THE NORIA OR PERSIAN WHEEL

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IN his *Systema Agriculturae, The Mystery of Husbandry Discovered* (2nd ed., London, 1675, p. 18), J. W. Gent has the following notice on the Persian wheel:

> 'The most considerable and universal is the Persian wheel, much used in Persia, from whence it hath its name, where they say there are two or three hundred in a river, whereby their grounds are improved extraordinarily. They are also much used in Spain, Italy, and in France, and is esteemed the most facile and advantageous way of raising water in great quantity to any altitude within the diameter of the wheel, where there is any current of water to continue its motion; which a small stream will do, considering the quantity and height of the water you intend to raise. This way, if ingeniously prosecuted, would prove a very considerable improvement; for there is very much land in many places lying near to rivers that is of small worth, which if it were watered by so constant a stream as this wheel will yield, would bear a good burthen of hay, where now it will hardly bear corn. How many acres of land lie on the declining sides of hills by the rivers sides, in many places where the water cannot be brought unto it by any ordinary way? Yet by this wheel placed in the river or current, and a trough of boards set on tresles to convey the water from it to the next place of near an equal altitude to the cistern, may the land be continually watered so far as is under the level of the water. Also there is very much land lying on the borders of rivers that is flat and level, yet neither doth the land-floods overflow the same, or at most but seldom; nor can the water be made by any obstruction thereof, or such-like way to overflow it. But by this Persian Wheel placed in the river in the nearest place to the highest part of the land you intend to overflow, therewith may a very great quantity of water be raised. For where the land is but little above the level of the water, a far greater quantity of water, and with much more facility may be raised, than where a greater height is required; the wheel easier made, and with less expence.'

Gent offers a good woodcut of the Persian wheel, and his account goes to show that in the latter part of the seventeenth century no better method of raising water for irrigation purposes was known in Europe. The term 'Persian wheel' is still used in English in the same sense, and is registered as such in the *Oxford English Dictionary*.

The Persian wheel is familiar to us under the name *noria*, which we adopted from the Spaniards. The latter, on their part, received it from the conquering Arabs. The consensus of opinion is that the word is based on Arabic ناعورة *nā'ūra* or *nā'ōra*, with the article *an-nā'ōra*, which is still preserved in the Spanish forms *anoria* and *añoria;* in old Spanish it was *naora* and *alnagora*. Both the Arabic and Spanish word refers to the same hydraulic device. The Portuguese form *nora* is still nearer to the Arabic prototype, and the Arabic

etymology is listed as early as 1830 by J. De Sousa (*Vestigios da lingoa arabica em Portugal*, p. 169: 'Maquina hydraulica, que serve de tirar agua dos poços, cisternas, e rios'). L. Marcel Devic (*Dictionnaire étymologique des mots français d'origine orientale*, 1876, p. 177) states that the Arabic noun is derived from the verb نعر *na'ar*, which means 'laisser jaillir le sang par saccades, en parlant d'une veine; ce qui s'applique assez bien aux norias, formées d'une série de seaux en chapelet qui se remplissent au fond du réservoir et viennent se vider l'un après l'autre à l'extérieur'. The Arabic etymology of *noria* has remained uncontested, and has been adopted by W. Meyer-Lübke (*Romanisches etymologisches Wörterbuch*, 1911, No. 5856; also by K. Lokotsch, *Etym. Wört. der europ. Wörter orientalischen Ursprungs*, 1927, No. 1561) and by all our English dictionaries. The *Oxford English Dictionary* defines *noria* as 'a device for raising water, used in Spain and the East, consisting of a revolving chain of pots or buckets which are filled below and discharged when they come to the top'. Another Spanish-Portuguese word has a bearing on the same contrivance: Spanish *arcaduz* or *alcaduz*, Portuguese *alcatruz*, which represent Arabic القادوس *al-qādūs* and signify 'the bucket of a noria' (Devic, p. 6; Meyer-Lübke, No. 1456).

From Italy the Persian wheel spread to Warsaw, Poland, where Peter Mundy (*Travels*, iv. 203, Hakluyt Society, 1925) saw one in operation in 1643 and described it under the title 'A Strange Water Work' as follows:

> 'The gardener's servant showed me a house in a garden near the palace, which by wheel works drew water out of a well of itself, which he gave me to understand after this manner, viz.: among other is one great principal wheel unto which are fastened a great number of pots. This wheel, having once motion given it, forces up a quantity of water through pipes by the help of pump holes, leathers, etc., as I have seen in other water works. Of this water, part runs to the palace and the rest runs back into the vessels fastened on the great wheel, which being of a great compass, a little weight on the circumference causes it to go about. Having once motion, it forces up so much water that supplies the king's house and itself again to continue the said motion of itself, so that if this be true, as I think it is, it may be rightly called a perpetual motion: the water in the well supplied by his own spring. It was contrived by an Italian, who dieing and the work coming out of frame, there has been none since can be found that can bring it into order again, so that at present there must be twelve Tartar slaves to supply the work which the wheel alone performed of itself.'

Sir Richard Carnac Temple, Mundy's editor, comments justly, 'Mundy is describing what is known in India as the 'Persian wheel' (*rahat*), in this case driven by water machinery supplied by itself. In India, Persia, and Mesopotamia it is driven by a bullock. Such wheels are still common in Italy and Portugal'. Mundy himself (*Travels*, ii. 228, Hakluyt Society, 1914) had observed them also in Spain and India. 'In Spain', he writes, 'we call them noraies' (noria).

A. von Kremer (*Culturgeschichte des Orients unter den Chalifen*, ii. 322)

maintained that the water-wheel was brought by the Arabs to Spain, but added judiciously that he hardly believed that its invention was a merit of the Arabs; and I concur with him in this opinion. G. Staunton (*Account of an Embassy from the King of Great Britain to the Emperor of China from the Papers of the Earl of Macartney*, ii. 1797, p. 479) writes: 'Most Eastern nations seem to have been acquainted at an early period with the machine for raising water, known by the name of the Egyptian wheel, which was however unknown in Europe till the Saracens introduced it into Spain, in an imperfect state, and under a very awkward form.' Ibn al-'Auwām, an Arabic agricultural writer, who lived at Seville in the twelfth century, has given a technical description of the noria in his famous treatise on agriculture (*Le livre de l'agriculture d'Ibn al-Awam*, traduit de l'arabe par Clément-Mullet, i, 1864, p. 129). The most interesting contributions to our knowledge of water-raising devices from Arabic sources we owe to the eminent Arabist and physicist, the late Eilhard Wiedemann (*Beiträge zur Geschichte der Naturwissenschaften*, vi, 'Zur Mechanik und Technik bei den Arabern', Erlangen, 1906, pp. 13, 50; x, 'Zur Technik bei den Arabern', p. 331). The water-wheels are also styled *zurnūq*, *daulāb*, *hannāna*, and in Egypt *sāqīya* ساقية. *Hannāna* means 'the constantly groaning ones' from the creaking sound produced by the wheels, which even impressed the poets as beautiful. *Daulāb* or *dulāb* دولاب, a word of Persian origin (*dol-āb*), means a 'wheel', and specifically refers to a water-wheel drawn by oxen or horses and designed for drawing water from a well, while *gharrāf* غراف is a water-wheel drawn by oxen or horses and designed for drawing water from a river. The word *nā'ūra* (plural *newā'ir* نواعير) is chiefly used in the Maghreb, but also in Syria and Persia. The water-wheels are constructed by a special class of artisans whose craft descends from father to son; the most skilful ones live in Syria. Historically the noria can be traced to the earliest times of the Caliphs. Man-power also was then enlisted to operate it, sometimes for the purpose of inflicting a punishment. The earliest example cited by Wiedemann refers to the year A.D. 884–5, and is an account by Ahmad Ibn al-Tayyib.

There was a celebrated noria at Fez, Morocco, which raised the water of the river up to the royal garden and which became proverbial (Gaudefroy-Demombynes, *Masālik El Abṣār*, p. 156, Paris, 1927, who remarks that the norias and their sighs are a theme of Arabic poetry). The *sāqīya* of Egypt is described by E. W. Lane (*Account of the Manners and Customs of the Modern Egyptians*, 5th ed., 1871, p. 26): it mainly consists of a vertical wheel which raises the water in earthen pots attached to cords and forming a continuous series; a second vertical wheel fixed to the same axis, with cogs; and a large horizontal cogged wheel which, being turned by a pair of cows or bulls or by a single beast, puts in motion the two former wheels and the pots. T. Shaw (*Travels, or Observations Relating to Barbary and the Levant*, Oxford, 1738, p. 431) writes: 'Persian wheels, called *sakiah* in Egypt, were in general use along the banks of the Nile, from the sea to the cataracts.' Again, the term 'Persian wheel' is noteworthy.

In Syria and along the banks of the Tigris and Euphrates the norias are

still in operation. At Basra the water-wheels were also driven by camels. Near Mecca norias were likewise employed. Yāqūt writes that 'the water of Ma'din al-Burm is well-water which irrigates the fields by means of the *zurnūq*.' Dimashqī, who wrote a cosmography about A.D. 1325, refers to the norias of Ḥamā on the river 'Āṣī (Orontes) as being of a construction as seen nowhere else, in order to maintain considerable streams of water for the irrigation of numerous gardens abundant in fine and excellent fruits such as the apricot of camphor and almond flavours not found in any other country (A. F. Mehren, *Manuel de la cosmographie du moyen âge*, p. 281, Copenhague, 1874; see also Gaudefroy-Demombynes, *La Syrie à l'époque des Mamelouks*, 1923, p. 106; S. Guyard, *Géographie d'Aboulféda*, ii, pt. 2, 1883, pp. 40, 138). Yāqūt likewise speaks of the irrigation of the gardens through the water of the 'Āṣī. Large water-wheels still exist at Ḥamā (R. Oberhummer and H. Zimmerer, *Durch Syrien und Kleinasien*, p. 92). Illustrations of such wheels may be viewed in the book of A. T. Olmstead, *History of Assyria* (New York, 1923), Figs. 66, 71, 76.

In the environment of Constantinople the Persian wheel was noticed by G. Jacob (*Altarabisches Beduinenleben*, 1897, p. 228), and it likewise occurs in Asia Minor (K. Kannenberg, *Kleinasiens Naturschätze*, 1897, p. 83, under the name *sakie*). In other words, it is widely diffused all over the Islamic world, including northern Africa.

The tendency of certain Egyptologists to draw retrospective conclusions from present-day conditions is well known, and it is even more drastic among Assyriologists. Thus we are treated to the gratuitous speculation that the ancient Egyptians 'perhaps utilized also the *sāqīya*' (F. Hartmann, *L'Agriculture dans l'ancienne Égypte*, 1923, p. 118, who, however, adds cautiously, 'an ancient design of which has not yet been found'). There is no tangible evidence for this assertion, and the fact remains that the *sāqīya* was introduced into Egypt during the Middle Ages by the conquering Arabs. Again, there are Assyriologists who from the modern water-wheels existing in Mesopotamia conclude naïvely that they must have been in existence in ancient times (cf. Handcock, *Mesopotamian Archaeology*, p. 369: 'What the larger machines were we do not know, but as Johns suggests, they may have very possibly consisted in a set of buckets fastened to a wheel, etc.: but whatever the machine was it must have been fairly elaborate, for it sometimes required as many as eight oxen to work it.' (B. Meissner, *Babylonien und Assyrien*, i. 192, in discussing the methods of irrigation in ancient Babylonia, says nothing about this alleged use of the noria). It might be confidently stated that if the noria had been known in ancient Egypt and Babylonia, it must have spread to Greece and Italy, or that at least some notice of it would have been preserved by Greek or Roman writers, neither of which, however, is the case. The passage in Vitruvius x. 5, as already pointed out by J. Beckmann (*Beyträge zur Geschichte der Erfindungen*, ii, 1788, p. 14), relates to water-mills, not to water-wheels for irrigation (cf. M. H. Morgan, *Vitruvius*, 1914, p. 294, and A. Neuburger, *Technik des Altertums*, 2nd ed., 1921, p. 232).

Abu 'Abḍallah el-Maqdisi, called El-Muqaddasi, wrote in A.D. 985: ''Aḍud

al-Daula dammed the river which flows between Shīrāz and Iṣṭakhr by means of a gigantic wall whose foundations he closed with lead. Behind, the water is stowed, and is higher than the river. On both sides he set up ten water-wheels and beneath each water-wheel a mill—at present one of the wonders of Fars. There he built a city and conducted the water into canals and supplied three hundred places with water.' In another manuscript the following version occurs: 'And on each side he made arches from which the water flowed roaringly and impetuously into the lowest parts of the norias and set these in motion. Around the felloes of the wheels there are boxes which fill themselves with water. When they have performed a revolution, they pour the water into canals from which it is distributed among three hundred places' (Wiedemann, op. cit., p. 324).

According to Rashīd-ad-Dīn, when the Mongol forces laid siege to Baghdad in A.D. 1258, their lower camp was pitched at a place called Dūlāb-i Baqal, which means 'the Water-wheel of the Vegetable Garden' (G. Le Strange, 'Baghdad during the Caliphate', *JRAS.*, 1899, p. 882).

F. von Schwarz (*Turkestan*, 1900, p. 346) refers to the peculiar water-wheels used in Russian Turkestan, which he says are called *čigir* (in W. Radloff's *Wörterbuch der Türkdialecte*: *čikir*, given as Jagatai). He describes them 'as paddle-wheels crudely patched together from wooden rods and operated by the current of the channel water. To the periphery of these wheels are usually attached earthenware pots which draw water in the canal at the turning of the wheels and empty the water into a wooden gutter. Beside the garden of the Tashkent observatory a Sart had once set up such a water-wheel which had a diameter of about six metres and which irrigated a small cotton plantation. Owing to the frequent need of repair these wheels are but seldom utilized at Tashkent where there is no lack of water. Among the agricultural Kirgiz, who have an abundance of draught-cattle, water-wheels driven by oxen are also used' [as also in China]. F. von Schwarz concludes, 'The water-wheels used in Central Asia agree perfectly with those of Egypt, which goes to prove that the Central Asians derived them from the Egyptians' (which, of course, is an untenable conclusion).

H. Moser (*L'Irrigation en Asie centrale*, 1894, p. 266) states that the word *čigir* is Turkish in origin and that the Bukharians still bestow upon this apparatus the name 'Persian wheel' (*roue persane*). He observed these Persian wheels on the banks of the Amudarya and in Khiwa. They reminded him of the *sāqīya* of Egypt, and he thinks it probable that the latter is akin to the *čigir* in origin and that this origin is very ancient. His description is as follows:

> 'Il se compose essentiellement d'une roue en bois, de 3 à 4 mètres de diamètre, tournant dans un plan vertical au dessus d'un puisard de façon à ce que la circonférence de la roue plonge, en bas de sa rotation, au dessous du niveau de l'eau. Sur le pourtour de la circonférence sont fixés, à des intervalles convenables, des cruchons de poterie ou de bois évidé, obliquement au rayon de la roue, de façon à ce qu'ils s'emplissent dans le puisard, puis se déversent à la hauteur voulue dans un canal récepteur. A l'aide d'un engrenage à roues dentées en bois, le tchiguir est mis en mouvement par un

cheval, chameau, bœuf, âne ou quelquefois plusieurs de ces bêtes de somme disparates accouplées ensemble. Cet appareil peut élever de 4 à 5 mètres cubes d'eau à l'heure.'

Peter Mundy (*Travels*, ii. 228) observed Persian wheels at Fatehpur Sīkrī in the palace of the Moguls: 'The water to water it is also to fill the tanks aloft, first into one tank and then from that into another higher, and so into four or five until it come aloft, by that which we in Spain call Noraies [noria].' Sir Richard Carnac Temple, Mundy's editor, annotates that 'the ruins of the series of Persian wheels and reservoirs, by which water from the lake outside the city was supplied to the palace, still exist.'

John Fryer, who travelled in India and Persia from 1672 to 1681, noticed the use of Persian wheels both in India and Persia. They have 'pans or buckets of leather hanging round about a wheel, some always in the water, others rising up, and at the same time others pouring out as the wheel turns round: and thus are their best gardens kept alive.' While in Persia, he speaks of 'the Indian wheel drawn up and let down by oxen, with as little intermission day or night, as Sysiphus's repeated trouble is reported' (*New Account of East India and Persia*, ii. 94, 171; iii. 156, Hakluyt Society, 1912, 1915).

A. Neuburger (in H. Kraemer, *Der Mensch und die Erde*, ix. 306) pleads for India as the home of the water-wheel, 'as may be concluded from various criteria'; but no evidence for this assertion is forthcoming.

'Persian wheels', N. G. Mukerji writes in his *Handbook of Indian Agriculture* (2nd ed., Calcutta, 1907, p. 142), 'are in use on the Malabar coast, in Rajputana, Kathiwar, and the Punjab. Some are of very simple and cheap construction. This type is used chiefly on the coast of Kathiwar, Gujarat, and the west coast of India generally. A bamboo or wooden drum of light framework turns on an axle which rests on two pivots. A sitting man turns the drum with his hands and feet. Round the drum is attached an endless garland of mud vessels which are brought up by the revolution of the drums carrying water in them, and discharging the water (from three mud vessels at a time), into a trough of stone whence it flows out to the field. With this implement one man can irrigate one-tenth of an acre a day. The Persian wheel of the Punjab pattern is the same as the Egyptian-Persian wheel.'

Mukerji further refers (p. 145) to the noria or bucket-pump as another form of improved Persian wheel, which consists of buckets chained one to another in an endless series and worked by hand or animal power.

Discussing the subject of irrigation in India, W. Crooke (*Things Indian*, New York, 1906, p. 282) writes,

'Lastly comes the curious machine known as the Persian wheel, of which the history is obscure. It does not seem to be used in Persia [this is erroneous], but it is represented by the Egyptian *sāqīya*, and it appears in Palestine. Possibly the Indian title merely implies that the idea came from the West. In Egypt it was probably a late invention, as it has not been recognized on the tomb frescoes. The Burmese have a somewhat similar machine, the

yit, in which, as in the Persian wheel, the water is raised by a wheel, to which bamboo baskets are attached [as in China]. The Persian wheel is known as far south as Malabar, and it is purely a matter of habit or tradition whether the farmer uses the wheel or the leather bag,' &c.

'Pucka wells are usually worked by the *harth*, or Persian wheel. A broad-edged lantern wheel whose axis lies horizontally over the centre of the well's mouth, carries on its broad edge a long belt of *moonj* rope, made like a rope ladder, the ends of which joined in an endless band reach below the surface of the water. To this at every step of the rope ladder, an earthen pot called *tind* is fixed. As the wheel revolves, the large rope belt descends into the water with its pots, the pots become filled with water, and are drawn up: as they reach the top of the wheel, they are by the revolution of the wheel inverted, and their contents poured out into a trough, which is ready to receive them, and which leads to the water-course of the fields to be irrigated. The wheel bearing the belt and waterpots is caused to revolve by having on the same axle another wheel parallel to it, and cogged in one side, the teeth of which work into the cogs of another vertical lantern wheel, whose axis again rests in a bar supported between two upright brick or wood pillars at one side of the well's mouth; this vertical wheel is turned by a pair of oxen yoked to a pole, which is fixed into the axis of the wheel in question. The oxen by walking round and round on a tramway drag the pole with them, and cause the whole apparatus to turn' (B. H. Powell, *Hand-Book of the Economic Products of the Punjab*, i, 1868, pp. 207–8).

In his *Bihār Peasant Life* (Calcutta, 1885, p. 210) Sir George A. Grierson writes, 'The Persian wheel is not used in Bihār. Its name, *rahat*, is however known in Patna.' The sole allusion to the Persian wheel in Sanskrit literature I have encountered so far occurs in Bāṇa's *Harsha-Carita* (translated by Cowell and Thomas, 1897, p. 264): 'His right hand shook a rosary, like a Persian wheel containing the buckets for raising water from the well of all delightful motions.' It seems, therefore, that the Persian wheel was known in India at least in the sixth century of our era.

With reference to the Burmese methods of irrigation good information is contained in J. G. Scott's *Gazetteer of Upper Burma and the Shan States* (pt. 1, ii, Rangoon, 1900, pp. 342–3). The *yit*, referred to above by W. Crooke, is described there as 'an ordinary water-wheel with lengths of bamboo tied transversely opposite the floats. These act as buckets for lifting the water and, as the wheel revolves with the current, are tilted so as to empty themselves into a trough or channel, which carries the water into the fields. In some places in the Shan States where the rivers have a deep channel, these wheels are forty or fifty feet high and raise water enough to form quite a considerable rivulet.'

The noria is also widely distributed throughout the Far East, and is a conspicuous and indispensable adjunct of Chinese and Japanese agriculture. The Chinese water-elevators have attracted the attention of many travellers, and have frequently been depicted and minutely described, but no one seems

to have noticed that they are identical in principle and construction with the water-raising devices of the West, nor has any one ever raised the question as to their origin and historical connexions. In an excellent study, entitled 'Westöstliche Landwirtschaft' (in *Festschrift P. W. Schmidt*, pp. 416–84), P. Leser has recently traced the interrelations of the East and West in matters of agricultural implements, but he has not dealt with machinery for irrigation. The older literature relative to the noria in China is listed by J. H. Plath ('Die Landwirtschaft der Chinesen', *Sitzungsberichte der bayerischen Akademie*, 1873, pp. 815–17). A brief summary of the subject is given by W. Wagner (*Die chinesische Landwirtschaft*, Berlin, 1926, pp. 189–99) and F. H. King (*Farmers of Forty Centuries*, Madison, 1911, pp. 300–3, 363, 411, with good illustrations; see also S. Syrski in *Anhang Berichte über österr. Exped. nach Siam, China und Japan*, 1872, p. 79; G. Schlegel, *Ouranographie chinoise*, 1875, p. 457; S. W. Williams, *The Middle Kingdom*, 1901, ii. 7; H. R. Davies, *Yün-nan*, 1909, p. 158; J. G. Anderson, *The Dragon and the Foreign Devils*, 1928, p. 27; and others).

As regards the water-wheel of Japan I shall refer only to E. S. Morse (*Japan Day by Day*, ii, 1917, p. 284), who gives a sketch of it, saying that it is a Chinese device, rare about Tokyo and farther north, but not uncommon in the southern provinces of Japan. According to G. Sarton (*Introduction to the History of Science*, i, 1927, p. 580), the introduction of the noria into Japan is ascribed to Yoshimine Yasuyo, a scholar and son of Kwammu-tennō, emperor from A.D. 782 to 805.

F. H. Nichols (*Through Hidden Shensi*, New York, 1902, p. 31) writes,

> 'Every quarter of a mile or so a donkey at the end of a long pole may be seen walking around a windlass. He is raising water from a well by a chain-pump, whence it is discharged into the furrows that cross the fields in every direction. Some of the wells are very deep, and are constructed on the Artesian principle, a series of hollow bamboo-rods taking the place of an iron pipe. A well-donkey is a thing essentially Chinese. No one drives him or apparently takes the slightest interest in him. He wears big straw blinders over his eyes, which prevent his seeing anything. He is oblivious of his surroundings. All the ordinary aims and ambitions of donkey life he seems to have forgotten. Hour after hour he walks slowly around the windlass, only a speck on the flat landscape, only a cog in the simple but vast system of agriculture which keeps millions of men alive.'

In the Chinese standard work on agriculture, the *Nung cheng ts'üan shu* 農政全書, published in 1640, seven years after the death of its author, Sü Kwang-k'i 徐光啟, the famous disciple of the early Jesuits, six illustrations of native hydraulic engines are given (reproduced also in *Shou shi t'ung k'ao*, ch. 37, pp. 4-5, and *T'u shu tsi ch'eng*, xxxii, ch. 244) under the generic name *shwi ch'o* 水車 ('water engines'). The first, *fan ch'o* 翻車, is the chain-pump (also described and figured by G. Staunton, *Macartney's Embassy*, ii. 481; J. F. Davis, *China*, ii, 1857, p. 258; *Chinese Repository*, v, 1837, p. 494).

The second of these, designated *t'ung ch'o* 筒車 ('tube engine'), corresponds exactly to the noria or Persian wheel, save that, as implied by the term, the buckets are replaced with bamboo tubes, in conformity with the universal use of bamboo as a convenient material throughout China. Williams speaks of buckets, and Anderson of tub-shaped containers. This noria is also figured and described by Davis (ii. 260). The third, styled *shwi chwan fan ch'o* 水轉翻車 ('revolving machine turned by water'), corresponds exactly to the *sāqīya* of Egypt. The fourth shows the same apparatus operated by a water-buffalo; the fifth, the same set in motion by two donkeys; and the sixth, called *kao chwan t'ung ch'o* 高轉筒車, is a double chain-pump running over two sprocket-wheels, a lower one in the water, a higher one in the rice-field.

Those who have not access to Chinese publications will find the Chinese illustrations well reproduced and described in the excellent book of O. Franke, *Kêng Tschi T'u, Ackerbau und Seidengewinnung in China* (Hamburg, 1913, pp. 149–52). It is noteworthy that the chain-pump appears in the series of engravings prepared by Lou Shou about A.D. 1145 (Franke, Plate XXXVI; and compare Pelliot, *A propos du Keng Tche T'ou*, Plate XXIII). The principle in all of these machines is the same, the only difference being in the mode of applying the moving power; one is worked by the hand, another by the feet, of a labourer, and the third by an animal (R. Fortune, *Two Visits to the Tea Countries of China*, i, 1853, p. 230). J. Barrow (*Travels in China*, 1804, p. 540) remarks that 'the water-wheels still used in Syria differ only from those of China by having loose buckets suspended at the circumference, instead of fixed tubes.'

In regard to the inventor of the water-wheel, Chinese records refer to the names of two individuals, Pi Lan 畢嵐 and Ma Kün 馬鈞 (see *Shi wu ki yüan* 事物紀原, ch. 9, p. 3*b*, by Kao Ch'eng 高承 of the Sung period, ed. by Li Kwo 李果 in 1472, original edition in Gest Chinese Research Library, McGill University, Montreal). Pi Lan is said to have lived under the reign of the Emperor Ling (A.D. 156–189) of the Later Han dynasty and to have constructed a *fan ch'o* used for sprinkling the streets. Ma Kün (Giles, in his *Chinese Biographical Dictionary*, p. 565, mentions him as 'a famous mechanic who constructed a variety of ingenious machines') lived in the third century A.D. under the Wei dynasty, and it is on record that 'when he lived in the capital, he owned a plot of arid land suitable as a garden, but there was no water to irrigate it; thus he made a turning wheel (*fan ch'o*) which he caused to be revolved by boys, and this wheel conducted the water for the irrigation of his garden.' This wheel, as also added in the *Shi wu ki yüan*, is identical with the one now used by farmers for field irrigation and took its beginning from Ma Kün of the Wei. This text is quoted in the *Shi wu ki yüan* from the *Wei lio* 魏略, an historical work now lost, written by Yü Huan 魚豢 and covering the period from A.D. 239 to 265; portions of it are preserved in the commentary of P'ei Sung-chi to the *San kwo chi* (Chavannes, *T'oung Pao*,

1905, p. 519). As the *Wei lio* is a reliable work, the passage cited from it in the *Shi wu ki yüan* may correctly reflect the tradition of the Wei period (see also *Ko chi king yüan*, ch. 48, pp. 7–8; *Shi wu yüan hui* 事物原會, ch. 23, p. 3; *T'u shu tsi ch'eng*, and others). There is no doubt that Ma Kün was a good hydraulic engineer, for the *Shi wu ki yüan* (ch. 9, p. 26*b*) has preserved another tradition according to which he made for the Emperor Ming of the Wei artificial fountains in the shape of animals, fishes, and dragons.

The *Shi wu yüan shi* 事物原始 ('Origin and Beginning of Things') connects the invention with the name of the Emperor Ling, but attributes its inception to another engineer, called K'o Mien 渴免, who used the device of bamboo tubes attached to the wheel. Fang I-chi 方以智, in his *Wu li siao shi* 物理小識 (written toward the end of the Ming dynasty, ch. 8, p. 31), refers solely to the Emperor Ling and concludes that the method of irrigation by means of water-wheels was known in China from under the Han; he also points out a passage in a poem of Su Shi or Su T'ung-po (A.D. 1036–1101) relative to the raising of water by means of bamboo tubes from the wells of Se-ch'wan.

In the palace of the Mongol emperors at Peking there was east of the Wan-sui Hill a stone bridge in the middle of which there was an aqueduct leading the water of the Kin-shwi to the top of the hill; the water was pumped to the top of the hill by means of machines, and was poured from the jaws of a stone dragon into a square basin (E. Bretschneider, 'Arch. and Hist. Researches on Peking', *Chinese Recorder*, vi, 1875, p. 319, after *Ch'o keng lu*).

The history of the water-wheel for irrigation cannot be dissociated from that of the water-mill which is based on the same mechanical principle. As formerly pointed out by me (*Chinese Pottery of the Han Dynasty*, p. 33), the invention of mills driven by water is attributed by the Chinese to Tu Yü 杜預 (A.D. 222–284); and this event coincides exactly with the time of Ma Kün, the inventor of the irrigation water-wheel. I also drew attention at that time to the curious coincidence that water-mills sprang up in China at about the same time as in the Roman empire. Strabo is the first to mention a water-mill with reference to Mithridates who had one in his residence at Cabira, and this hints at the fact that water-mills were first known in the Orient (J. Beckmann, *Beyträge zur Geschichte der Erfindungen*, ii, 1784, pp. 12 et seq.; O Schrader, *Reallexikon*, 2nd ed. by A. Nehring, ii, 1923, p. 27). They gradually spread in Italy in the early days of the Imperium. In view of the fact that the noria did not conquer Europe at the same time it would follow that the use of the water-wheel for mills is older than its use for irrigation purposes, or at least that the Persian wheel had not yet advanced beyond the western boundaries of Iran in Roman times; and this is in harmony with my conclusion that it was the Arabs who brought it from Persia to the empire of the Caliphs and to Egypt. Now, if in the third century of our era Tu Yü constructed a water-mill on the same principle as the water-mills of western Asia, and if simultaneously Ma Kün constructed a noria or what ultimately resulted in this device, we cannot believe in the miracle that these two Chinese engineers

should have independently evolved what pre-existed in the West and achieved the same result; the only possible conclusion is that the two worked out their ideas on plans and models brought to China from some locality of central Asia, which presumably was Sogdiana.

The ancient territory of Sogdiana appears to have the best claim to the invention of water-raising devices by means of wheels. From ancient times Sogdiana enjoyed an unrivalled state of prosperity: its fecund valleys, the wealth of its soil, industry, and commerce, and its powerful cities fired the imagination of the ancients to such a pitch that they styled it Paradise of Asia. It is well known how highly agriculture was esteemed in the ancient Persian religion, how the farmer's good deeds and irrigation of the fields in particular are extolled in the Avesta, and how highly developed the art of gardening was in Persia and how the Persian garden became the model for all gardens of Asia. In Sogdiana (K'ang), it is stated in the Annals of the T'ang Dynasty (*T'ang shu*, ch. 221 B; cf. Chavannes, *Documents sur les Tou-kiue occidentaux*, p. 135), 'they have very ingenious machines'. Soon after General Chang K'ien's famous expedition to the West, Chinese engineers wended their way to central Asia (*Shi ki*, ch. 123; cf. Hirth, 'Story of Chang K'ien', *JAOS.*, 1917, pp. 111, 113). There is no doubt that such engineers, on their return to the homeland, brought back plans and specifications of water-raising engines.

Barthold and Petrow have written in Russian detailed monographs on the history of artificial irrigation in Russian Turkestan, which goes back to the times of the first colonizers of the country (F. Machatschek, *Landeskunde von Russisch Turkestan*, 1921, pp. 141, 327). Another method, that of subterranean irrigation, the so-called *kyärise*, is also due to Persia whence it was introduced into the adjoining countries (Machatschek, p. 144, and Vavilov and Bukinich, *Agricultural Afghanistan* [in Russian], Leningrad, 1929, pp. 140, 547). Of this method a Chinese record is also preserved. Ch'ang Te, who in A.D. 1259 was delegated by the Mongol Emperor Mangu to his brother Hulagu in Persia, noticed that the people of Persia dig wells on the summits of mountains and conduct the water several tens of miles down into the plain for the purpose of irrigating their fields (E. Bretschneider, *Chinese Recorder*, v, 1874, p. 326, who annotates: 'This is still the custom all over Persia. The aqueducts are all subterraneous in order to prevent the evaporation of the water. As in Persia it never rains in the summer, agriculture would be impossible there without this artificial irrigation.').

It is possible that the water-mill also is of Iranian origin. Dimashqī (translation of Mehren, p. 254) describes a water-mill at Merend in Aderbeidjān Kedrenos, a Greek monk of the eleventh century, who compiled a Synopsis of History beginning with the creation of the world and terminating with the year 1057, says that under the reign of the Emperor Constantine, Metrodoros a Persian by birth, went off to India and constructed for the Brahmans water-mills and baths—things previously unknown in the country (McCrindle, *Ancient India as Described in Classical Literature*, p. 185).

According to Gauthiot (*Journal asiatique*, 1916, i, p. 251) a water-mill is

called *āsyāw* in Pahlavi, *āsyā* in Persian; in the dialects of the north-east of Iran: *yāva-rěněm* ('grain-mill'). The Iranian tribes of the Pamir are familiar with the water-mill (Wakhī *khadorg*, Sariqoli *khadorj*, Minjan *khairgha*, Sanglikh *khadari*).

Another type of mill, the windmill, is likewise of Oriental origin. For a long time this was denied. The learned Beckmann (op. cit., p. 32) wrote in 1788, 'It has often been asserted that wind-mills were first invented in the Orient and became known in Europe in consequence of the crusades, but this is improbable. First of all, they do not now occur in the Orient or but seldom, not in Persia (with reference to Chardin), not in Palestine, not in Arabia. Second, wind-mills occur prior to the crusades or at least right in their beginning,' &c. Windmills therefore were believed to be of medieval European origin, and even in the second edition of Schrader's *Reallexikon* (ii, 1923, p. 28) all that is said about the subject is that windmills seem first to be mentioned in an Anglo-Saxon document of A.D. 833; this account, however, according to F. M. Feldhaus (*Technik der Vorzeit*, col. 1326), is a forgery. This opinion of a European origin is no longer tenable. Dimashqī (translation of Mehren, p. 246) describes wind-mills in a country west of Sejistān (Seistān), where the winds and floating sands are very frequent: 'therefore the inhabitants avail themselves of the winds to turn their mills and to transport the sand from one place to another, so that the winds are subject to them as they were formerly to Solomon.' The construction of these wind-mills is then described in detail (see also Barbier de Meynard, *Dict. géogr. de la Perse*, 1861, p. 301). Above all, we owe valuable information on the subject to the learned researches of E. Wiedemann ('Zur Mechanik und Technik bei den Arabern', *Sitzber. phys.-med. Soz. Erlangen*, 1906, pp. 44–9). The Caliph Omar I (A.D. 634–644) ordered a Persian, Abū Lulua, to make a wind-mill for him. More information is given by Wiedemann on the wind-mills of Sejistān.

On a former occasion (*Chinese Pottery of the Han Dynasty*, p. 19) I have set forth that windmills are unknown in China. F. H. King (*Farmers of Forty Centuries*, 1911, pp. 332–5) has figured and described a sail windmill pumping sea-water into evaporation basins at the Taku government salt-works, but this device is entirely different from our windmill and independent of the development of the latter. The only example of a windmill that has come within my experience during my travels is the windmill employed by the Tibetans for driving their prayer-wheels, and a specimen obtained by me may be seen in the collections of the Field Museum, Chicago. I have no doubt that the Tibetan notion of the windmill is traceable to Tibetan contact with Iranian regions. The fact that the windmill is practically absent in China and in the Roman empire and that it appears in Europe only during the Middle Ages goes to prove that the windmill is a late invention, much later than the water-mill and the water-wheel.

The position of the noria in the history of agriculture remains to be determined. On several occasions I have emphasized the fact that the entire economic structure of ancient Chinese civilization rests on a common

foundation with the other great civilizations of Asia and ancient Egypt. The whole agricultural complex—intensive farming by means of the plough drawn by an ox, cultivation of wheat and other cereals, artificial irrigation, pottery shaped by means of the wheel—is fundamentally the same everywhere (see my *Beginnings of Porcelain in China*, 1917, p. 176). The elements of this economic basis certainly go back to a prehistoric age unfathomable by dates. A system of canals and the use of the well-sweep are features of this prehistoric irrigation. The noria, however, does not belong to this ancient complex. It is plainly an invention of historical times made in an age when mechanical engineering had reached a high stage of development. It is not one of those subconscious or semiconscious gropings of primitive or prehistoric man, but it is the outcome of a volitional, judiciously conceived plan of a thinking engineer well versed with the laws of mechanics. There are good reasons for the conviction that this engineer was an Iranian, probably a Sogdian. The designation 'Persian wheel' is valid. It cannot be fortuitous that this name appears in Europe, in Bukhāra, as well as in India.[1]

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[1] After the above article was completed in July, 1929, I received a copy of *A History of Mechanical Inventions*, by Abbott Payson Usher, just published by McGraw-Hill Book Co., New York. On pp. 80–1 the noria is briefly dealt with in a descriptive manner without any reference to Asia. The subject of windmills and water-mills is treated somewhat more critically, and the Oriental origin of the former is admitted (p. 128).

In regard to Japan, reference should be made to the article of J. Troup, 'On a Possible Origin of the Waterwheel,' *Transactions of the Asiatic Soc. of Japan*, xxii, 1894, 109–114.