pl. v (c); Needham (42).

^b Cf. fn. (c) on p. 568 above.

^c Cf. Vivian & Marsh (1), p. 190. As late as 1910 expositions of flying theory, such as that of Ferris (1), generally started by considering kites. The book of Chanute (1) gives the fullest account of the influence of kites on glider design.

^d He himself experimented with a gunpowder motor, (1), p. 42, in 1807.

^e *Nei Phien*, ch. 15, pp. 12a ff.; *Tao Tsang* ed., pp. 13a ff.; cit. *TPYL*, ch. 15, p. 4b (abridged). Tr. auct.

^f The first sentences of Ko Hung's reply concern the use of drugs which will make the body ethereally light, and he also says a few words about stilts.

^g Some texts read *huan*,⁸ 'disposed in a ring', but the technical sense is not much altered thereby.

^h This phrase might also be translated 'rushing wind' or 'violent wind', or alternatively 'wind from very high in the sky, from the four stars of the box of the Great Bear'. The idea of speed, it is important to note, is contained implicitly in the expression 'hard wind'.

ⁱ The distance which Ko Hung happens to mention would be equivalent to about 65,000 ft. Today meteorological balloons commonly reach this height, and manned balloons have been as high as 100,000 ft. About 40,000 ft. is an operational level for stratosphere flying. Rockets, of course, have reached far out beyond Ko Hung's wildest dreams, but this Section was first written before the sputnik and cosmic-vehicle age had dawned.

^j A reference to Chuang Tzu?

¹ 道 ² 飛車 ³ 還鯢以引其機 ⁴ 罡風 ⁵ 太清
⁶ 氣 ⁷ 劉炁 ⁸ 環

rush forward effortlessly (lit. automatically) (gliding)." This account comes from the adepts (*hsien jen*¹), and is handed down to ordinary people, but they are not likely to understand it.'

For the beginning of the +4th century this is truly an astonishing passage, and if it can be equalled by any Greek parallel, one would be glad to know the reference. There can be no doubt that the first plan which Ko Hung proposes for flight is the helicopter top; 'returning (or revolving) blades' can hardly mean anything else, especially in close association with a belt or strap. This kind of toy was termed in 18th-century Europe the 'Chinese top',^a though it seems to have been known in the West already in late medieval times.^b In +1784 it attracted the attention of Launoy and Bienvenu in France^c who made a bow-drill device drive two contra-rotating propellers consisting of silk-covered frames (Fig. 706).^d In +1792 it stimulated Sir George Cayley, who may truly be called the father of modern aeronautics, to his first experiments on what he afterwards called 'rotary wafts' or 'elevating fliers'. He tells us so himself in the paper which he contributed to *Nicholson's Journal*^e in 1809, and he too used a bow-drill spring to work two feather air-screws which kept the top mounting into the air.^f The ordinary 'Chinese top' was simply an axis bearing radiating blades set at an angle, and given a powerful rotation by the pulling of a cord previously wound round the stem, hence Ko Hung's reference to leather straps. One of its commonest names in China was the 'bamboo dragonfly' (*chu chhing-thing*²).^g Figure 707 is a diagram drawn by Cayley himself which he sent to a French engineer, Dupuis-Delcourt,^h in 1853, saying that while the original toy would rise no higher than 20 or 25 ft., his improved models would 'mount upward of 90 ft. into the air'.ⁱ This then was the direct ancestor of the helicopter rotor and the godfather of the aeroplane propeller.

There can be little doubt that the helicopter top was connected in its origin with the hot-air zoetrope (*tsou ma têng*³), which has already been discussed in the physics Section (Vol. 4, pt. 1, p. 123), and with the Mongol prayer-wheel operated by a chimney

^a The first appearance of this toy in China is a very obscure question. Search should be made among Chinese paintings of the genre which depicts pedlars selling children's toys (cf. p. 586).

^b Gibbs-Smith (7) convincingly adduces a painting of c. +1460 at the Musée de l'ancien Evêché, Le Mans, and a +16th-century stained-glass panel in the Victoria and Albert Museum. Feldhaus (20), p. 285, fig. 191, adds a remarkable helicopter top with no less than three superimposed airscrews painted in a picture by Pieter Breughel the elder, c. +1560, and now in the Kunsthistorische Museum at Vienna. Gibbs-Smith (9) accepts Chinese provenance before Leonardo's time.

^c It is exceedingly unlikely that they knew of Leonardo da Vinci's helical screw helicopter design; Duhem (1), pp. 279 ff., (2), fig. 42b; Ucelli di Nemi (3), no. 3; Feldhaus (18), p. 149; Beck (1), p. 351, etc.

^d Cf. Duhem (1), p. 282, (2), p. 232, fig. 156a; Gibbs-Smith (1), pp. 171 ff.

^e Cayley (2), in Hubbard & Ledebor (1), vol. 1.

^f Cf. Duhem (1), p. 282, (2), p. 232, fig. 156b; Gibbs-Smith (1), p. 189, pl. II (a).

^g Many Chinese scientific friends, e.g. the entomologist Dr Chu Hung-Fu, and our colleague Dr Lu Gwei-Djen, well remember playing with them as children. See Tatin (1) for a typical 19th-century European type, powered by Pénaut's rubber motor.

^h For publication in a new aeronautical journal.

ⁱ Hubbard & Ledebor (1), vol. 1, opp. p. x; Hodgson (2), fig. 135. One of Cayley's more extraordinary designs was that for a 'convertiplane', i.e. an aircraft with helicopter screws for vertical ascent which would close to form wings when the desired altitude had been reached, horizontal motion being assured by two ordinary propellers (1843); cf. Gibbs-Smith (1), pp. 11, 143, 190, 193 ff. and pls. II (c), XXI (f). Not till 102 years later were successful vertical take-off machines of this kind built, notably the McDonnell xv (1) and the Fairey Rotodyne.

¹ 仙人 ² 竹蜻蜓 ³ 走馬燈

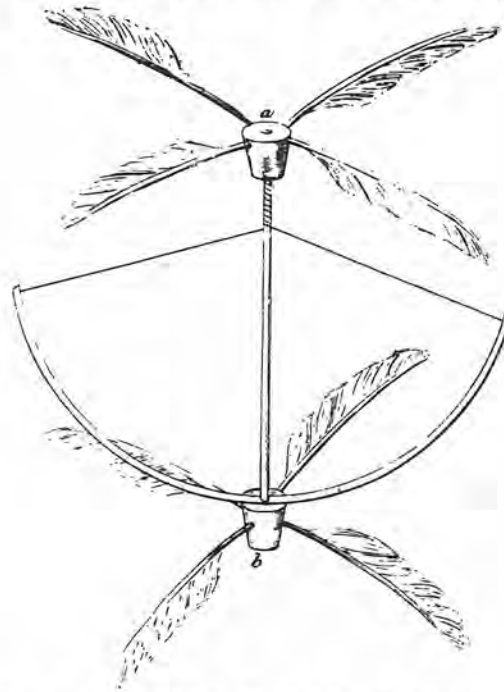


Fig. 706. The 'bamboo dragonfly' (*chu chhing-thing*) or Chinese helicopter top, studied by Launoy & Bienvenu in +1784 and by Cayley in +1792 (drawing by Cayley in 1809). A bow-drill spring rotates two feather air-screws (*a, b*) which carry the top high up into the air.

air-current, which we mentioned only a few pages above (p. 566). The use of a similar horizontal vane-wheel to work a roasting-spit, often found in the great kitchens of Europe,^a was apparently not known in East Asia. All these were essentially rotors with vanes (*yeh lun*¹), moving in relation to currents of air parallel with their axes,

^a One of these was sketched by Leonardo about +1485; cf. Duhem (2), fig. 42a; Beck (1), fig. 605; Uccelli (1), fig. 37. As we noted on p. 124 above, this was an elegant automation since the hotter the fire the faster the roast would spin. In the +16th century it was frequently described (cf. Beck (1), fig. 375; Uccelli (1), figs. 38, 40). In +1629 Branca proposed (pl. 2) to use the ascending air-current from a forge to work a small rolling-mill by means of reduction gearing, but he employed a vertical paddle-wheel, not a zoetrope vane-wheel. Conversely, there was a horizontal wheel in his famous Aeolian stamp-mill (pl. 25), but again it was a paddle-wheel 'turbine' and not a vane-wheel. Still, wind-wheels were certainly 'in the air' at this time. Branca's illustrations are often reproduced (e.g. Uccelli (1), figs. 41, 42; Schmithals & Klemm (1), fig. 46; Vowles & Vowles (1), p. 126). Lynn White (5, 7) well appreciates the connection of the spit vane-wheel with the marine screw and the aeroplane propeller. He is inclined to place it in a group of Sino-Tibetan inventions adopted by Europe in the +15th century, associating it with the horizontal windmill (p. 567 above), the ball-and-chain flywheel device (p. 91 above), and also with such cultural borrowings as the 'Dance of Death' motif (cf. Baltrušaitis, 1). If Gibbs-Smith (7) is right in his identifications, the helicopter top must be added to the list. Lynn White further makes the interesting suggestion that this 'cluster of transmissions' may be connected with the slave-trade which brought thousands of Tartar domestic servants to Italy in medieval times, and which reached its height by the middle of the +15th century (cf. Vol. 1, p. 189; further references in Lynn White, 5). On p. 544 above and in Sect. 30d we define a 'Twelfth-century Cluster' and a 'Fourteenth-century Cluster' of transmissions. Both were more important than this fifteenth-century one, but the second and third may well be due, at least in part, to the remarkable social movement of which Lynn White reminds us.

¹ 葉輪

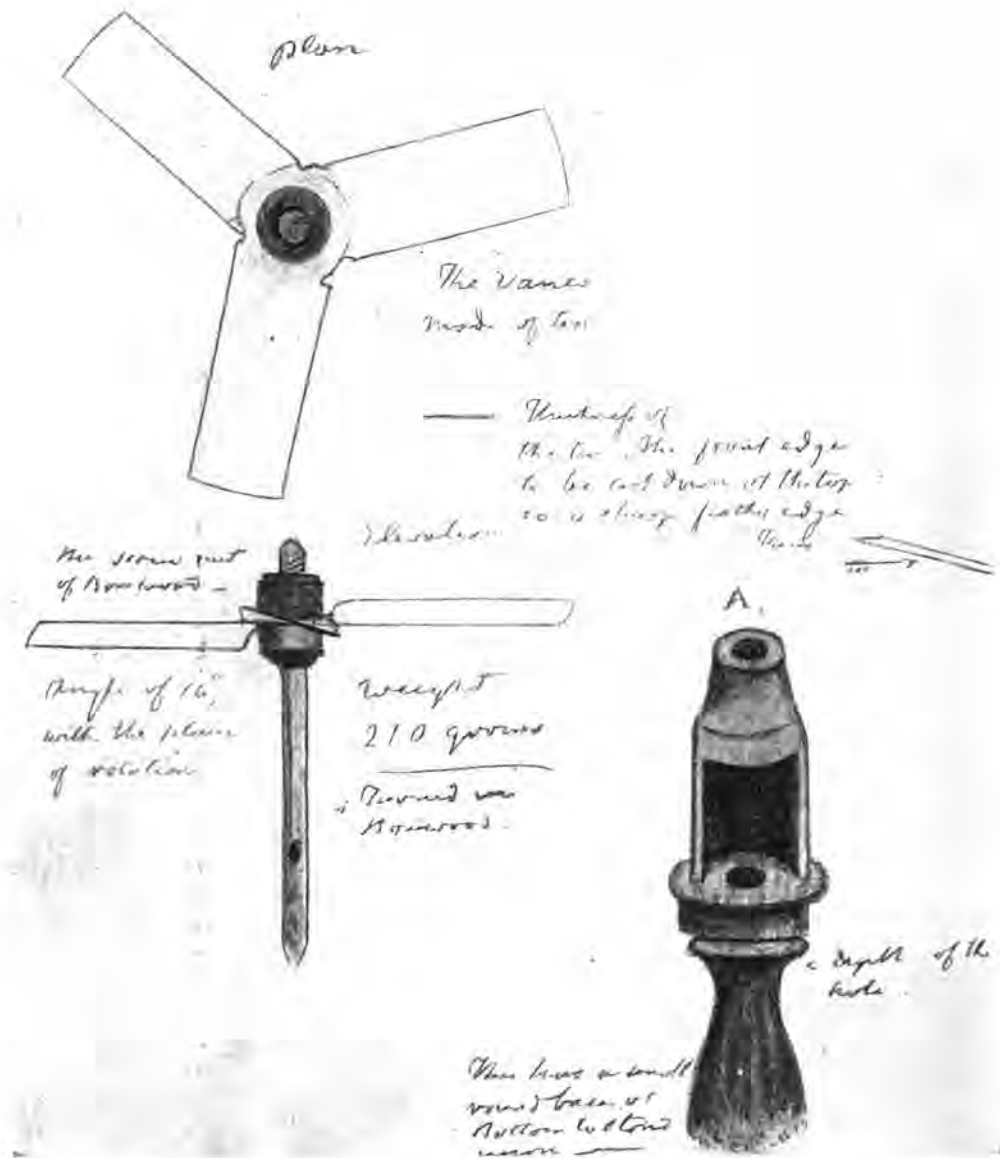


Fig. 707. Page of drawings sent by Cayley to Dupuis-Delcourt in 1853 illustrating an improved Chinese helicopter top which would mount more than 90 ft. into the air. From Hubbard & Ledebor (1). This was the direct ancestor of the helicopter rotor and the godfather of the aeroplane propeller.

the helicopter top ad-aerially because of the motion imparted to it by the cord, the zoetrope and the prayer-wheel ex-aerially because of the ascending current of hot air. But since the aeroplane propeller had to be vertically mounted, not only to bring about motor transportation (as the marine screw propels the ship), but to assure the airborne character of the flying-machine itself by driving the wings forward and so providing the necessary airstream lift, it was likely to spring from the European rather than the Chinese engineering tradition. For time after time in the present book we have shown that Chinese technicians preferred horizontal mountings and Westerners vertical ones.

The role of the vertical windmill in the generation of the aeroplane propeller has been particularly well appreciated by Gibbs-Smith.^a Some twenty years before the practical work of Launoy and Cayley, an obscure French mathematician, Alexis Paucet (1), revived (it seems quite independently)^b the idea of Leonardo for a helicopter screw, but he added to his proposed *aeronef* or 'ptérophore' an air-screw for horizontal motion—both being of the continuous Archimedean or marine variety (1768).^c Significantly, he entitled his book a contribution to the 'theory of windmills'. But it seems that Vallet was the first to try out a vertical ad-aerial air-screw in practice when in 1784 he attempted, fruitlessly, to move a river-boat by a hand-operated propeller.^d The same year however saw a successful ascent by Blanchard and Sheldon at Chelsea in a balloon equipped with a single hand-driven propeller, most significantly called a 'moulinet'.^e The effect it produced was of course minimal, and Blanchard later suggested that steam power would some day be employed to drive it. Also in 1784 Meusnier^f proposed that an elongated balloon should be fitted with three propellers in series, thus anticipating the dirigible.^g But this took a long time to develop, and it was 1843 before the propellers of Monck Mason's clockwork-powered model airship carried it the length of a London hall.^h Though full-size dirigibles became feasible by the end of the ensuing decade,ⁱ another development in this same year was even more significant for the future, namely the design of W. S. Henson for an 'aerial steam carriage' which fitted propulsive air-screws to a fixed-wing aeroplane.^j

The transition from the spatial position of the helicopter rotor to that of the aeroplane propeller had however already been made (at the ex-aerial level) in China. Liu Thung,¹ in his early 17th-century *Ti Ching Ching Wu Lüeh*² (Descriptions of

^a (1), pp. 3, 5, 170 ff.

^b His inspiration was derived explicitly from the Archimedean screw.

^c See Duhem (1), pp. 280 ff. Paucet also suggested the use of screw propulsion for ships.

^d Gibbs-Smith (1), pp. 8, 170 ff.

^e *Ibid.* pp. 170, 336 ff.; illustration in (3). Vallet also experimented with a propeller attached to the gondola of a balloon. The year 1784 was a kind of *annus mirabilis*, for as we have already seen Launoy & Bienvenu were at the same time working on their helicopter top. Moreover the previous year had seen Montgolfier's invention of the first practical balloon.

^f He could not have had a more appropriate surname.

^g See Uccelli (1), p. 893, fig. 16; Duhem (2), p. 224, fig. 151; Gibbs-Smith (1), p. 171, (3).

^h Gibbs-Smith (1), p. 337, (3).

ⁱ Notably Giffard's airship of 1852.

^j This impressive design is frequently reproduced; see Brooks (2), fig. 214; Schmithals & Klemm (1), fig. 120; Gibbs-Smith (1), pl. 11 (e); Needham (42).

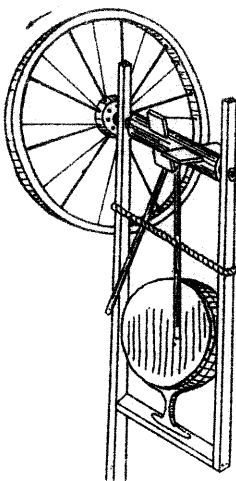
¹ 劉侗

² 帝京景物畧

Things and Customs at the Imperial Capital),^a says that after kite-competitions were forbidden, many-coloured wind-wheels (*fēng chē*¹) were made,^b which when set up facing the wind (*ying fēng*²), or rapidly carried in the hand, whirled round showing their red and green colours confusingly. The arms of these wind-wheels, which were of course vertically mounted,^c were also used (in strange echo of Heron) to do work as lugs by depressing a lever and beating a drum (see inset). There is room for some surprise, at first sight, that such things as the helicopter top and the zoetrope, with blades or vanes set screw-fashion, should have originated in China, a culture to which the screw and worm were, as we have seen (p. 124 above) essentially foreign. Evidently the setting of vanes at a skew angle so as to constitute flat surfaces tangent to the curves of a worm, and thus give or receive motion, did not involve the invention of the continuously curving forms of the screw.^d

In quite a different manner, moreover, Chinese technology had already prepared the way for those vertically mounted rotary roars which would one day send the wings of aircraft tearing through the heavens. At an earlier stage (pp. 150ff.) we saw how advanced the medieval Chinese technicians were in their construction of rotary fans, notably the winnowing-fan used in agriculture, but also air-conditioning fans for palace halls. All these were vertically mounted just as propellers would one day be, and although they gave radial rather than axial flow, the rotary blowers of China preceded those of Europe by some fifteen centuries.

Perhaps the most extraordinary prefiguration occurred when the Chinese toy-makers proceeded to fit Liu Thung's wind-wheels to children's kites. Early in the present century these were quite common at Nanking.^e Such ex-aerial wheels rotating just for joy on cambered wings exactly at the time when the aeroplane, with all its



^a Quoted by Liu Hsien-Chou (1), pp. 68 ff.

^b Note the ambiguity of the term; cf. fn. (e) on p. 561 above.

^c 'Pinwheels' set up to make a noise in the wind are fairly common in south-east Asia, e.g. Bali (cf. Bateson & Mead, 1). Other such playthings can be seen in the paintings of Hieronymus Bosch (c. +1500); Gibbs-Smith (1), p. 171. It would be important to establish the time of first appearance of toy wind-wheels in China. This could perhaps be done by studying one of the subjects which the old Chinese artists delighted to paint, namely the pedlars of children's toys. Here a preliminary reconnaissance found none in the painting of this kind by Su Han-Chen³ (c. +1115 to +1170) reproduced by Cohn (2), pl. 77. But there is another by Wang Chen-Pheng,⁴ dated +1310, which shows at least two, perhaps four; two look like small vertically-mounted anemometers, and one seems to be of the folded-paper type. This picture will be found in Sirén (10), vol. 6, pl. 47.

^d Nor did that wonderful invention of the aboriginal Australians, the boomerang, closely related though it is to the helicopter rotor and the gyroscope (cf. Duhem (1), pp. 269 ff.). Of course, such a failure is easier to understand in a culture which remained at so primitive a level of general technology.

^e Personal recollection of Dr Lu Gwei-Djen. We shall see presently that they may have stimulated Chinese artists' conceptions of aerial voyages in the novels which they illustrated.

¹ 風車

² 迎風

³ 蘇漢臣

⁴ 王振鵬

potentialities for good and evil, was being born, might almost symbolise contrasting conceptions of civilisation.^a

Let us now return to Ko Hung. His words about the series of different kinds of animals would be incomprehensible if we did not know well the perennial Chinese tradition of making kites in the shapes of animals.^b I have no doubt that what he was referring to were man-lifting kites, and though as yet we have no evidence that Ko Hung or any of his contemporaries constructed such large instruments, there would have been really nothing to prevent it. For people expert in kite-flying the possibility was obvious.^c And it happens that we do possess from a time not long after that of Ko Hung himself, a remarkable account of this very thing.

The setting was the reign of a cruel and tyrannical emperor in a short-lived dynasty, Kao Yang,¹ Wên Hsüan Ti of the Northern Chhi, who ruled from +550 to +559. Though we may not need to believe all that we are told of his excesses, there is no doubt that humane Confucian government was at a discount in his time. One of his more peculiar methods of punishment was to make his prisoners participate in dangerous experiments on flight. Thus in the chapter in the *Sui Shu* on the history of law we find the following:^d

On one occasion the emperor visited the Tower of the Golden Phoenix^e to receive Buddhist ordination. He caused many prisoners condemned to death to be brought forward, had them harnessed with great bamboo mats (*chhü chhu*²) as wings, and ordered them to fly down to the ground (from the top of the tower). This was called a 'liberation of living creatures'.^f All the prisoners died, but the emperor contemplated the spectacle with enjoyment and much laughter.^g

This was by no means the first time in Chinese history that trials had been made of wing-beating or ornithopter flight. As far back as the beginning of the +1st century there had been a well-authenticated attempt to imitate avian motions, though the name of the inventor has not been preserved.^h In +19, Wang Mang, the only Hsin emperor, pressed by the nomadic warriors on the north-west frontiers, mobilised all who professed to be the masters of strange arts, and had them put to practical test.

^a Some time after writing these lines, I was interested to find a remark by Wu Nan-Hsün (1), p. 169, that in China the kite began by being applied to war-like purposes and ended as a children's toy. With this as a text for a sociological discourse, much could be said.

^b Chadwick (1) and others have reproduced 18th-century pictures of Chinese kite-flying which show this. Wei Yuan-Tai (1) illustrates contemporary examples. Cf. Fig. 704b.

^c It has been said that man-lifting kites are shown in medieval Chinese paintings (Duhem (1), p. 201), but this we have not been able to confirm.

^d Ch. 25, p. 10b, tr. Balazs (8), p. 56, eng. auct.

^e This was one of three at the north-west of the capital (Yeh, near modern Lin-chang, north of the Yellow River). It was the tallest of them, about 100 ft. in height.

^f A Buddhist practice for acquiring merit; birds and fishes were let go after being caught. But pre-Buddhist also, and *Lieh Tzu* cannot be dated thereby (cf. Bodde, 19).

^g The commentary in *TCTC*, ch. 167 (p. 5189) says that any prisoner who descended successfully was to be pardoned. We have already come across another instance of the use of prisoners in experiments (Vol. 2, p. 441). That was for testing alchemical elixirs about +400. We shall return to the matter in Sect. 33; meanwhile see Ho Ping-Yü & Needham (4).

^h The incident has already been referred to, Vol. 1, p. 110 above.

¹ 高洋

² 遺錄

One man said that he could fly a thousand *li* in a day, and spy out the (movements of the) Huns. (Wang) Mang tested him without delay. He took (as it were) the pinions of a great bird for his two wings (*ta niao ho wei liang i*¹), his head and whole body were covered over with feathers,^a and all was interconnected by means of (certain) rings and knots (*huan niu*²).^b He flew a distance of several hundred paces, and then fell to the ground. (Wang) Mang saw that the methods could not be used, but wishing to gain prestige from these (inventors) he ordered that they should be given military appointments and presented with chariots and horses, while waiting for the army to set forth.^c

This attempt, then, forms an early Chinese link in the long line connecting the Daedalus legend with Meerwein^d and even with Lilienthal. Ko Hung must certainly have known about it. One feels some difficulty in drawing any sharp distinction between the wing-beating 'tower-jumpers', as modern historians of aeronautics like to call them, and the eventually successful gliders, for some of the former (no doubt fortuitously) glided long enough before landing to survive. So although the first true glider flights were those of Cayley's passengers in 1852 and 1853, the idea has very ancient origins. After all, birds themselves glide on motionless planes as well as beating their wings in their ascent. We must therefore place Wang Mang's pioneer, as well as the back-room experts of Kao Yang, in that line of temerarious bird-men^e which runs through the Saxon monk Aethelmaer in the +11th century^f to the numerous experimenters of the +17th and +18th^g of which Meerwein was one of the most intelligent. The wild youth of the ornithopter endeavour ended with the Montgolfier period; whether it has a future, who can say?

But there was something more interesting in the wicked emperor's proceedings of +559 than the crude imitation of birds. The *Tzu Chih Thung Chien* (Comprehensive Mirror of History for Aid in Government), drawing upon other contemporary official sources, says:^h

Kao Yang made Thopa Huang-Thou³ (Yuan Huang-Thou⁴) and other prisoners take off from the Tower of the Golden Phoenix attached to paper (kites in the form of) owls (*ko chheng chih chhih i fei*⁵). Yuan Huang-Thou was the only one who succeeded in flying as far

^a There was probably some magic in this; cf. p. 569 and what has been said about the feathered immortals in Vol. 2, p. 141. We can be sure that Wang Mang's inventor was a Taoist.

^b Hinges and pivots are also implied.

^c *Chien Han Shu*, ch. 99c, p. 5b, tr. auct. adjuv. Dubs (2), vol. 3, p. 382. We have to thank Prof. Liu Hsien-Chou for drawing our attention again to this passage.

^d C. F. Meerwein, architect to the prince of Baden, built and tested a flying-machine in 1781; see Duhem (1), p. 231, (2), p. 204, fig. 137; Gibbs-Smith (1), pp. 311 ff. It was really a glider in which the pilot lay prone under an elongated ovoid wing with sharp ends and upward convexity. The surface necessary to support a man was correctly calculated, and the dihedral angle of the two halves of the monoplane could be altered only slightly. This was the moment when beating wings gave place to adjustable but essentially motionless wings.

^e Cf. Duhem (1), pp. 110, 150, 167, 210, 222, 229, 231; Hodgson (2); Gibbs-Smith (1), pp. 3 ff., 6 ff., 12.

^f Better known as Eilmer (or, erroneously, Oliver) of Malmesbury; he was an old man in +1066; cf. Sarton (1), vol. 1, p. 720; Lynn White (6).

^g E.g. Guidotti (+1628), Besnier (+1678), de Bacqueville (+1742), etc.

^h Ch. 167 (p. 5189), tr. Balazs (8), p. 132, eng. auct.

¹ 大鳥翮爲兩翼

² 環紐

³ 拓跋黃頭

⁴ 元黃頭

⁵ 各乘紙鸞以飛

as the Purple Way, and there he came to earth. But then he was handed over to the President of the Censorate, Pi I-Yün,¹ who had him starved to death.

Here the context was the destruction of the Thopa and Yuan families which had been the ruling houses of the Northern, Eastern and Western Wei dynasties. In this, the last, year of the tyrant's reign, there had been a massacre of no less than 721 surviving members of these families, and Yuan Huang-Thou was himself a prince of the Wei.^a For us of course the technical aspects are the main interest, and it is quite remarkable that in these experiments kites were used. Since the imperial road called the Purple Way was 5 *li* (about 2½ km.) north-west of the city, the prince succeeded in 'riding on the hard wind' for a considerable distance. Moreover, the circumstances show that what was going on was not quite simply a cruel emperor's sport with prisoners, for the cables of the kites must have required man-handling on the ground with considerable skill, and with the intention of keeping the kites flying as long and as far as possible.

Thus we have one circumstantial account of man-lifting kites within a couple of centuries of Ko Hung's time, and others are probably still buried in the texts. By the time when Marco Polo was in China (c. +1285) man-lifting kites were in common use, according to his description,^b as a means of divination whereby sea-captains might know whether their intended voyages would be prosperous or not.

And so we will tell you [he says] how when any ship must go on a voyage, they prove whether her business will go well or ill. The men of the ship will have a hurdle, that is a grating, of withies, and at each corner and side of this framework will be tied a cord, so that there be eight cords, and they will all be tied at the other end to a long rope. Next they will find some fool or drunkard and they will bind him on the hurdle, since no one in his right mind or with his wits about him would expose himself to that peril. And this is done when a strong wind prevails. Then the framework being set up opposite the wind, the wind lifts it and carries it up into the sky, while the men hold on by the long rope. And if while it is in the air the hurdle leans towards the way of the wind, they pull the rope to them a little so that it is set again upright, after which they let out some more rope and it rises higher. And if again it tips, once more they pull in the rope until the frame is upright and climbing, and then they yield rope again, so that in this manner it would rise so high that it could not be seen, if only the rope were long enough. The augury they interpret thus; if the hurdle going straight up makes for the sky, they say that the ship for which the test has been made will have a quick and prosperous voyage, whereupon all the merchants run together for the sake of sailing and going with her. But if the hurdle has not been able to go up, no merchant will be willing to enter the ship for which the test has been made, because they say that she could not finish her voyage and would be oppressed by many ills. And so that ship stays in port that year.

^a Cf. *TH*, p. 1235.

^b Moule & Pelliot ed., vol. 1, pp. 356 ff. The account survived only in the 'Z' MS. version, one of the most complete but also one of the rarest. Delighted at discovering this passage in the winter of 1960, I did not know that Lynn White (6) had also come upon it, but it was good to have his confirmation of my interpretation. It was probably, as he says, because this text had so little circulation that the idea of the man-carrying kite was not followed up in Europe for nearly three centuries. Only from +1589 onwards did della Porta mention it in his section on the 'flying Sayle' in *Magia Naturalis*.

¹ 畢義雲

Surely this was one of the strangest sights to be seen in the fabled +13th-century ports of Zayton and Khanfu.

The wonders of modern aviation have thrown kites so much into the background that it is generally quite forgotten that they could ever supply sufficient lift to carry human beings into the air.^a Yet this development played its part in the history of aviation. A number of tentative trials of this kind took place from the time of Pocock about 1825 onwards (Simmonds; Biot; Cordner; Wise, etc.),^b but full success was not attained until the work of B. F. S. Baden-Powell in 1894.^c Here a turning-point was the invention of the Australian Hargrave in the nineties, who (as we have seen, p. 582) devised the box-kite of rectangular cells, and thereby produced one of the precursors of the biplane.^d By 1906 it was possible for a man to remain for an hour at a height of 2600 ft. suspended by a train of kites.^e The significance of this was great. Only a few years before, Alexander Graham Bell had written: 'a properly constructed flying-machine should be capable of being flown as a kite, and conversely, a properly constructed kite should be capable of use as a flying-machine when driven by its own propellers'.

Lastly, what is to be said of Ko Hung's 'hard wind'? From the examples he gives of the gliding and soaring of birds, it is obviously nothing else than the property of 'air-lift', the bearing or rising of the inclined aerofoil subjected to the forces of an airstream, whether natural or artificial. It will not be forgotten that we have met with the 'hard wind' of the Taoists before (Vol. 3, pp. 222 ff. above), in the astronomical Section, where its role as a natural cause of planetary or stellar motion came in for remark. It was there suggested that someone had observed the high resistance of a strong current of air from the orifice of a metallurgical tuyère. But Ko Hung applies the concept very clearly to gliding flight, as indeed had Chuang Chou before him, when he wrote about the wings of the giant *phêng*¹ bird being airborne upon the density (*chi hou*²) of the wind beneath.^f Ko Hung ends by attributing to him the idea that flying things rise up 'using the clouds as steps', which may be more than a poetic metaphor, hinting as it does at the existence of those ascending air-currents which modern glider pilots have learnt so well to utilise. Something of these could probably have been observed in the behaviour of smoke, and particularly of the mists and clouds

^a Nothing need be said here of that other great service which the Chinese kite performed for modern science in the hands of Benjamin Franklin when in +1752 he identified the electricity of the lightning flash with that of the Leiden jar. Three years earlier Alexander Wilson had used a battery of kites to carry thermometers to a height of 3000 ft. to determine the temperature of the clouds (Pledge (1), p. 317).

^b Descriptions in Hodgson (2); Vivian & Marsh (1), p. 56; Duhem (1), p. 201; Gibbs-Smith (1), pp. 12, 16, 46, 162.

^c Gibbs-Smith (1), pp. 34, 162. Great improvements were made by S. F. Cody from 1901 onwards (cf. p. 568).

^d Cf. Gibbs-Smith (1), pp. 337 ff.

^e Vivian & Marsh (1), p. 189. Figure 708 shows a kite-train bearing aloft a military observer at the Rheims meeting of 1909. On this cf. Gibbs-Smith (1), p. 247; Broke-Smith (1).

^f See Vol. 2, p. 81 above. After all, the augurs had been watching bird flight for a very long time (Vol. 2, p. 56 above). But they had been doing so in the West too.



Fig. 708. A train of kites bearing aloft a military observer (Lt. Bassel) at the Rheims aeronautical meeting of 1909 (Vivian & Marsh, 1).

on the lofty mountain heights which the Taoists delighted to frequent.^a And so we end our study of one of the most remarkable (indeed prophetic) ancient texts on the prehistory of aviation which any literature can show.

(5) THE BIRTH OF AERODYNAMICS

Let us now attempt to place all this in correct perspective with regard to the growth of aeronautical science and practice. Leaving aside for the moment the development of aerostatic machines (the balloon was really a product of 18th-century pneumatic chemistry), and of jet-propulsion (for we must treat of the Chinese invention of rockets elsewhere, in Section 30), we may concentrate attention upon wings or aero-foils, and air-screws. Man's attention (at least in the West) was attracted first by the beating of the bird wing, its gliding properties being neglected; hence Leonardo's main interest was, as we have seen, in flying-machines on the flapping or ornithopter principle.^b The decisive contribution of Alfonso Borelli, in his *De Motu Animalium* of +1681, was to show that human muscles were anatomically and physiologically incapable of providing motive power for unaided winged flight with the materials then available, and there the matter rested. But the idea of beating wings was very tenacious. The first conception of powered flight still envisaged them,^c and so did the first dissociation of the bearing function from the propulsive function.^d It was George Cayley at the beginning of the 19th century who broke completely with the old obsession, and became the precursor of Lilienthal and the Wrights rather than the successor of Aethelmaer and Leonardo.^e As we know from the Cayley papers,^f he was the first to analyse the aerodynamic properties of the atmosphere by physical means, the first to lay down the scientific principles of heavier-than-air flight, the first to experiment with a captive plane at various angles of incidence,^g the first to make model and full-size glider aeroplanes with rudders and elevators and to test them in free flight, the first to discuss streamlining and the 'centre of pressure' of a surface in an air-stream, the first to realise that curved wings give a better lift than flat ones, and to recognise the existence of a low-pressure region above them, the first to suggest multiple superimposed wings, and the first to state that the lift of a plane varies as the square of the relative air-speed multiplied by the density. All this was done in a single decade, between 1799 and 1810. How great a pioneer Cayley was may be appreciated

^a Cf. the observation of Cotte in +1785 that certain cloud layers might move in directions quite different from that shown by the weathercock at ground level (Duhem (1), p. 188). See also Scorer (1) on lee waves in the atmosphere.

^b Cf. pp. 575, 583 and Hart (1, 2, 4).

^c John Wilkins, in his *Mathematical Magick* of +1648, suggested the use of a steam-engine, Bk. 2, chs. 6-8.

^d Tito Livio Burattini, a Venetian engineer in the service of the King of Poland, built in +1647 at Warsaw a model aircraft which had four fixed glider wings as well as others which were made to beat; cf. Duhem (1), pp. 161 ff.

^e We speak here of Leonardo da Vinci theoretically, for it is certain that his projects could have exercised no influence on the development of aviation before the latter part of the 19th century; see Gibbs-Smith (1), pp. 187 ff.

^f Edited by Hodgson (3). Cf. Gibbs-Smith's summary of his achievements, (1), pp. 10, 189, (8).

^g The 'whirling-arm' he used for this was an 18th-century device with which Robins had studied ballistics (+1746) and Smeaton windmill sails (+1759).

even further when we remember his studies on the air-screw, arising from the Chinese top, already mentioned; his anticipation of the internal combustion engine; and his practical and rational proposals for applying power to balloons. Thus the dirigible, adumbrated by Meusnier and others in +1784, became a reality with Giffard in 1852, and in due course handed over its propellers to their more onerous duties in heavier-than-air flying-machines.

Cayley was not indeed the first to see the importance of the Chinese top, for Launoy and Bienvenu in +1784 had already successfully experimented with it, and Paucton even earlier, in +1768, had proposed both the helicopter rotor and the vertical air-screw propeller. Although he himself worked from first principles, his position in history is a singularly focal one, the junction-point of Western vertical and Chinese horizontal mountings, as they contributed to modern aeronautical engineering. The first model aircraft (in the modern sense) to fly on the helicopter principle, however, was that of W. H. Phillips in 1842; the same year in which Henson began to patent a design basically similar (as we have seen, p. 585) to that of a modern twin-engined monoplane.^a The first 'modern' powered model aeroplane was built on this pattern in the same decade by Henson & Stringfellow, but it could hardly sustain itself and made only slow descending power-glides. Thus it was 1857 before the first model was made which would take off under its own power, fly freely for some distance and land safely. This was the achievement of Félix du Temple de la Croix, employing first clockwork and later steam.^b After his work many experiments with models were made, and with them it was possible to study such important phenomena as stalling.^c Aerofoil design, with the realisation that the upper surface of the wing must be convex, was advanced in the work of Wenham (1866), Pénaud (1876) and others, while the last decades of the century saw widespread empirical work with full-scale gliders.^d Finally in 1903 came the first successful full-scale flying by the Wright brothers, using the internal combustion engine and an aeroplane in all fundamental respects identical

^a Gibbs-Smith (1), p. 13; the model of W. H. Phillips was steam-driven and the blades were rotated by jets from their tips—a remarkable anticipation of current practice.

^b Gibbs-Smith (1), pp. 15, 314 ff.; in 1874 du Temple's full-scale steam-powered aeroplane just succeeded in being airborne for a short distance after taking off down an inclined ramp.

^c As the angle of attack of a wing is increased, the lift coefficient rises from zero at the 'no-lift angle' to a maximum (about 16°) at which 'stalling' occurs and the aircraft ceases to fly, rolls violently, and enters a falling spin. The cause of this is the separation of the airstream from the upper surface of the wing, causing turbulence near the trailing edge, consequent drag, sudden reduction of lift, and backward motion of its line of action. The result is a tendency to pitch forwards and dive uncontrollably, and rolling occurs because the stall usually occurs on one wing first. Movable flaps which can be lowered at the trailing edges of the wings increase the lift at the slow speeds necessary for landing. By inserting slots in the wing (now usually a single slot along the wing's leading edge, with a slot of roughly aerofoil cross-section forward of it), Handley-Page found that the stalling angle could be raised to 26° or more. The reason is that the smooth stream of air leaving the trailing edge of the slot prevents the separation of the flow from the upper surface of the wing and the consequent reduction of lift. The great practical value of this device is that it allows of a greater lift coefficient and therefore much slower landing speeds. Although the turbulence which occurs in stalling is incidental, there is reason to believe that the remarkable invention of the slotted wing may have been suggested by the fenestrated rudders of Chinese ships, which will be described below in Sect. 29*h* (private communication from Prof. E. V. Telfer). Sir Frederick Handley-Page tells me, however, that he cannot now remember such a stimulus.

^d Otto Lilienthal, P. S. Pilcher, O. Chanute and others, whose deeds are recounted in Gibbs-Smith (1), pp. 28 ff.



Fig. 709. Pictures from the *Ching Hua Yuan*, a novel by Li Ju-Chen written about 1815, adumbrating practical aircraft. The illustrations were provided for the edition of 1832 by Hsieh Yeh-Mei. A scene from ch. 66 shows an aerial car with four road-wheels and two screw-bladed rotors set between them on each side. The inscription says: 'The Emperor takes a flying car to consult with the Crown Prince on the publication of the Yellow Rescript (of successful candidates); while the Empress conducts the examination of the talented beauties.'



Fig. 710. Another scene from the *Ching Hua Yuan*, ch. 94, shows three flying cars each with four screw-bladed rotors taking the place of the road-wheels, and engaging with gear-wheels which seem to be connected with some hidden power mechanism. Drawing by Hsieh Yeh-Mei, 1832. The inscription says: 'The Prince of Wên-Yen, obeying orders, returns to his own country (by air); and the Erudite Girl, thinking of her parents, departs (by air) for the Mountain of the Immortals.' A veritable airport.

with those of today.^a This incorporated both the devices, the ad-aerial screw rotor and the kite wing, which Ko Hung had spoken of sixteen centuries earlier. The kite was married to the windmill.^b

Such was the key combination. Though the idea of it was implicit in Cayley's work, it remained (to use a singularly appropriate expression) 'in the air' during the first decades of the 19th century, crystallising only in Henson's famous design of 1842-3, and in the models of Henson & Stringfellow (1847) and Félix du Temple de la Croix (1857). It would be interesting indeed if Chinese imagination participated in this crucial period, and the facts are well worth examination. Duhem^c & Huard^d have both pointed out that a Chinese novel which appeared about this time was illustrated by pictures of imaginary flying-machines which combined propeller blades with kite surfaces resembling those of a biplane. This novel was difficult to identify from their descriptions,^e but it is in fact the *Ching Hua Yuan*¹ (Flowers in a Mirror), written by Li Ju-Chen² (+1763 to 1830) between 1810 and 1820.^f Published eight years later, it was reprinted in 1832, when Hsieh Yeh-Mei³ added 108 pictures, and it is in two of these that the aircraft are shown. The first (for ch. 66, see Fig. 709) shows a car amidst clouds, open save for an awning; it has four wheels as if for land travel, but between them on each side there is a screw-bladed rotor in a position analogous to that of the wheel on a paddle-wheel boat. The second (for ch. 94, see Fig. 710) is more interesting, for it shows three flying cars, each with four screw-bladed rotors taking the place of the ordinary land wheels, and, most curiously, between each of these propellers a large gear-wheel which seems to connect them with a power-source. This clearly shows that the artist had in mind mechanically driven ad-aerial (not ex-aerial) wheels. Duhem is probably claiming too much when he says^g that the rectangular bodies of the machines and the parallel awnings above them are like the lifting surfaces of a biplane. After all, even the box kite was not known in China or anywhere else at that time. But there may have been significance in something which probably was familiarly known there, namely, those children's kites fitted with toy wind-wheels which rotated as the kite flew;^h and whether or not his ideas derived from them, it seems that Hsieh Yeh-Mei did really conceive of wheels acting in some way on the air and not merely rotated by it. So ended the classical contributions of Chinese culture to aeronautics.

^a See Gibbs-Smith (1), pp. 35 ff., 224 ff.; Brooks (2).

^b So Gibbs-Smith (2).

^c (1), pp. 12, 268, (2), pp. 200-4.

^d (2), p. 29.

^e They gave it the title of 'Une Fleur dans la Neige', and one of them wrote the author's name 'Jin Ho Yuen'. I am indebted to Dr Huard, Mr P. van der Loon, and Mr Cyril Burch, for helping me to clear up the mystery. The true title refers to evanescent beauty, and the novel was of permanent social significance since it dealt with questions such as the emancipation of women, though superficially an account of fantastic adventures and strange countries; see Hummel (2), p. 473; Lu Hsün (1), pp. 329 ff; Adkins (1). The aircraft are mentioned in chs. 66, 70, 82, 85, 86, 87, 91, 94 and 95.

^f No. 4228/4231 in the catalogue of Courant (3); for translations cf. Davidson (1), p. 3.

^g (2), p. 200.

^h Cf. p. 586 above.

¹ 鏡花緣

² 李汝珍

³ 謝葉梅

(6) THE PARACHUTE IN EAST AND WEST

What remains in this Section is of comparatively minor importance, yet not without interest. On account of its great simplicity one would suppose that the parachute idea, analogous to that of the sea-anchor, would be quite old in many civilisations. Feldhaus, however, finds no instance in Europe earlier than the description by Leonardo about +1500 in the Codex Atlanticus,^a which was followed before long (perhaps quite independently) by the 'Homo volans' of Faustus Verantius (c. +1595, first published +1615, pl. 38). Historians doubt whether it was ever tried in practice before Blanchard and perhaps Montgolfier used it for animals about +1778, and the personal descents of Lenormand and Garnerin made some years later.^b

In China, however, there are much older references. In the *Shih Chi*, completed by -90, Ssuma Chhien related a story^c about the legendary emperor Shun.¹ His father Ku Sou² wanted to kill him, and finding him at the top of a granary tower, set fire to it, but Shun escaped safely by attaching a number of large conical straw hats together and jumping down. The +8th-century commentator Ssuma Chên³ understood this clearly in the sense of the parachute principle, saying that the hats acted like the great wings of a bird to make his body light and bring him safely to the ground.^d A much later, but much more circumstantial, reference occurs in the *Thing Shih*⁴ (Lacquer Table History),^e written by Yo Kho⁵ in +1214. The grandson of the great general Yo Fei is describing what he saw in Canton as a young man when his father was governor in +1192. After an interesting description of the manners and customs of the foreign community of Arab merchants established there, he speaks of their mosques and of a 'grey cloud-piercing minaret like a pointed silver pen'. Inside this there was a winding spiral staircase for the muezzin, with round look-out openings at every several tens of steps, from which the Arabs watched and prayed for their ships arriving in the spring. Yo Kho goes on:^f

On the very top there is a huge golden cock instead of the usual (Buddhist) wheels (on pagodas), but it is now short of one leg. The Cantonese people used to say that this defect dated from the time of the former governor Lei Tshung⁶ (c. +1180), when some robber came and stole it away, leaving no trace behind him. They said that one day in the market there was a poor man selling something made of pure gold. When someone picked it up and asked him how he had got it, he said 'The foreigners used to be so strict that no one could enter their establishments, but I hid above a beam for three nights and got inside the minaret with some dried food to sustain me during the daytime. Then at night I used a steel (saw) to cut it off, and hid it within my clothes, but I could not get more than one leg.' Again they

^a (1), col. 279; (18), p. 141. Cf. Ucelli di Nemi (3), no. 84.

^b Hodgson (2); Gibbs-Smith (1), pp. 165 ff.

^c Ch. 1, p. 22b, tr. Chavannes (1), vol. 1, p. 74.

^d Indian contemporaries of Ssuma Chên also describe a descent from a tower by means of 'umbrellas'; *Prabhavakacarita*, ix, 87-9, cf. Raghavan (1). The story concerns the two nephews of the Buddhist commentator Haribhadra, whom we have encountered already in connection with water-raising machinery (p. 361 above).

^e The passage was noted by Kuwabara (1), pt. 2, p. 30.

^f Ch. 11, p. 6b, tr. auct. with Lu Gwei-Djen.

¹ 舜

² 瞽叟

³ 司馬貞

⁴ 槎史

⁵ 岳珂

⁶ 雷濂

asked him how he got away, to which he replied 'I descended by holding on to two umbrellas (yü kai') without handles. After I jumped into the air the high wind kept them fully open, making them like wings for me, and so I reached the ground without any injury.' Although the robber only stole one leg, down to the present time they have never been able to repair it.

Perhaps the thief had heard some story-teller relating the tale of Shun and his father; in any case it is remarkable that his own words should have been preserved.^a All these indications must mean that the idea was current in China, but the observation of air-resistance to an outstretched fabric is so simple that it may well have originated in many places independently. Indeed it would follow merely from the use of ship sails. If the parachute principle was not developed in China as it was in later Europe, this was because it was naturally ancillary to aviation itself, a typical piece of post-Renaissance technology.

Surprisingly, however, we have unusually concrete evidence that the invention was in fact at least once a transmission to the west. The Ambassador of Louis XIV in Siam, Simon de la Loubère, who was there in +1687 and +1688, described in his *Historical Relation* the exploits of Chinese and Siamese acrobats, saying:^b

There dyed one, some Years since, who leap'd from the Hoop, supporting himself only by two Umbrella's, the hands of which were firmly fix'd to his Girdle; the Wind carry'd him accidentally sometimes to the Ground, sometimes on Trees or Houses, and sometimes into the River. He so exceedingly diverted the King of Siam, that this Prince had made him a great Lord; he had lodged him in the Palace, and had given him a great Title; or, as they say, a great Name.

Now the researches of Duhem^c have revealed that this passage was read in the following century by L. S. Lenormand, who was stimulated by it to make practical trials in +1783, from the tops of trees and buildings, which were quite successful.^d It was Lenormand who gave the parachute its present name and recommended it to Montgolfier, who fully appreciated its importance. This led to the descent of Garnerin from a balloon in +1797. There are not many cases in which so clear a line of transmission is detectable.

(7) THE BALLOON IN EAST AND WEST

The balloon may be said to be related topologically to the parachute, for a sufficient constriction of the latter's orifice turns it into the former. But physically they are quite different, for in one case the descent of a curved fabric surface is delayed by the drag of the aerial medium, while in the other, its ascent is facilitated by the presence of a medium lighter than air confined beneath it. As we have already indicated, the

^a If any reader should doubt the possibility of his feat, similar accounts collected by Kerlus (1) may prove convincing. The facts could easily be tested.

^b (1), p. 47.

^c (1), pp. 237, 248, 263, (2), pp. 232 ff.; cf. Huard (2), p. 29.

^d It is certain that Lenormand did not know of the suggestions of Leonardo, and that he was stimulated by the Siamese relation; it is almost certain that he was ignorant of Veranzio's proposal.

¹ 雨蓋

balloon or aerostat, the 'cloud captured in a bag', was a product of the pneumatic chemistry of the European 18th century.^a Remarkably enough, the first two aerial voyages ever made by man were accomplished in a single year, +1783, by Pilâtre de Rozier and the Marquis d'Arlandes in a Montgolfier hot-air balloon, and then in the following month by J. A. C. Charles and his mechanic Robert in a hydrogen balloon. The simpler of these forms, using nothing but hot air, could have originated very much earlier than this, and in fact in model form it did.

Easter merry-makers in +17th-century Europe had an entertaining trick of making empty eggshells rise in the air literally 'under their own steam'. This is reported in many books, for example Jacques de Fontenay's poem *L'Oeuf de Pasques* of +1616, which describes it as a traditional custom.^b The procedure was simple enough, requiring only a little deftness; the contents of an egg being emptied through a small hole and the shell very carefully dried, the right amount of dew (pure water) was introduced and the hole closed with wax. Then in the hot sun the egg would move uneasily, grow light, and rise up into the air, floating a moment before falling.^c How ancient this trick was in Europe we do not know, but we were quite astonished to read of it in the book of Duhem because we had already come across a similar model of the lighter-than-air flying-machine in a Chinese text, not of the +17th but of the -2nd. This is the *Huai-Nan Wan Pi Shu*¹ (The Ten Thousand Infallible Arts of the Prince of Huai-Nan), that compendium of ancient Taoist techniques which we have occasion to refer to so often in this work.^d Liu An's book of secrets, if not exactly now as he himself knew it, must certainly be a Han compilation. The text says, in its usual concise way: 'Eggs can be made to fly in the air by the aid of burning tinder.' And an ancient commentary incorporated in the text explains: 'Take an egg and remove the contents from the shell, then ignite a little mugwort tinder (inside the hole)^e so as to cause a strong air-current. The egg will of itself rise in the air and fly away.'^f Thus the method of Liu An was more akin to that of the Montgolfier brothers than to that of the eggs raised by steam, since nothing but hot air was employed. The discovery of this text puts a rather different complexion on the relations of China and Europe in the prehistory of aerostatic flight.

When the present Section was first drafted we doubted whether China had had any part in this, but we are now inclined to think that the Han tradition was never lost. China was likely to be the home of hot-air balloons for several different reasons. Paper was available, as nowhere else in the world, from the Han period onwards, and

^a Cf. Duhem (1), pp. 332, 369, 370 ff., 418 ff., 437, 442 ff.; Gibbs-Smith (4), pp. 53 ff., 64 ff., 74 ff.

^b The literary references are given in Duhem (1), p. 401. Illustration in Fludd (2), p. 186.

^c The water-vapour formed by the evaporation of the dew expels the air through the pores in the shell, and ultimately when the wax melts, through the hole. The hot steam inside the egg is just sufficiently buoyant to raise the shell for a short time into the air before being dissipated itself by the same channels.

^d Cf. Sections 26 (Vol. 4, pt. 1, pp. 69, 91, 279, 316 above), 30, 33, 34, 40 and 44. On the book's bibliography, see Kaltenmark (2), p. 32, and on its comparative position in the literature of China and Europe, Ho Ping-Yü & Needham (2).

^e Normally used for making incense sticks and moxibustion cones (cf. Vol. 1, Fig. 29).

^f *TPYL*, ch. 736, p. 86 and ch. 928, p. 66, tr. auct.

¹ 淮南萬畢術

the development of the classical globular paper lanterns would have encouraged experimentation. When their upper openings were too small and the source of light and heat unusually strong, they must sometimes have shown a tendency to rise and float free of support. And indeed it is not difficult to find instances of the popular survival of hot-air balloons as an ancient sport in the Chinese culture-area. Goullart, for instance, gives a graphic description of seasonal customs involving this in the Lichiang region of Yunnan province.^a He tells us that in July, the critical month before the rainy season, the rice was already planted and the people did not have much to do, so in the evenings, besides dancing, the young men and the Nakhi girls flew hot-air balloons made of rough oiled paper pasted over a bamboo framework. With bunches of burning pine splinters underneath, these would sail up into the night air, some floating in the distance like red stars for several minutes before bursting into flame and falling far away. Duhem, again, reports similar pastimes in Cambodia.^b Medieval descriptions are still needed to fill the gap in continuity, but it is probable that further search will reveal them. The Han evidence and the ethnological evidence together make a *prima facie* case for a perennial Chinese tradition, and indeed it is very unlikely that the tribal people and peasants of north-western Yunnan derive their proceedings from the France of Montgolfier.^c

It might even be urged that a practice originally Chinese was brought to the knowledge of Europeans at the time of the Mongol invasions. Much evidence has been collected from eastern European chronicles^d that hot-air balloons shaped like dragons were used for signalling or as standards by the Mongol army at the Battle of Liegnitz in +1241, and this is accepted as assured by many writers.^e Certainly many of the early +15th-century German works on military technology, such as the MSS. of Konrad Kyeser's *Bellifortis*, show drawings of horsemen holding what appear to be flying dragons in the air on the end of cords.^f He states that they contained oil-lamps as well as combustibles to give an effect of vomiting forth fire. It is rather difficult to evaluate these descriptions and pictures, which in some respect recall kites rather than hot-air balloons, and the subject needs further study, but we are inclined to believe that a considerable aerostatic element was involved.^g Whatever the arrangements actually were, they seem to have continued into the +16th century, for an account of the entry of Charles V into München in +1530, with an accompanying contemporary woodcut, attests the appearance of a similar flying or floating and fire-breathing dragon.^h

^a (1), p. 178. Mr Wei Tê-Hsin remembers 'ke ploys in Fukien.

^b (1), p. 409.

^c This presents a case somewhat parallel to that of the Cardan suspension seen above, p. 233. Gimbal lamps in their nests of pivoted rings made during the last two centuries on the frontiers of Tibet derive much more probably from the Chinese tradition beginning with Ting Huan in the +2nd century than from the Italy of Jerome Cardan.

^d See Hennig (1); Feldhaus (8, 15, 20).

^e See Feldhaus (1), cols. 653 ff.; Forbes (4a); Plischke (2). Large paper lanterns for signalling are often referred to in Chinese accounts of military operations, as at the siege of Khaifeng by the Mongols in +1232 (*TCKM*, pt. 3, ch. 19, p. 50a; cf. p. 577 above), but we have not met with any statement that they floated in the air.

^f See Berthelot (5); Feldhaus (1), *loc. cit.*, and others.

^g Duhem (1), for example, pp. 404, 411, 412, is sceptical, but reproduces the illustrations, (2), pp. 36 ff., figs. 17, 18. Cf. the dragon standards of Romans and Parthians (Feldhaus (1), col. 198).

^h Bassermann-Jordan (1), pp. 64 ff.

If some of these creatures had an orifice behind as well as at the front, they were perhaps precursors of the wind-sock. And here again there is an East Asian background, for Tissandier (6), describing some of the kites of Japan, mentions and depicts a huge hollow paper fish with a large open mouth and a smaller opening at the rear, which was used for decoration and as a sensitive wind-vane or weathercock. As he was writing in 1886, no reverse influence from occidental aviation technology could have been in play, and if the wind-sock was found in Japan it had almost certainly been in China earlier.

Perhaps these phenomena may have some relation to the ideas of Albert of Saxony (+1316 to +1390),^a who imagined that things might float at the surface between the sphere of air and that of fire, just as they floated at the surface between water and air. Could he have known of the Mongol hot-air dragon-standards? In any event, his suggestion stimulated the Jesuit Caspar Schott in +1658, who was the first to speak of the possibility of aerostatic flight.^b Schott also discussed the flying eggs of de Fonteny and others. Then in +1709 came the activities of the Brazilian priest Fr Gusmão, who succeeded in burning the curtains of the King of Portugal's audience hall with a model Montgolfière.^c Barely eight decades had then to pass before men were truly in the air. Thus by tracing a tenuous thread, illuminated only very fitfully, we come back to a view often formerly held on less secure evidence, namely that China did play a considerable part in the prehistory of the balloon and the airship.

So far as we know, traditional China carried out no aerostatic experiments of Montgolfian scale and daring.^d But the great interest taken by Chinese scholars, however, in the news which came from France in the penultimate decade of the +18th century, might bear witness to the existence of certain traditions. In one of his most curious letters, written from Peking on 15 November +1784 (just a year after the first Paris ascents), the Jesuit J. J. Amiot (4) described the interest which the literati were showing, and said that they were disposed to reconsider in a Montgolfian light ancient stories long dismissed as fables. Amiot himself, no disparager of ancient China's sages, wondered whether perhaps Huang Ti or Shen Nung might not have known of some fluid lighter than air long since forgotten. 'This suggestion', he added, 'I send for what it may be worth.' But there was excitement not only in the capital. The southerner Wang Ta-Hai travelled abroad in the East Indies between +1783 and +1790, making notes which he collected in his *Hai Tao I Chih Chai Lüeh* prefaced in

^a Cf. Sarton (1), vol. 3, pp. 1428 ff.

^b Duhem (1), pp. 334 ff., 339.

^c The epic, or tragi-comedy, of Fr Gusmão is a very involved story, and may be read in Duhem (1), pp. 417 ff. or Gibbs-Smith (4), pp. 53 ff., (5).

^d There is a peculiar story, generally dismissed out of hand, which may yet prove to have some basis at present unknown. Giles (9) tells us that a certain Fr Besson is said to have written in +1694 that a balloon ascended from Peking at the accession of the emperor 'Fo Kien' in +1306. But no new reign began in that year, and no emperor bore that name. Pfister (1), in his encyclopaedia of the Jesuit mission in China, knows no such Father as Besson, but there was a Joseph Besson (+1607 to +1691) who was a missionary in Syria, so the rumour may have been started by him. Curious 18th-century prints in Chinoiserie style of this aerostat, pictured as an elongated dirigible with nine gondolas, continue to appear in popular articles. Cf. Duhem (1), pp. 85, 376, 403, 409, but even he brings no solution for this puzzle; nor Feldhaus (2), p. 54.

the following year. In this he gave an account, necessarily at second hand, of the new balloon or 'sky-ship' (*thien chhuan*):^a

This boat is short and small, resembling a dome-shaped pavilion and capable of containing ten men. Attached to it there is a pair of bellows, or air-pump, of exquisite workmanship, in shape like a globe; several people work this with all their might, whereupon the ship flies up high into the heavens. There it is borne about by the winds, but if they wish to navigate it they spread sails and make use of quadrants to measure distances. When they reach their destination they take in their sails and let the ship descend. It has been reported that these ships have been burnt and injured by the sun's rays, while persons venturing in them have been scorched to death, so people hardly dare to go on using them.

This sounds like an echo of a hydrogen balloon, with a second conversation about Daedalus and Icarus occupying the same line. But it testifies to the living interest shown by Chinese scholars and travellers, conscious of their own past, in the opening phase of man's conquest of air and space.

(n) CONCLUSION

About the year 1911 an old gentleman taking a stroll in Peking had his attention drawn to an aeroplane flying overhead, but with perfect sang-froid remarked 'Ah, a man in a kite!'^b Chinese reactions to modern technology did not stop there, however, and quite a number of authors, though lacking that balanced judgment which an exhaustive acquaintance with sources both eastern and western alone could give, did not fail to maintain the emergence of occidental technology from oriental origins. Wang Chih-Chhun,² for instance, wrote:^c

The useful arts and techniques originated from the earliest generations; thus geometry was invented by Jan Tzu (Jan Chhiu,³ one of the disciples of Confucius), but later on the Chinese lost his books and Western people studied them, so that they became skilled in mathematics. So also the automatically striking clock was invented by a (Chinese) monk, but the method was lost in China. Western people studied it and developed refined (time-keeping) machines. As for the steam-engine, it really originates from (the monk) I-Hsing of the Thang, who had a way of making bronze wheels turn automatically by the aid of rushing water—all that was added was the use of steam and the change of name. As for fire-arms, they originated in the fighting at Tshai-shih⁴ in the time of Yü Yün-Wên⁵ (of the

^a Ch. 5, tr. Anon. (37), p. 55. We say necessarily at second hand, for it is quite unlikely that any Montgolfian balloons had been seen in Asia before 1800. Possibly the first were those used by the French in their invasion of Viet-Nam (Tonkin) in 1884 (cf. Lê Thánh-Khôi (1), p. 378). Several interesting contemporary Chinese prints showing these observation-balloons have been published by Tissandier (1). The French balloon corps had been started in 1877, and the same writer gives details of the corresponding Chinese unit trained by French instructors at the request of Li Hung-Chang in 1888. This was the embryo of the Chinese Air Force of today. French balloon observers were used again during the troubles of 1900, and an album of their photographs of Peking exists (Anon. 43).

^b For this story I am indebted to Mrs Ingle, formerly of Chhilu University.

^c In his *Kuo Chhao Jou Yuan Chi*⁶ (Record of the Pacification of a Far Country); an account of his ambassadorship to Russia, ch. 19; quoted *KCKW*, ch. 5, p. 284, tr. auct. Cf. p. 525.

¹ 天船

² 王之春

³ 冉求

⁴ 采石

⁵ 虞允文

⁶ 國朝柔遠記

Sung); when he defeated the enemy by the aid of certain firearms called *phi-li(-phao)*.^{1, a} Thus the wonderful techniques of Western people are all based on the remains of ancient (Chinese) inventions. How could they be cleverer than Chinese people?

Wang Chih-Chhun's reaction (about +1885) was no doubt considered chauvinistic, and when such statements reached the ears of the 'gentlemen of the world' at that time, they were laughed out of court. But the progress of sober history has swung the pendulum the other way, and there now appears more solid basis for such protests, exaggerated though they may have been, than seemed at the time. Whoever has read through the foregoing pages of this Section will allow that the balance shows a clear technological superiority on the Chinese side down to about +1400.

Historians are coming to recognise this. When des Noëttes (3) drew up his table of medieval acquisitions, he stated clearly that many of them had come from the East of Asia. We can no longer accept, wrote Carl Stephenson, the easy formula of an Italian Renaissance in which all the great scientific and technological advances arose from the rediscovery of the Greek and Latin classics. Rather they depended upon the expertise of the medieval artisans and the stimuli which these men had received from the peoples of Asia. Medieval technology, wrote Lynn White, consisted not simply of the equipment inherited from the Roman-Hellenistic world modified by the ingenuity of Western Europeans; it embodied also vitally important elements derived from the northern barbarians, the Byzantine and Near East, and from the Far East. Haudricourt (1) is more precise—'The history of technology', he says, 'is still in its childhood, but nevertheless one can affirm that the astonishing industrial development of Europe was conditioned by a previously continuous inflow of Asian novelties, Indo-Iranian in antiquity, Chinese in the middle ages.' And Febvre (2) adds: 'Europe was an Asian cross-roads'.^b

The lateness of the date at which the Europeans still thought they had a good deal to learn from the Chinese may come as something of a surprise. Greenberg (1), approaching the matter from the point of view of economic history, has pointed out that 'until the epoch of machine production, when technical supremacy enabled the West to fashion the whole world into a single economy, it was the East which was the more advanced in most of the industrial arts'. He then throws light on the genesis of the Opium Wars by showing, from many hitherto unpublished documents, that while the West was eager to get tea, silk, textiles, porcelain, lacquer, and the like, there was nothing from Europe which the Chinese at that time (late +18th and early +19th centuries) wanted in exchange.^c The East India Company resorted to the drug

^a See above, p. 421, and below, Vol. 5, pt. 1 (Sect. 30). The battle occurred in +1161.

^b Cf. also Lopez (1); Chatley (23); Middleton Smith (1); Bodde (13); Huard (2). Sometimes recognition is given to medieval technological innovations with a rather misleading emphasis. Thus Crombie (1), e.g. pp. 16 ff., is so concerned to praise the scientific achievements of the European Middle Ages that in enumerating inventions he fails to add that the majority of them were not made in Europe at all. It is true that he partly repairs this elsewhere (2).

^c This fact found classical expression in the famous edict of the Chhien-Lung emperor on the Macartney mission in +1793, translated most recently by Cranmer-Byng (1), p. 134: 'We have never

¹ 霹靂炮

traffic in order to avoid the drain of bullion from the West. So high was the prestige of Chinese 'know-how' in those days that in 1847 St Julien (4) wrote:

Il est permis de penser que pour satisfaire aux besoins des arts et servir les progrès de la civilisation, la génie des Européens trouvera par lui-même, pendant bien des siècles encore, après des essais et des efforts longtemps continués, une multitude d'inventions utiles ou bienfaisantes, que les Chinois avaient trouvées avant eux, mais qui gisent cachées dans leurs livres, et y resteront inconnues, tant qu'un gouvernement libéral et éclairé ne fera pas entreprendre, à ses frais ou sous ses auspices, soit le dépouillement, soit la traduction, des ouvrages où des procédés scientifiques et industriels, applicable à notre état social et à nos besoins, sont consignés et nettement décrits.^a

And one cannot discount his words entirely as those of a sinologist in search of financial support, for half a century afterwards the silk industry of Lyons was still organising full-scale missions^b to study the traditional procedures of the Chinese sericultural provinces.

For the details of the transmissions, in so far as it is possible to formulate them at the present stage, the reader is referred to pp. 222 ff., 544, 584 above. The only important basic machine which the Chinese did not have was the continuous screw, and for this the great development of pedals and treadles (unfamiliar in Europe) was no small compensation. Some techniques, such as the water-wheel, evolved in parallel in the two civilisations. Perhaps the most extraordinary reflection which occurs to us is that while China (allowing something for probable losses of texts) has nothing to show which equals the systematic treatment of mechanics and pneumatics by the Alexandrians (Ctesibius, Philon, Heron), those men were living in a civilisation which was incapable of utilising horse power to draw weights of more than half a ton, and which persisted in the universal employment of the primitive vertical loom. Some have thought, indeed, that the more advanced character of oriental technology was dimly realised by the Greeks, and it has even been suggested that the fable of Atlantis

valued ingenious articles', it said, 'nor do we have the slightest need of your country's manufactures.' There is general agreement with Greenberg's view; cf. Lattimore (7) and Gallagher & Purcell (1). Purcell regards the words of this edict as the key to the understanding of Sino-Western relations throughout the +18th century (p. 580), and emphasises also the converse fact that the traditional industries of China served an important export market. Chinese ramie, silk and other textiles flowed into Mexico via Manila; Burma and South-east Asia obtained ironware in quantity from China; and great quantities of Chinese porcelain went to Borneo and all Indonesia. Indeed the marked success of Chinese mercantile settlers led to serious persecutions, notably in Dutch Indonesia in +1740, and in the Spanish Philippines in +1709, +1755 and +1763 (Gallagher & Purcell, pp. 587, 591).

^a This contention was very general at the time. The following year saw the appearance of Rondot's review (1) of the manufactures of China. Two years later the Mission Press at Shanghai issued a translation of excerpts on sericulture from the *Nung Chêng Chhian Shu* of +1639 (Anon. 39), illustrated with Chinese diagrams of the early 19th century (cf. pp. 2, 107, 382 above). Julien's study of the history and fabrication of Chinese porcelain (7) followed in 1856, and the general account of ancient and modern industries from Chinese sources by Julien & Champion (1) in 1869.

^b See Anon. (23). So also, as late as 1896, the Blackburn Chamber of Commerce sent a mission to China; cf. Bourne, Neville & Bell (1). Though most of these later groups were primarily interested in the opening up of trade (and even perhaps in 'spheres of influence' or other forms of partition), their problems were intimately related to the study of indigenous industrial techniques. In 1884 Tissandier (7) could write: 'Que de procédés de l'Extrême-Orient déroutent encore nos chimistes! La fabrication de la laque, celle de l'encre de la Chine, du vermillon, la métallurgie et la confection des tam-tams, la fabrication de certains papiers, de plusieurs espèces de vernis, sont encore pratiqués dans le Céleste Empire et au Japon, à l'aide des procédés que jusqu'ici nous cherchons en vain.'

in Plato's dialogue *Critias*,^a the island of Atlantis, whose people were such great architects and builders of irrigation-canals and bridges, has reference to the civilisations of Asia. If so, it is probably rather to Mesopotamia than further East, since at the time when it was written (c. -360, not long after the death of Mo Ti) Chinese superiority in technique had hardly gained the lead which it did some centuries later. Yet very large public works had been constructed in China in the -6th and -5th centuries.^b

Let the last words come from the realm of Islam, for the Arabs were very well qualified to be impartial judges of engineers both European and Chinese. From Ruy Gonzales Clavijo, Spanish ambassador to Timur Lang (Tamerlane, +1336 to +1404), we hear that at Samarqand 'the craftsmen of Cathay are reputed to be the most skilful by far beyond those of any other nation; and the saying is that they alone have two eyes, that the Franks may indeed have one, while the Muslims are but a blind folk'.^c Truer perhaps, and better, was the remark of Abū 'Uthmān 'Amr ibn Baḥr al-Jāhiz (d. +869)—'Wisdom hath alighted on three things; the brain of the Franks, the hands of the Chinese, and the tongue of the Arabs.'^d

^a Jowett (1), vol. 3, pp. 429 ff., 519 ff.

^b Cf. Chi Chhao-Ting (1), p. 66.

^c Cit. Olschki (4), p. 98; Yule (2), vol. 1, pp. 174, 264. We do not know who originated this saying, or where, but it was repeated over and over again. Abū Manṣūr Tha'ālībī, writing in about +1030, reports it, and so does Sharaf al-Zamān Ṭāhir al-Marwazī just under a century later, in the following words: 'The people of China are the most skilful of men in handicrafts—no other nation approaches them. The people of Rūm (the Eastern Roman Empire) are proficient too, but they do not reach the level of the Chinese. The latter say that all men are blind in craftsmanship, except the men of Rūm, who being one-eyed, know but half the business' (cf. Minorsky (4), pp. 14, 65). A curious Sufic mystical parable in the *Mathnawī* of Jalāl al-Dīn Rūmī (d. +1273) involves a contest in painting between Greeks and Chinese at a Sultan's court (1, ll. 3467 ff. Nicholson tr. vol. 2, p. 189). Then the adage about the blindness comes again in the *Fleurs des Histoires d'Orient* written by Prince Haythou of Armenia in +1307 (Bk. 1, ch. 1; Yule, *ibid.* p. 258), and before long it was copied from somewhere by Sir John Mandeville (c. +1362), ch. 23 (Letts ed., vol. 1, p. 151). After Clavijo it reappears in Nicolò Conti (c. +1440; Yule, *ibid.* p. 175) and in Josafat Barbaro (c. +1470; Yule, *ibid.* p. 178). Its estimate of the Chinese craftsmen was echoed by a host of travellers; for example the technicians of the Macartney embassy in +1793 such as Dinwiddie (1), p. 49; Barrow (1), p. 306; cf. Cranmer-Byng (2), p. 264.

^d Hitti (1), pp. 90, 382, quoting *Majmū'at Rasā'il*, pp. 41 ff.; cf. al-Jalīl (1), pp. 109 ff.

BIBLIOGRAPHIES

- A CHINESE AND JAPANESE BOOKS BEFORE +1800
- B CHINESE AND JAPANESE BOOKS AND JOURNAL ARTICLES SINCE +1800
- C BOOKS AND JOURNAL ARTICLES IN WESTERN LANGUAGES

In Bibliographies A and B there are two modifications of the Roman alphabetical sequence: transliterated *Chh-* comes after all other entries under *Ch-*, and transliterated *Hs-* comes after all other entries under *H-*. Thus *Chhen* comes after *Chung* and *Hsi* comes after *Huai*. This system applies only to the first words of the titles. Moreover, where *Chh-* and *Hs-* occur in words used in Bibliography C, i.e. in a Western language context, the normal sequence of the Roman alphabet is observed.

When obsolete or unusual romanisations of Chinese words occur in entries in Bibliography C, they are followed, wherever possible, by the romanisations adopted as standard in the present work. If inserted in the title, these are enclosed in square brackets; if they follow it, in round brackets. When Chinese words or phrases occur romanised according to the Wade-Giles system or related systems, they are assimilated to the system here adopted without indication of any change. Additional notes are added in round brackets. The reference numbers do not necessarily begin with (1), nor are they necessarily consecutive, because only those references required for this volume of the series are given.

Korean and Vietnamese books and papers are included in Bibliographies A and B.