

Chapter 1

Anonymous Developments

Throughout the chapters of this book, the reader will be able to see that the preliminary information about machines and mechanisms is described as something already existing at the time of the treatises referring to that information. The information and the machinery itself already formed part of the cultural heritage of the community that was used to construct and use them. Only rarely, at the beginning of history, and then eventually with greater frequency, are machines presented as the results of conscious individual designs.

This anonymity becomes more explicit when a machine writer refers to cultures, which are different from his own, by attributing the invention to Chinese designers, Persians, or Celts, as being distant in time or space.

Machines and mechanisms are described as interesting curiosities, on the same level as customs, plants, or exotic animals. This has become clear with the appearance of ethnology as a structured science. Marcel Gauss, in his “Introduction to Ethnology” written as the basis for his lectures at the University of Paris, introduces technology and, in particular, mechanical technology, as one of the criteria for classification, together with economic, legal, or religious phenomena among others.

Similarly, the nineteenth century saw the appearance of societies that were devoted to regional studies of an ethnological nature, as a consequence of an interest in the visibly rapid disappearance of ancestral customs and ways of life, with the purpose of preserving them, at least in documented form. In the Spanish context, as in many other countries, societies of friends of the country were founded. Those societies also made frequent reference to popular machines and mechanisms. Many books were written on rural machinery with the same spirit but, unfortunately, most of the time they had only regional circulation. Emblematic examples are the Spanish books on Water Mills on Grand Canary Island by J.M. Díaz Rodríguez, and in Asturias, the book Hydraulic Devices by Gonzalo Morís.

Archaeology is an obvious source of knowledge for anonymous machine developments, but there are serious difficulties in recognising a finding of this kind that is not simply a single object but an ordered set of parts. For example, an isolated gearwheel may be misunderstood as a solar symbol, or a connecting rod,

for a schematic representation of a female god. Only if parts are discovered in connection with the rest of a mechanism, is it possible to recognise their mechanical function. In general, in archaeological remains it is extremely rare to find fully intact a mechanical device. This makes an appropriate interpretation of those remains very difficult, particularly when the concept and design of a machine is related to the relative movements of several components. Since current archaeology gives more importance to the whole context of finds than to an isolated object, there is yet an intrinsic difficulty in recognising several scattered and incomplete parts as the components of a mechanism.

Finally, the most important development concerning anonymous machines are related to biological forms. Nature has continuously solved mechanical problems in order to construct and maintain life and has demonstrated brilliant ingenuity and creativity in the design of highly efficient mechanisms. This short book would have a significant gap if it would not deal, at least succinctly, with this part of machine history.

Through the above-mentioned observations, it is evident that there is difficulty in finding proper sources for this chapter, and even more difficulty in ordering them as they come from such different fields as archaeology, general and regional ethnology, and biology. The authors are aware of the limitations and omissions in this respect.

On Machines Before Man

Mechanical design existed even before man appeared on the Earth. A human being itself is a complex machine. The Universe looks like a machine in motion, mainly with well-defined cycles that are subject to mechanical laws as was observed by the first men and the first civilisations as a “harmony of the heavenly bodies” and even influencing events and individuals. In a sample view, Biology can offer us examples of mechanical design, like the leg of an arthropod or a vertebrate (Fig. 1.1) whose design involved the solution of several mechanical engineering problems.

When fishes first emerged out of the sea into an air-filled environment, their fins had to be redesigned in order to adapt them to locomotion on land and to support their body weights, even by strengthening the materials of their structure (bone towards cartilage). The weight and locomotion considerably increased the actions within and towards the body when compared with the situation that had been practically weightless in the water. Even the tribological contact within the joints had to be redesigned with better lubrication. Thus, the leg mechanism became an effective means of locomotion over all types of terrain (Fig. 1.2), as well as being useful for climbing or digging. Another leg redesign turned vertebrates into flyers when the basic leg design was modified to evolve into a wing (Fig. 1.3).

In addition, some vertebrates returned to the sea, by further modification of the legs in order to make them similar to the fins of their ancestor fishes, and in even more likely, they became closer to the amphibians (Fig. 1.4) that were then living on dry land.

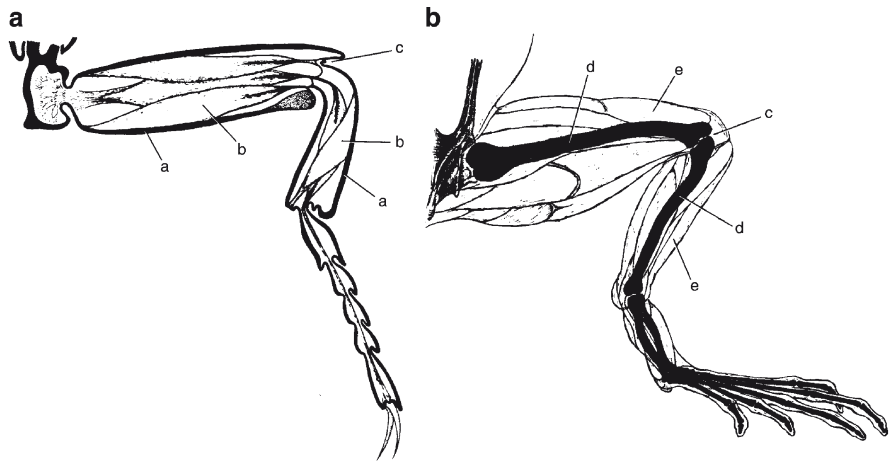


Fig. 1.1 Legs of a vertebrate and an arthropod [60]

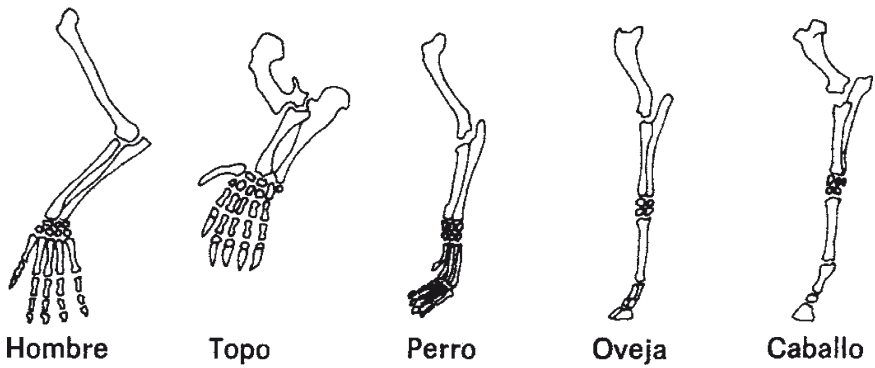


Fig. 1.2 Different leg designs [111]

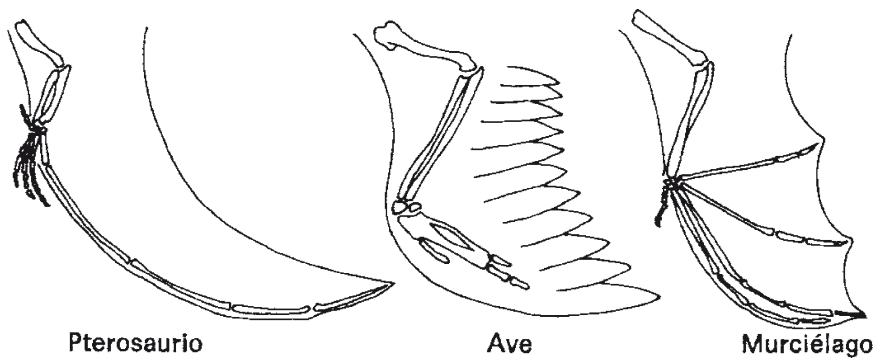


Fig. 1.3 The evolution of a leg into a wing [111]

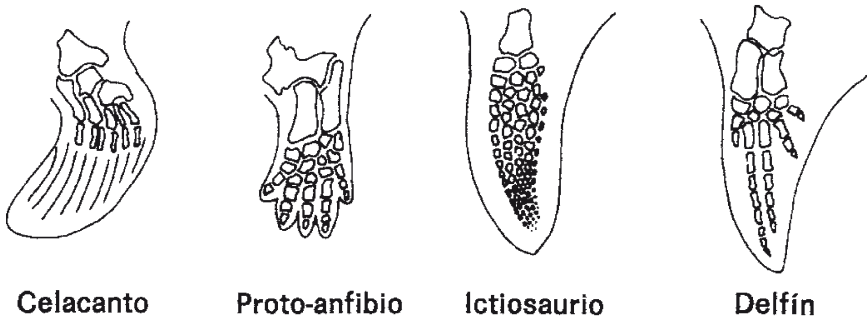


Fig. 1.4 Legs went back to the fin [111]

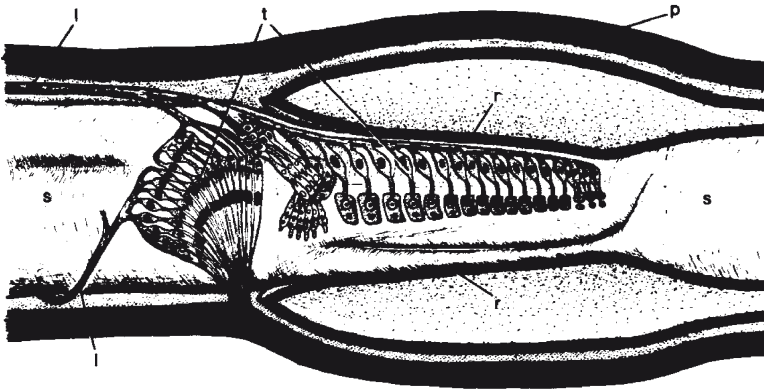


Fig. 1.5 Ear in a grasshopper's front leg [60]

Together with these original machines that made efficient use of the energy that is supplied by the muscles, Nature also designed what today might be called precision mechanisms. Sound analysis was performed by a system of vibrating sacs in a grasshopper's ear that is made with the aim to resonate by the different frequencies (Fig. 1.5). This is a very simple design as compared to other types of animal ears.

Another precision mechanism that is created by nature, is the moveable eye whose mechanical design with slight variations, is common to cephalopods and vertebrates (Fig. 1.6). It consists of a suitably lubricated spherical joint that allows the eye to be positioned rapidly and precisely in a proper desired direction. It also contains a system for filtering incidental light and a method of focussing by changing the lens curvature in mammals and by adjusting the lenses backwards and forwards in fish. These are only two of the mechanical features of the eye design.

Because of their exoskeleton structure, arthropods show the appearance of living machines and they are very interesting and inspiring from a mechanical engineering viewpoint. Beside the economy of means that is applied by Nature in this design, the mechanical perfection of a crustacean, an arachnid or an insect is

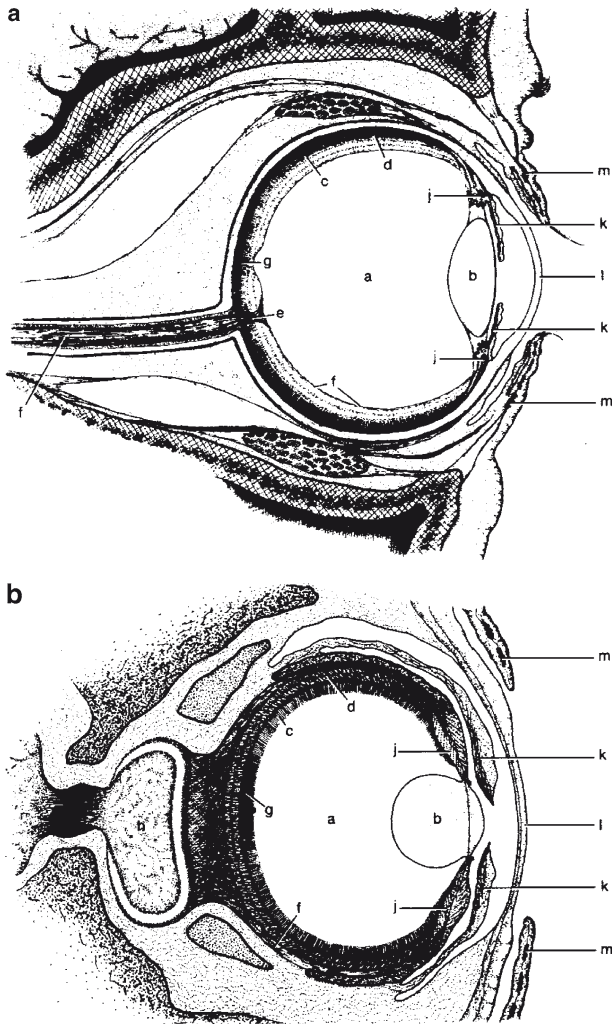


Fig. 1.6 Spherical joints in eyes [60]

amazing. With a similar anatomy, arachnids are designed (Fig. 1.7) in a way that their structures of locomotion are easily adapted to a large variety of environments like, for example, in scorpions, spiders, and mites. The precision by which the different moving parts are assembled together is really amazing. For example, there are one hundred in the case of a mite, and the overall size of the machinery leg is only few hundredths of a millimetre.

Animals themselves construct mechanical devices. It cannot be said that they make designs since they are already part of their genetic inheritance. But they properly adapt those designs to specific circumstances within which they use those constructions. This is the case of a spider's web or a weaver bird's nest.

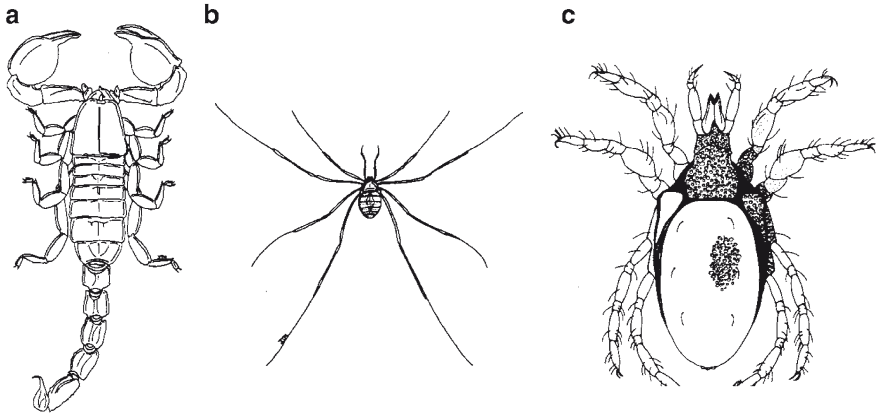


Fig. 1.7 Leg structures [77]: (a) a scorpion; (b) a spider; (c) a mite

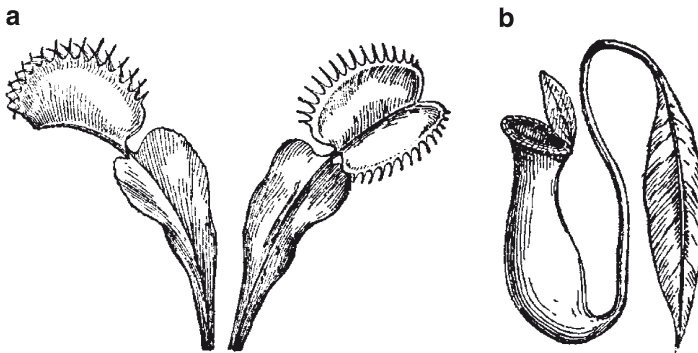


Fig. 1.8 Moving plants [37]: (a) Flycatchers; (b) Ascidia of Nepenthes

Some spiders make traps with moving parts which can be understood as real mechanisms. Carnivorous plants also have moving parts (Fig. 1.8a), that trap insects with movements that belong more properly to an animal rather than to a plant. This can be seen in the lid of the container in Fig. 1.8b that is used to protect the collected rainwater against evaporation.

Observing Nature must have inspired primitive men even until recent times, if we consider that ships copy the shape of ducks, including the head, and bird-like flying machines have been attempted.

On the Machines of Primitive Man

The concept of primitive man also includes a technological concept, which is better described as “a man that uses little developed technologies.” Cromagnon man’s mental capacity was similar to modern man’s, and present primitive cultures possess

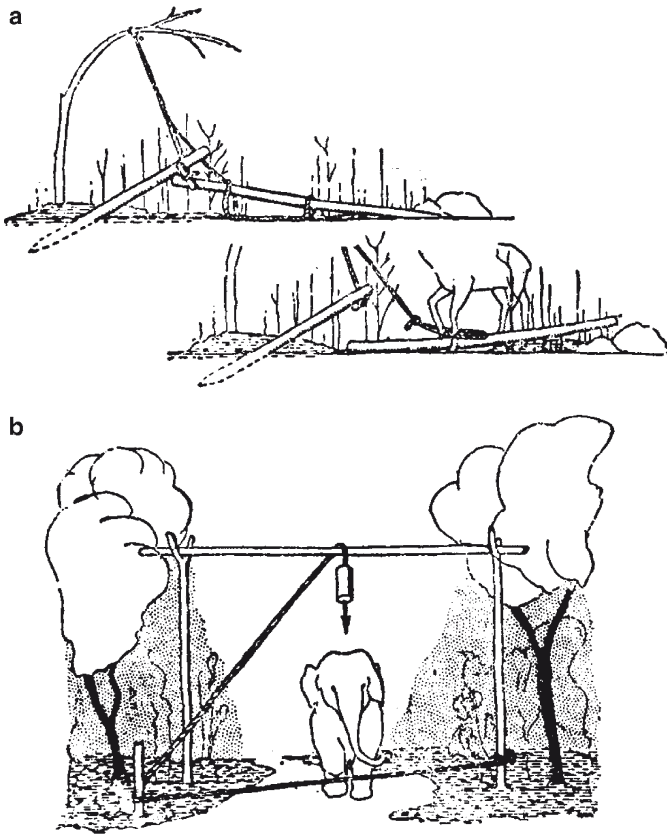


Fig. 1.9 Trap mechanisms [79]: (a) Snare for catching giraffes and other animals; (b) Elephant trap in East Africa

highly sophisticated languages and concepts for religion, cosmogony, and social views which can hardly be called primitive. Mastering technology can be understood as an arduous task that takes time and requires specific external circumstances. Oral transmission considerably limits technological developments and until the time when writing was invented man remained primitive. For a long period of time, man was a hunter-collector and continues like this in some current isolated cultures. Studying these cultures is of great help for understanding technological remains and techniques that were developed by mankind at his origins. Indeed, traps for hunting animals (Fig. 1.9) were the first machines built by man since they involved fast mechanisms that operated automatically as the animal passed through. The energy that is needed to operate these mechanisms ranges from gravity to energy supplied by vegetable springs that were also used in bows for arrows.

Observation of a spider's hunting process should have given the primitive hunter the idea to use nets to catch flying, land, and aquatic animals (Fig. 1.10). The trap was often completed with a closing mechanism or elastic catch that would allow passage in one direction only.

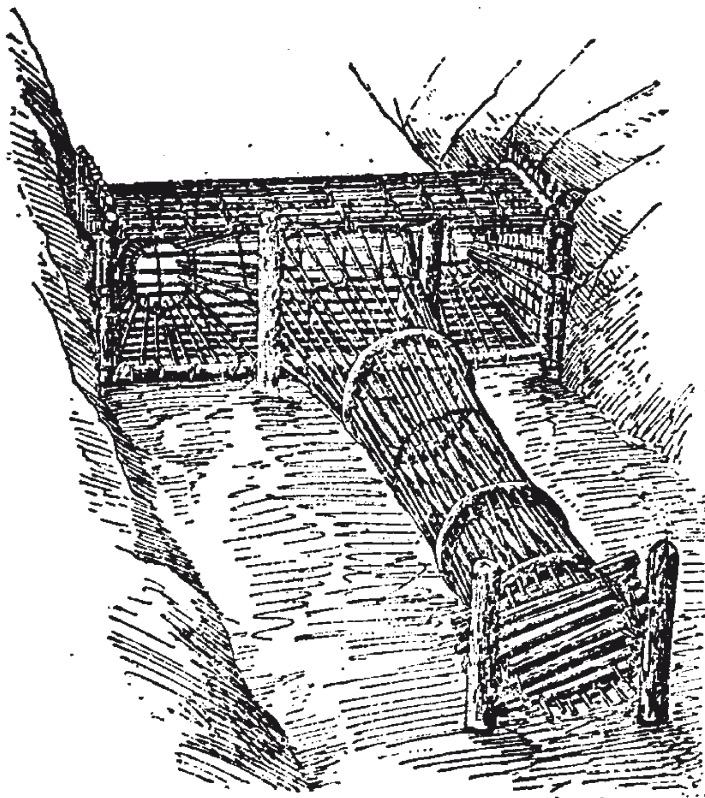


Fig. 1.10 River salmon trap of the Kwakiutl [79]

By looking at anthropological remains, man has used fire since remote times. In order to make fire by friction, he invented a machine that consists of a stick spinning fast that is driven by a bowstring (Fig. 1.11). Beside the mechanism's apparent simplicity, its successful operation involved the joint use of several devices, namely for converting translation to rotary movement, generating initial torque tension in the rope-pulley, multiplying the speed, supporting as a friction bearing, etc. It is curious that even today making fire is still linked to friction.

However, primitive cultures of south-east Asia use an ingenious mechanism (Fig. 1.12) that causes the tow to ignite by the air that is heated by adiabatic transformation similar to what happens in a modern diesel engine. The tinder is inserted into a cylinder which is plugged by the piston. A sudden blow to the piston shaft head causes a sudden decrease in the volume of air that is inside. This raises the temperature to a level that is required to ignite the tinder. A close fit is necessary between the diameters of the piston and cylinder. They must both also be made of suitable (wood) materials.

It is hard to say when those devices that present-day primitive man uses, were first used by the original primitive man. Those devices were manufactured with

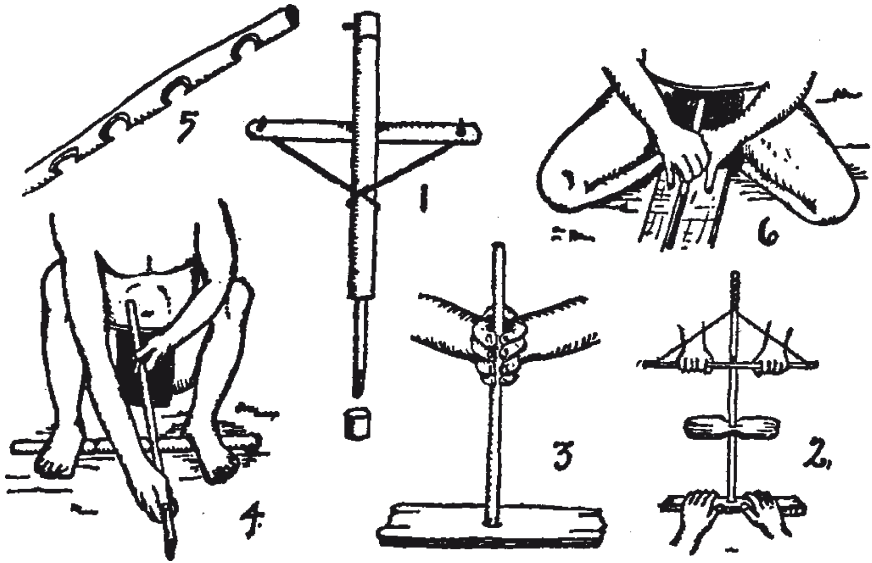


Fig. 1.11 Fire-making techniques [79]: (1) Yukaghir bow drill; (2) Pump movement drill; (3) Hand drill; (4) Saw for making fire; (5) Instrument from Queensland; (6) Melanesian fire plough method

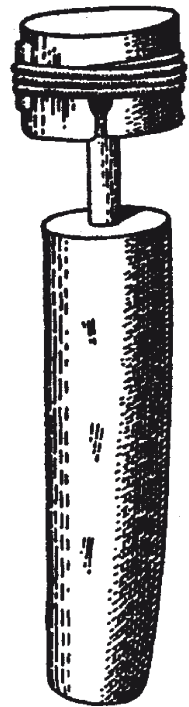


Fig. 1.12 Fire piston [81]

perishable vegetable materials, remains of which have not survived in Palaeolithic sites. For example, it may be assumed that the boomerang used by the Australian aborigines has been known since pre-history since there are European Neolithic cave-paintings that can be interpreted as such.

By pure logic, it is highly unlikely that many prehistoric mechanisms or machines made of wood will have survived at Palaeolithic sites. We should not think that the ingenuity of prehistoric man was less than that of present-day man belonging to primitive cultures, since the evolutions should be due to similar needs in similar surroundings. Thus, the mechanism that was designed to make fire had been used to drill both large and small holes (Fig. 1.13) and as a domestic device for churning milk to obtain butter (Fig. 1.14).

During the Neolithic revolution, over a few thousand years man domesticated animals and plants and he started a sedentary existence that enabled him (and maybe he was forced) to invent new machines. The wheel made its appearance with various uses, such as the potter's wheel (Fig. 1.15).

The development of agriculture made cereals an abundant food source and the human population rapidly increased. In order to grind the grain, more productive machines than the previous mortars were needed. In this case, even a wheel, made of stone, offered an appropriate solution as in the first hand mills (Fig. 1.16), where a spherical joint between the operating stick and concentric hole in the upper millstone ensured efficient operation. The apparent simplicity of the device reveals significant mechanical contributions when it is carefully analyzed.

Extensive agriculture is inseparable from irrigation. The first machine for raising water from wells or river beds was based on the use of a lever (Fig. 1.17), by using gravity as an aid to human effort.

Mechanisms similar to the lever have been known since the time of the hunter-collectors. The dart launcher in Fig. 1.18 gave a larger launching momentum than the provided by the hunter's arm. The fact that some of these launching mechanisms were made of bone or ivory has permitted them to survive in prehistoric sites.

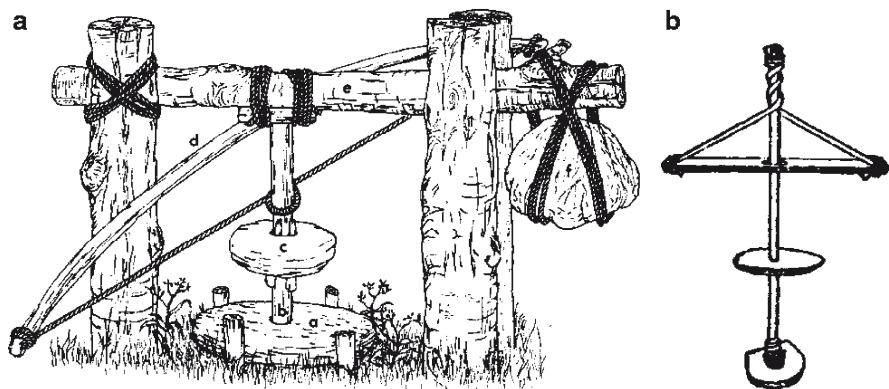


Fig. 1.13 Mechanisms of fire making used as: (a) bow drilling machine in a reconstruction [119]; (b) fire drilling mechanism [79]

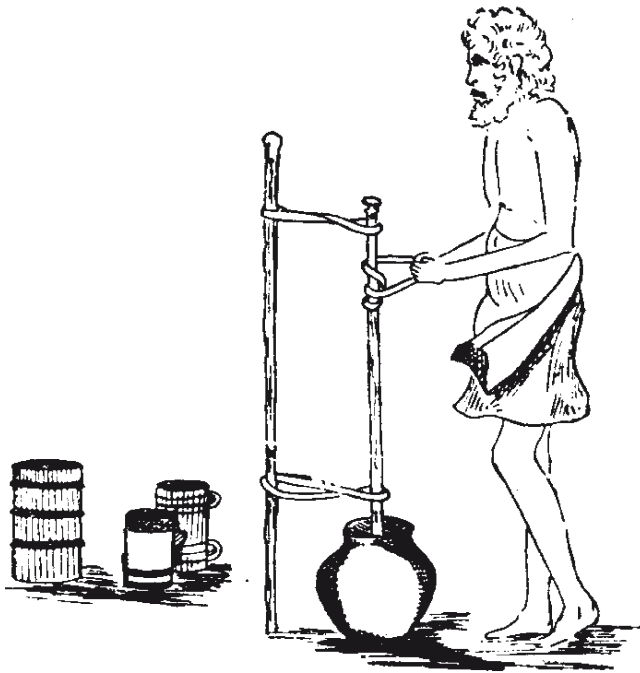


Fig. 1.14 Churn for butter drilling [79]

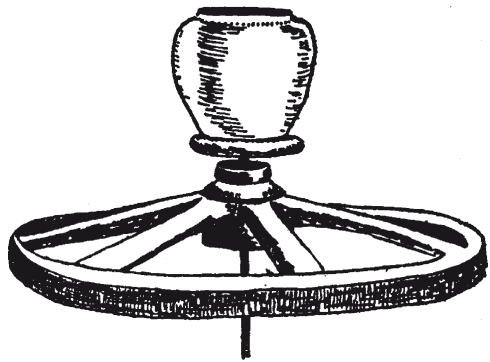


Fig. 1.15 Potter's wheel [79]

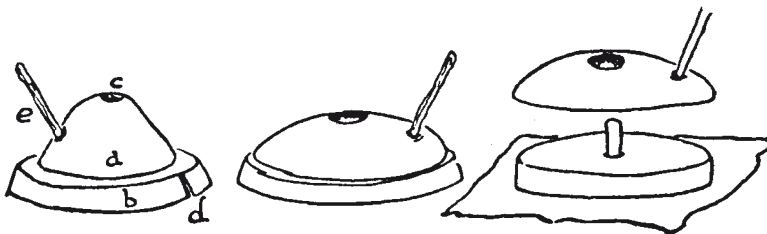


Fig. 1.16 Stone wheeled hand mills [40]: (a) Mill from Ifni, (b) Barley mill, Río de Oro, (c) Stone mill on hide, El Rehá (Río de Oro)

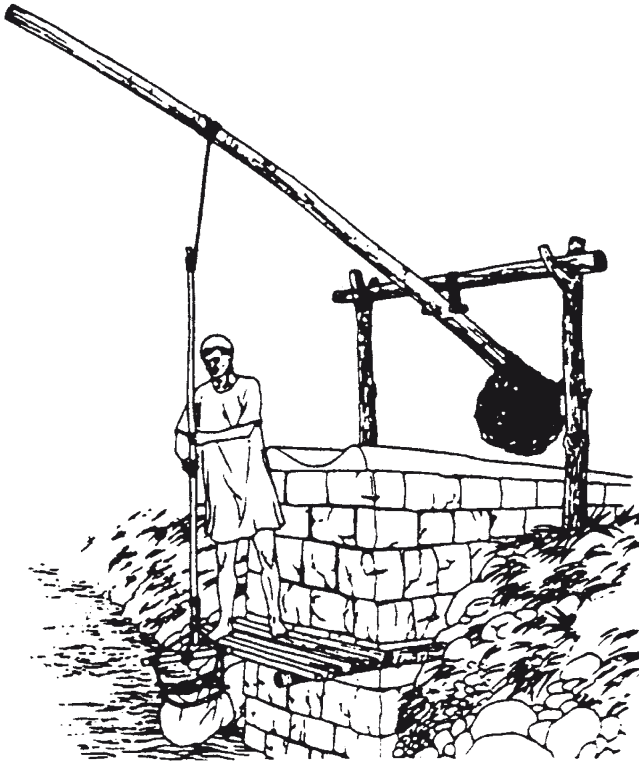


Fig. 1.17 Water extraction system with lever and counterweight (named as shadoof) [84]

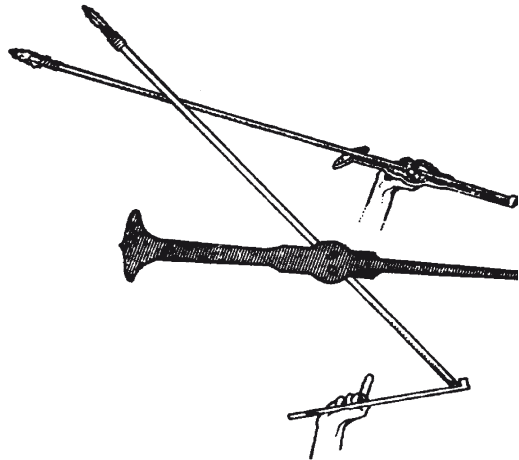


Fig. 1.18 Spear launching mechanisms [79]

Sometimes, a half-cylindrical bearing supported the dart with the moving end of the launching mechanisms, which reinforces the idea that the device was a precursor of well-developed mechanisms.

On Popular Machines

In rural environments machines are sometimes used whose designs show interesting variations of mechanisms that are already described in ancient treatises. It is difficult to know up to what point these rural craftsmen reinvented the machines or whether they started out from existing mechanisms. This problem of multiple origins within cultural dissemination is typical in ethnology when similar features are found in cultures that are far from each other.

However, it is worth noting that in their treatises, ancient authors wrote about machines that were used in their times as well as about other machines that were developed by well-known persons. Therefore, it seems not only fair to mention, even if only in a brief outline, the contributions of machines that were developed by the anonymous, inventive genius of ordinary people.

Very probably, the belt and pedal operated lathe appeared at the beginning of time and at least at the same time as the potter's wheel, with the same purpose of making containers, as shown in the example in Fig. 1.19. Since the parts turning in

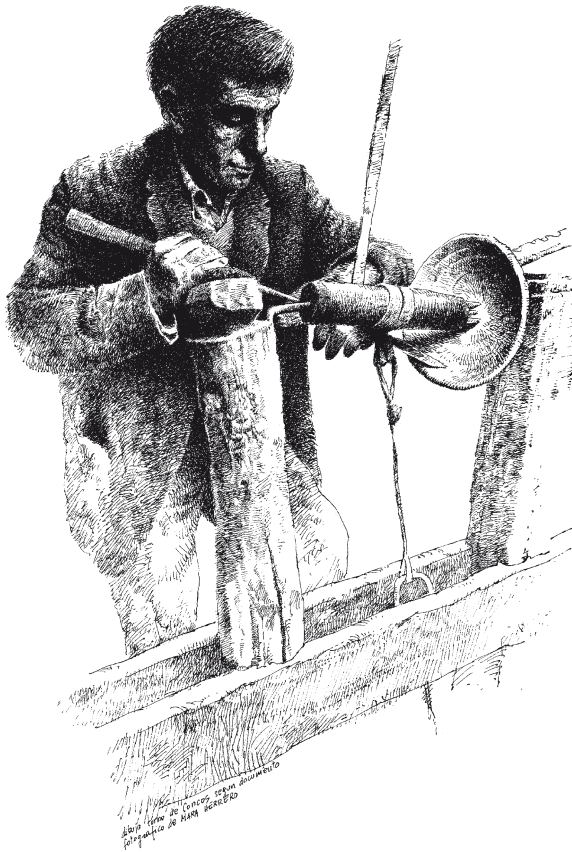


Fig. 1.19 Conqueiro lathe [74]

the lathe were made of wood, it is unlikely that any archaeological remains will have survived, unlike ceramic containers. The machine itself, made with perishable materials, is unlikely to have resisted time. The same considerations can be made for popular textile machinery (Fig. 1.20).

Ordinary people's inventive genius was not only reflected in the conception of complete mechanisms, but also in the invention of ingenious mechanical parts. Figure 1.21 shows the pivot supporting an upright shaft, that was called, not surprisingly, an "egg", since it was a resource that the designer had at his disposal but with an appropriate choice of materials.

When mankind evolved to the Stone Age, several mechanisms became necessary to make metallurgy furnaces work. Ones of these were the bellows (Fig. 1.22a, b), whose operation is similar to the piston pump in Fig. 1.22c. Those devices depended of the invention of a valve system that permitted fluid to pass along in



Fig. 1.20 Spinning wheels [74]

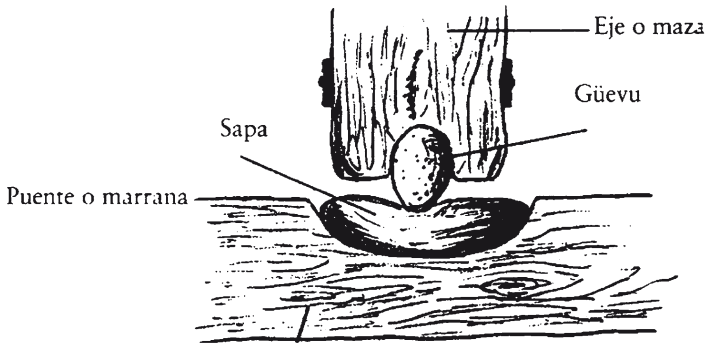


Fig. 1.21 Support system using an upright shaft bearing [84]

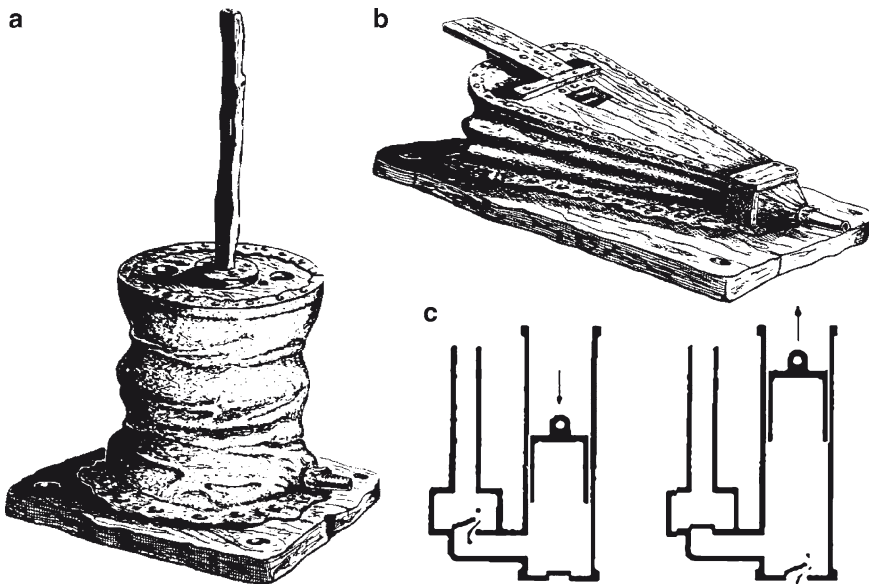


Fig. 1.22 Devices for air supplies: (a) a piston bellow and (b) planar bellow [84]; (c) a scheme for a piston pump, from “Ancient Greek Technology” by Elias Sfetsos

one direction only. The step from manual operation to the use of hydraulic energy as the driving force was only a question of time, but above all, it was due to a need for greater power.

But when hydraulic energy was already being used to supply furnaces with air, popular ingenuity came up with a new system that supplied the furnace

Fig. 1.23 Cross-section of a Catalan forge [84]

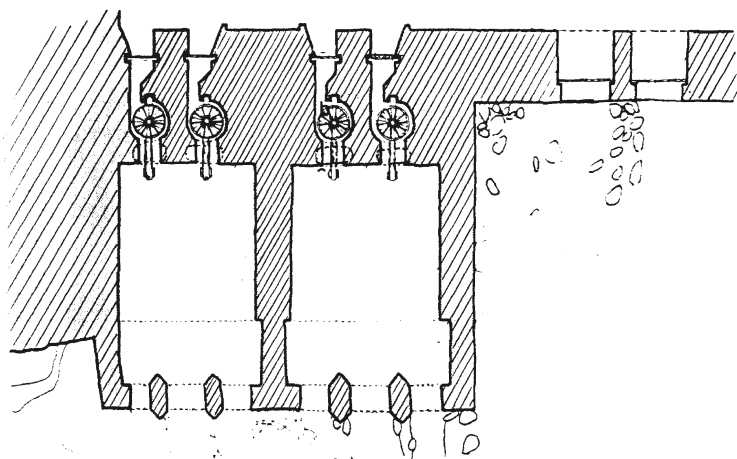
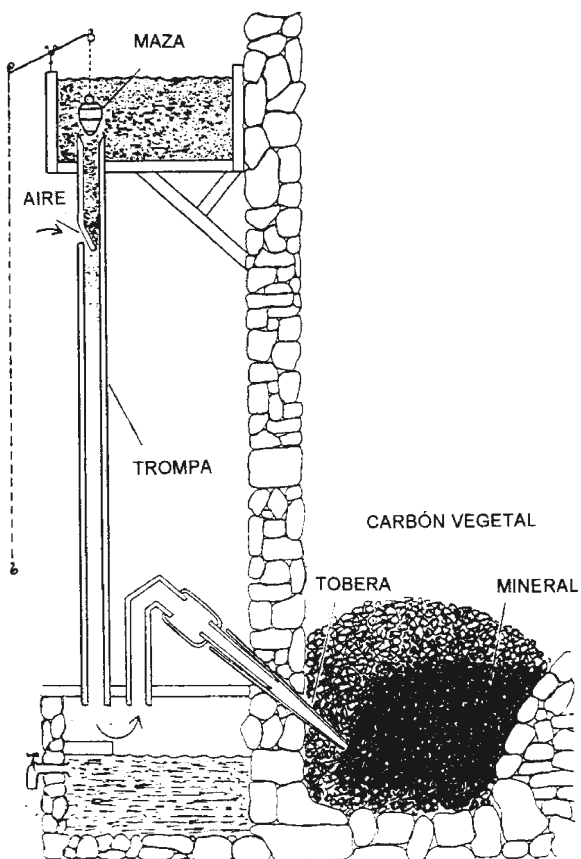


Fig. 1.24 A tide mill of thirteenth century [84]

with continuous air. An upright siphon (Fig. 1.23), through which the air flows, was the driving mechanism. In Compludo, which is a place close to Leon, there is a seventh century foundry that is still in use with this blast system, although nowadays it merely operates as a tourist attraction. It was not until the eighteenth century that Venturi explained the effect on which this system was based.

A further example of popular ingenuity is the use of tidal energy for operating mills. In the eleventh century, along the European Atlantic coast mills had been built by using the periodic changes in sea-levels as a power source (Fig. 1.24), since the tide is of relevant size. This new power source included changes to the mill design that were operated by river currents, as already described in Antiquity. The mill design in Fig. 1.24 was already working in Asturias in 1232, according to written documents.