

CHARLES BABBAGE

Charles Babbage (1792-1871) was Lucasian Professor of Mathematics at Cambridge University and spent a considerable part of his life, his personal wealth, and a grant received from the British government in an attempt to build an analytical calculating machine. Although he was never successful in constructing such a machine, he provided the specifications which foresaw the automatic computer as we have it today.

It was in the course of his attempt to get the various parts constructed for his computer that Babbage made his second contribution to modern management. He spent ten years visiting various factories and work shops in England and on the continent, and in 1832 published the results of this experience and his thoughts on various subjects in a book entitled, *On the Economy of Machinery and Manufacturing*. It discusses some of the problems created by the relatively new organization known as the factory, and traces "both the causes and the consequences of applying machinery to supercede the skill and power of the human arm."

Quoted below are sections dealing with the division of labor and with his suggested system of manufacturing. In other sections of his book Babbage introduces ideas on production, human relations, sales, costs, and organization, all of which appear to have surprising applicability today.

On the Division of Labour

Perhaps the most important principle on which the economy of a manufacture depends, is the division of labour amongst the persons who perform the work. The first application of this principle must have been made in a very early stage of society; for it must soon have been apparent, that more comforts and conveniences could be acquired by one man restricting his occupation to the art of making bows, another to that of building houses, a third boats, and so on. This division of labour into trades was not, however, the result of an opinion that the general riches of the community would be increased by such an arrangement; but it must have arisen from the circumstance,

Reprinted from the book, On the Economy of Machinery and Manufactures, by Charles Babbage, Chapter 19, pages 169-176, 183, 184, 185-187. Published by Charles Knight, London, 1835.

of each individual so employed discovering that he himself could thus make a greater profit of his labour than by pursuing more varied occupations. Society must have made considerable advances before this principle could have been carried into the workshop; for it is only in countries which have attained a high degree of civilization, and in articles in which there is a great competition amongst the producers, that the most perfect system of the division of labour is to be observed. The principles on which the advantages of this system depend, have been much the subject of discussion amongst writers on Political Economy; but the relative importance of their influence does not appear, in all cases, to have been estimated with sufficient precision. It is my intention, in the first instance, to state shortly those principles, and then to point out what appears to me to have been omitted by those who have previously treated the subject.

1. Of the time required for learning. It will readily be admitted, that the portion of time occupied in the acquisition of any art will depend on the difficulty of its execution; and that the greater the number of distinct processes, the longer will be the time which the apprentice must employ in acquiring it. Five or seven years have been adopted, in a great many trades, as the time considered requisite for a lad to acquire a sufficient knowledge of his art, and to enable him to repay by his labour, during the latter portion of his time, the expense incurred by his master at its commencement. If, however, instead of learning all the different processes for making a needle, for instance, his attention be confined to one operation, the portion of time consumed unprofitably at the commencement of his apprenticeship will be small, and all the rest of it will be beneficial to his master: and, consequently, if there be any competition amongst the masters, the apprentice will be able to make better terms, and diminish the period of his servitude. Again, the facility of acquiring skill in a single process, and the early period of life at which it can be made a source of profit, will induce a greater number of parents to bring up their children to it; and from this circumstance also, the number of workmen being increased, the wages will soon fall.

2. Of waste of materials in learning. A certain quantity of material will, in all cases, be consumed unprofitably, or spoiled by every person who learns an art; and as he applies himself to each new process, he will waste some of the raw material, or of the partly manufactured commodity. But if each man commit this waste in acquiring successively every process, the quantity of waste will be much greater than if each person confine his attention to one process; in this view of the subject, therefore,

the division of labour will diminish the price of production.

3. Another advantage resulting from the division of labour is, the saving of that portion of time which is always lost in changing from one occupation to another. When the human hand, or the human head, has been for some time occupied in any kind of work, it cannot instantly change its employment with full effect. The muscles of the limbs employed have acquired a flexibility during their exertion, and those not in action a stiffness during rest, which renders every change slow and unequal in the commencement. Long habit also produces in the muscles exercised a capacity for enduring fatigue to a much greater degree than they could support under other circumstances. A similar result seems to take place in any change of mental exertion; the attention bestowed on the new subject not being so perfect at first as it becomes after some exercise.

4. Change of Tools. The employment of different tools in the successive processes is another cause of the loss of time in changing from one operation to another. If these tools are simple, and the change is not frequent, the loss of time is not considerable; but in many processes of the arts the tools are of great delicacy, requiring accurate adjustment every time they are used; and in many cases the time employed in adjusting bears a large proportion to that employed in using the tool. The sliding-rest, the dividing and the drilling-engine, are of this kind; and hence, in manufactories of sufficient extent, it is found to be good economy to keep one machine constantly employed in one kind of work: one lathe, for example, having a screw motion to its sliding-rest along the whole length of its bed, is kept constantly making cylinders; another, having a motion for equalizing the velocity of the work at the point at which it passes the tool, is kept for facing surfaces; whilst a third is constantly employed in cutting wheels.

5. Skill acquired by frequent repetition of the same processes. The constant repetition of the same process necessarily produces in the workman a degree of excellence and rapidity in his particular department, which is never possessed by a person who is obliged to execute many different processes. This rapidity is still further increased from the circumstance that most of the operations in factories, where the division of labour is carried to a considerable extent, are paid for as piece-work. It is difficult to estimate in numbers the effect of this cause upon production. In nail-making, Adam Smith has stated, that it is almost three to one; for, he observes, that a smith accustomed to make nails, but whose whole business has not been that of a nailer, can make only from eight hundred to a thousand per

day; whilst a lad who had never exercised any other trade, can make upwards of two thousand three hundred a day.

In different trades, the economy of production arising from the last-mentioned cause will necessarily be different. The case of nail-making is, perhaps, rather an extreme one. It must, however, be observed, that, in one sense, this is not a permanent source of advantage; for, though it acts at the commencement of an establishment, yet every month adds to the skill of the workmen; and at the end of three or four years they will not be very far behind those who have never practised any other branch of their art. Upon an occasion when a large issue of bank-notes was required, a clerk at the Bank of England signed his name, consisting of seven letters, including the initial of his Christian name, five thousand three hundred times during eleven working hours, besides arranging the notes he had signed in parcels of fifty each.

6. The division of labour suggests the contrivance of tools and machinery to execute its processes. When each process, by which any article is produced, is the sole occupation of one individual, his whole attention being devoted to a very limited and simple operation, improvements in the form of his tools, or in the mode of using them, are much more likely to occur to his mind, than if it were distracted by a greater variety of circumstances. Such an improvement in the tool is generally the first step towards a machine. If a piece of metal is to be cut in a lathe, for example, there is one particular angle at which the cutting-tool must be held to insure the cleanest cut; and it is quite natural that the idea of fixing the tool at that angle should present itself to an intelligent workman. The necessity of moving the tool slowly, and in a direction parallel to itself, would suggest the use of a screw, and thus arises the sliding-rest. It was probably the idea of mounting a chisel in a frame, to prevent its cutting too deeply, which gave rise to the common carpenter's plane. In cases where a blow from a hammer is employed, experience teaches the proper force required. The transition from the hammer held in the hand to one mounted upon an axis, and lifted regularly to a certain height by some mechanical contrivance, requires perhaps a greater degree of invention than those just instanced; yet it is not difficult to perceive, that, if the hammer always falls from the same height, its effect must be always the same.

When each process has been reduced to the use of some simple tool, the union of all these tools, actuated by one moving power, constitutes a machine. In contriving tools and simplifying processes, the operative workmen are, perhaps, most successful; but it requires far other habits to combine into one machine these scattered arts. A previous education

as a workman in the peculiar trade, is undoubtedly a valuable preliminary; but in order to make such combinations with any reasonable expectation of success, an extensive knowledge of machinery, and the power of making mechanical drawings, are essentially requisite. These accomplishments are now much more common than they were formerly; and their absence was, perhaps, one of the causes of the multitude of failures in the early history of many of our manufactures.

Such are the principles usually assigned as the causes of the advantage resulting from the division of labour. As in the view I have taken of the question, the most important and influential cause has been altogether unnoticed, I shall re-state those principles in the words of Adam Smith: "The great increase in the quantity of work, which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances: first, to the increase of dexterity in every particular workman; secondly, to the saving of time, which is commonly lost in passing from one species of work to another; and, lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many." Now, although all these are important causes, and each has its influence on the result; yet it appears to me, that any explanation of the cheapness of manufactured articles, as consequent upon the division of labour, would be incomplete if the following principle were omitted to be stated.

That the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided.*

As the clear apprehension of this principle, upon which a great part of the economy arising from the division of labour depends, is of considerable importance, it may be desirable to point out its precise and numerical application in some specific manufacture. The art of making needles is, perhaps, that which I should have selected for this illustration, as comprehending a very large number of processes remarkably different in their nature; but the less difficult art of pin-making, has some claim to attention, from its having been used by Adam Smith; ...

* I have already stated that this principle presented itself to me after a personal examination of a number of manufactories and workshops devoted to different purposes; but I have since found that it had been distinctly pointed out, in the work of Gioja, Nuovo Prospetto delle Scienze Economiche, 6 tom. 4to. Milano, 1815, tom.i. capo iv.

...it will be convenient to present a tabular view of the time occupied by each process, and its cost, as well as the sums which can be earned by the persons who confine themselves solely to each process. As the rate of wages is itself fluctuating, and as the prices paid and quantities executed have been given only between certain limits, it is not to be expected that this table can represent the cost of each part of the work with the minutest accuracy, nor even that it shall accord perfectly with the prices above given: but it has been drawn up with some care, and will be quite sufficient to serve as the basis of those reasonings which it is meant to illustrate...

Pins, "Elevens," 5,546 weigh one pound; "one dozen" =6,932 pins weight twenty ounces, and require six ounces of paper.

Name of the Process	Work men	Time of making 1 lb. of pins	Cost of making 1 lb. of pins	Work man earns per day	Price of making each part of a single pin, in millionths of a penny
1. Drawing Wire	Man	Hours .3636	Pence 1.2500	s. d. 3 3	225
2. Straightening Wire	(Woman	.3000	.2840	1 0	51
	(Girl	.3000	.1420	0 6	26
3. Pointing	Man	.3000	1.7750	5 3	319
4. Twisting and Cutting Heads	(Boy	.0400	.0147	0 4 $\frac{1}{2}$	3
	(Man	.0400	.2103	5 4 $\frac{1}{2}$	38
5. Heading	Woman	4.0000	5.0000	1 3	901
6. Tinning, or Whitening	(Man	.1071	.6666	6 0	121
	(Woman	.1071	.3333	3 0	60
7. Papering	Woman	2.1314	3.1973	1 6	576
		<u>7.6892</u>	<u>12.8732</u>		<u>2320</u>

Number of Persons employed:--Men, 4; Women, 4; Children, 2. Total, 10.

It appears from the analysis we have given of the art of pin-making, that it occupies rather more than seven hours and a half of time, for ten different individuals working in succession on the same material, to convert it

into a pound of pins; and that the total expense of their labour, each being paid in the joint ratio of his skill and of the time he is employed, amounts very nearly to 1s. 1d. But from an examination of the first of these tables, it appears that the wages earned by the persons employed vary from 4½d. per day up to 6s., and consequently the skill which is required for their respective employments may be measured by those sums. Now it is evident, that if one person were required to make the whole pound of pins, he must have skill enough to earn about 5s. 3d. per day, whilst he is pointing the wires or cutting off the heads from the spiral coils,--and 6s. when he is whitening the pins; which three operations together would occupy little more than the seventeenth part of his time. It is also apparent, that during more than one half of his time he must be earning only 1s. 3d. per day, in putting on the heads; although his skill, if properly employed, would, in the same time, produce nearly five times as much. If, therefore, we were to employ, for all the processes, the man who whitens the pins, and who earns 6s. per day, even supposing that he could make the pound of pins in an equally short time, yet we must pay him for his time 46.14 pence, or about 3s. 10d. The pins would therefore cost, in making, three times and three quarters as much as they now do by the application of the division of labour.

The higher the skill required of the workman in any one process of a manufacture, and the smaller the time during which it is employed, so much the greater will be the advantage of separating that process from the rest, and devoting one person's attention entirely to it. Had we selected the art of needle making as our illustration, the economy arising from the division of labour would have been still more striking; for the process of tempering the needles requires great skill, attention, and experience, and although from three to four thousand are tempered at once, the workman is paid a very high rate of wages. In another process of the same manufacture, dry-pointing, which also is executed with great rapidity, the wages earned by the workman reach from 7s. to 12 s., 15s., and even, in some instances, to 20s. per day; whilst other processes are carried on by children paid at the rate of 6d. per day.