PART II

SOCIAL SYNTHESIS AND PRODUCTION

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Societies of Production and Societies of Appropriation*

We have already made mention of the factor by which the conditions of production within class societies differ from those of classless ones. The contrast hinges on the different nature of the social synthesis. If a society has the form of its synthesis determined by the labour relationship in the production process, thus deriving its fundamental order directly from the labour process of man's acting upon nature, then the society is, or has the possibility of being, classless. We have spoken of such societies under Marx's term 'communal modes of production'. Labour is either done collectively by members of a tribe, or if done individually or in groups the workers still know what each one does, and work in agreement. People create their own society as producers. The structure enables us to call them 'societies of production'. The alternative is a form of society based on appropriation.

We understand appropriation as functioning between men within society, as the appropriation of products of labour by non-labourers; not, as sometimes described, as man appropriating his needs from nature. Here we must differentiate between unilateral and reciprocal forms of appropriation. Unilateral appropriation of the surplus product leads to the manifold forms of a class society which Marx called 'direct lordship and bondage'. The appropriation here is carried out by the imposition of tributes, forced or voluntary, or by plain robbery; it is carried out as a public activity by the rulers and can be based on subjugation or on 'god-given rights'. But the questions which interest us attach

* In this part, as elsewhere in the book, we shall limit ourselves in the main to the broader aspects of historical understanding without dealing with them in detail.

to forms of society based on reciprocal appropriation as private exchange; in other words, to the various forms of commodity production. The common feature of all societies of appropriation is a social synthesis effected by activities which are qualitatively different and separated in time from the labour which produces the objects of appropriation. It is unnecessary to stress that no social formation, whether based on production or on appropriation, can be understood without due consideration of the productive forces in their particular state of development.

In Part I of this book we attempted to show that a social synthesis effected through the reciprocal forms of appropriation in commodity exchange leads to the inception of intellectual labour of a kind separated from manual labour. From this one might be tempted to generalise and to conclude: whatever the social formation, be it one of appropriation or production, the socially synthetic functions will determine the forms of consciousness of its epoch. If this generalisation proves true our analysis might gain significance for our present concern in the struggle for socialism.

II

Head and Hand in Labour

First of all it must be stated that no human labour can take place without a degree of unity of head and hand. Labour is not animal-like and instinctive, but constitutes purposeful activity; the purpose must guide the physical endeavour, no matter what kind, to its intended goal as a consequential pursuit. Marx writes

> We presuppose labour in a form in which it is an exclusively human characteristic. A spider conducts operations which resemble those of the weaver, and a bee would put many a human architect to shame by the construction of its honeycomb cells. But what distinguishes the worst architect from the best of bees is that the architect builds the cell in his mind before he constructs it in wax. At the end of every labour process, a result emerges which had already been conceived by the worker at the beginning, hence already existed ideally.[1]

But for us the essential question is: in whose head is the intended result of the labour process anticipated?

> In so far as the labour process is purely individual, the same worker unites in himself all the functions that later on become separated. When an individual appropriates natural objects for his own livelihood, he alone supervises his own activity. Later on he is supervised by others.[2]

Of course, in one special sense, as work carried out as a one-man job, the individual labour process stands at the beginning of commodity production, but not at the beginning of human history. It must thus be decided whether the intended achievement of a labour process is an idea in the head of a single performer, or of several collectively, or whether it might lie in an alien head which deals the workers mere snippets of the process which signify to them no end goal whatsoever. Dependent on these alternatives are the changes in the relationship between head and hand, the relation between intellectual and manual labour.

It is important for us to differentiate between personal and social unity, or division, of head and hand. Personal unity attaches only to the labour of the one-man producer. This does not mean that, conversely, all individual one-man production presupposes such a personal unity; for example the slaves who produced the pottery or textiles by their individual labour were far from being masters of its purpose or form. Personal division of head and hand applies to all labour whose purpose is prescribed elsewhere. Social unity of head and hand, however, characterises communist society whether it be primitive or technologically highly developed. In contrast to this stands the social division between mental and manual labour – present throughout the whole history of exploitation and assuming the most varied forms.

Viewed as a whole, the development of society moves historically from primitive communism where production is totally communal, step by step to the extension of individual one-man production covering every essential area and thus to the beginning of commodity production. At this stage the use of coinage heralds the epoch of the social form of thinking as separate pure intellect. Manual production becomes single production, but at the same time intellectual labour becomes universalised. This middle stage of the historical development was reached in classical antiquity and produced societies of appropriation in their absolute 'classical' form; that of Roman and Greek slave labour where the slave does not partake in human society. But from the breaking up of this epoch a process begins where socialisation seizes upon production and even upon manual labour itself, thus pushing forward to today's stage of development. Now, within the capitalist society of appropriation, the preconditions of a modern society of production have ripened and, as Marx and Engels predicted, mankind is face to face with the ineluctable alternative of a society of production, or a society of appropriation. My intention is to follow through the main stages of this whole development in the most compressed form.

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The Beginnings of Surplus Production and Exploitation

By this title we understand the transition from the primitive, communistic society of production to the first forms of society of appropriation. The beginnings of appropriation within society presuppose a growth in productivity or a development in the

productive forces of collective communal labour sufficient to expect regular surpluses of a worth-while dimension over and above subsistence level. As Marx puts it:

> It is only when men have worked their way out of their initial animal condition, when therefore their labour has been to some extent socialised, that a situation arises in which the surplus labour of one person becomes a condition of existence for another.[3]

The first beginnings of appropriation develop within the community and bring with them slow but nevertheless incisive changes in the conditions of production based on communal property and consumption. Marx recognises a particular phenomenon as necessarily mediating these changes; namely, the rise of exchange with other communities, an exchange having an erosive feed-back effect on the order of things within. A more permanent effect arises when those who benefit from the incipient appropriation become active forces driving on the development in their own interests and organising themselves into a separate social power. Their influence prompts increasing incursions into the communal property, particularly of the land, with growing conditions of dependency for the producers. Gradually there crystallise hard-and-fast class divisions within the society, based on inheritance, patriarchy, wars of conquest and extensive plundering and trade.

This brief outline is designed to bring out three fundamental factors: In the first place the primary producers, tillers of land, cattle-rearers, etc., remain for a long time communal; second, the enrichment of the appropriating class occurs in the forms of unilateral appropriation of the surplus product; third, the exchange of products maintains, for the most part, the character of external trade between different communities. It is only later that exchange develops into the form of the inner social nexus.

Individual production started at its earliest with the making of stone tools and weapons, but continued in the artisan crafts of later Neolithic inventions such as in secondary production like pottery, spinning and weaving, mainly by women; then towards the end of the Neolithic Age in the metal crafts which were the work of men. The secondary industries became the main area of

trade, just as trade became the promoting force for the growth of the secondary crafts. The production of surplus and the class-character of wealth underwent a massive impetus through the development and interaction of these two factors, secondary industries and trade, and so set in motion such an incredible achievement as the cultivation of the great fertile river valleys, which, from the Nile to the Yellow River occurred within the same time span, between the fifth and third millennia B.C.

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Head and Hand in the Bronze Age

Not before the development of iron metallurgy did individual, small-scale farming become the method and the standard of primary production; and between the Neolithic and the Iron Ages lie thousands of years, the millennia of the Bronze Age. This epoch had its own characteristic social formation, that of the ancient oriental cultures which, from the cultivation of the fertile river valleys, appear as large-scale civilisations compared with the preceding Neolithic communities. For our particular sketch, ancient Egypt will serve as a model, for it is here that the first preliminary forms of the division of intellectual from manual labour appear at their clearest. It is generally recognised that later Greek philosophy and science were heavily indebted to this epoch.

The ancient oriental social formation had the character of a two-story structure. The base comprised agriculture and animal husbandry on the fertile land and its surroundings, an economy which we can sum up under the name of alluvial primary production. This was still carried out by the methods of collective

communal production relying on stone tools and not on metal implements, because bronze was far too precious to be put in the hands of the cultivators.[4] In other words the communal character of the form of production was not dissolved. The fertility of the alluvial soils was preserved and increased by the skilful and methodically planned irrigation systems more or less common to all these civilisations, thus drawing from primary production a surplus which was vast measured by earlier standards.

The occupation and clearance of the river valleys was not done by the producers on their own initiative, but under the whip and direction of the rulers either of the same or another ethnic origin. From the very beginning their purpose was to appropriate the increased surplus product. This extraordinary achievement in itself presupposes a decisive division between the dominating and organising rulers and the physical exertions of the collective primary producers. The delivery of the surplus product by the producers or alternatively its collection by the rulers and their functionaries necessitated hardly any additional coercion. It was a result, by and large, of the reverential obedience of the producers to their rulers. The Pharaoh was the supreme owner of the cultivated land, and through his supposed sacred relationship with the powers of nature guaranteed the producers lasting possession of the soil and the very possibility for their preservation. The appropriation was public and official activity centred in the Pharaoh whose whole State was organised as a machine for the collection, storage and disposal of the surplus. This does not exclude the existence of exchange and trade, but it was carried on as external state trade with foreign communities.

Based on the appropriation of the vastly increased surplus, a culture now developed which formed the second story of the social formation. This employed the crafts of Neolithic origin to serve the exclusive and qualitatively highly refined needs of the rulers. The metallurgy of bronze and of the precious metals takes first place in these crafts, as in all probability the foundation and achievement of the whole culture would have been impossible using only stone tools. For the furtherance of these secondary crafts, including textiles, woodwork, rope-making, stone-cutting, jewellery, cosmetics, sculpture and so on, there unfolds a far-flung trade where the primary products, conserved and stored in chambers and granaries, were exchanged for the raw and

auxiliary materials necessary for the luxury production. It was a trade carried out with other States and communities by order and in the name of the Egyptian State, and in addition benefited their immense building projects and cult activities, state-organised mines, expeditions and war campaigns. The exchange trade, however, did not permeate the internal order of these Bronze Age societies.

This whole upper story of the civilisation rested, in direct 'lordship and bondage', on the unilateral appropriation of the primary surplus product. And it was to promote this appropriation and its actual performance, that script and the art of writing, numeration and arithmetic – in other words symbolic forms and separate intellectual labour came to be conceived and developed. Thus, in our opinion, intellectual in separation from manual labour arises as a means of the appropriation of products of labour by non-labourers – not originally as an aid to production. It served the calculation of tributes, the accounting of credits and repayments in the relation between the temple authorities or officials of the Pharaoh and their debtors, the storing and listing of appropriated products, the recording of the volume of incoming or outgoing supplies and other similar operations.

A good illustration is provided by the reports and surmises of Herodotus about the origins of geometry in ancient Egypt. Rope was its principal tool and 'geometry' was practised as a professional skill by people whom the Greeks, translating the Egyptian name literally, called 'harpedonapts': stretchers of the rope. The teaching and exercise manual of Ahmes found in the Rhind Papyrus together with numerous Egyptian reliefs show clearly that these stretchers of the rope were assigned, usually in pairs, to the high officials of the Pharaoh for the building of temples and pyramids, the laying down and paving of dams, the construction of granaries and measurement of their volume, and, most important, to parcel out the soil afresh when it re-emerged after the dispersal of the yearly floods of the Nile. This could evoke the impression that geometry had been invented for the sake of the cultivators – that is, in the relation of man to nature – rather than out of the social production relations and the economy, as Marx would lead one to expect. In actual fact, however, many of the Greek historiographers were inaccurate

and incomplete in their presentation, for in the text of Herodotus he says specifically that this partition of the soil was done for the purpose of reassessing the peasants' tributes for the coming year. Hence geometry did not appear to the cultivators in their own garb but in the attire of the Pharaoh's tax officials accompanied by their field measurers.

If the rope was handled with the necessary dexterity and with the know-how of long experience one can reasonably suppose that there were few problems of geometry that this technique could not successfully overcome. Among its achievements were the tripartition of angles, the magnification and dimunition of volumes including the doubling of cubes and finally even the calculation of the constant pi which Ahmes puts at 3·164. That this exercise of 'geometry' could only aspire to approximations, even if at times it achieved amazingly accurate ones, is self-evident, but a claim to 'mathematical accuracy', had this concept existed, would perhaps have seemed mere pedantry to these 'geomatricians'. Rope-stretching was a technique of measuring, nothing more, but it involved great skill and yielded a practical use-value as high, if not higher, than that of the geometry of the Greeks. According to all appearances it found acceptance in ancient India too, the earliest textbook of Indian geometry bearing the very title *The Art of the Rope*. There also was a special cultivation of the art of counting by means of the abacus and thus there unfolded in that country through two or more thousand years an art and knowledge of geometry and of numbers which astounded Europe when the Arabians began to make themselves the Islamic propagators of both traditions in the eighth and ninth centuries A.D. Joseph Needham has shown that in China there was a similar mathematical knowledge as elsewhere in the Far East.[5]

The mystery of the Egyptian calendar and of the astonishingly accurate calculation of the year and of the Nile floods have been robbed of much of their aura by modern research. According to the studies of Siegfried Schott[6] and Richard A. Parker[7] the alleged sun calendar of Egypt was in reality merely a moon calendar adapted by purely empirical interpolation to what was observed of the orbit of Sirius. The fabulous capabilities of the Egyptians in astronomy are thus reduced to proportions more in keeping with the rest of their proven intellectual practice. The

mystification inherent in this astronomy was, however, no error, but was the wily intention of the priests. The benefit to class rule of the mere appearance of the division of head and hand far preceded its real development. One knows of the artificial magic created by the priests to play on the credulity of the masses. Their wizardry went to the extent of bringing their figures of gods and goddesses alive by the action of steam from boiling vessels which was led through long underground pipes to the altar, so that the gods appeared to open their eyelids and their mouths and to let off steam in their anger. Thus a make-belief of division of head and hand prevailed in the service of class rule, and long preceded the reality.

The textbook of Ahmes preserved on the Rhind Papyrus in the British Museum consists of a collection of simple tasks for practical purposes – for instance, of the way to calculate the number of bricks required for the covering of an irrigation dam of a given height and length and slope – and for each of these tasks the pupil is given instructions on how to proceed. Even the concept of a theorem lies on a level of abstraction too high for this kind of 'mathematics', whose very characteristic is the lack of the logical foundation and systematic coherence by which it later assumes its intrinsic division from manual labour. It is true that intellectual and manual labour was already divided into activities of different people and, more important, of separate castes and classes conscious of the distance between each other. But mental labour did not yet possess the intellectual independence which severs it inherently from manual labour without the need of caste divisions or mystifications.

Our particular interest now centres on the reasons why, at the ancient oriental stage of social formation, the division of intellectual from manual labour lacked an inherent foundation. The base of this formation differed from that of commodity production by the unilateral appropriation operated by the rule of direct 'lordship and bondage'. Its economic context can be likened to that of a huge state household (as Marx puts it) planned and calculated to its finest detail.

But however different this practice of unilateral appropriation may have been from the relation of commodity exchange, it contained certain important features in common with the abstract function of the exchange relation. The action of

appropriation, just like that of exchange, was most strictly separated in time and place from any use of the appropriated objects. The products were stored and quantified without any change to the state in which they were delivered by the producer and accepted by the appropriator. Moreover, the unchanged substance of the objects of appropriation were not classified under the same terms as were the objects of use or labour. But even without a detailed form analysis of one-sided appropriation – which is not the same in ancient oriental as in medieval feudalism – the essential differences from commodity exchange are obvious. He who performed the action of appropriation (official of the Pharaoh, priest, scribe) did not act on his own initiative or for his own benefit. He collected the objects but did not deliver them. The man who did deliver them was not his personal debtor. The appropriator was only the functionary of a superior total power, one single link of an entire, complex, extensive hierarchy in the service of this power. He saw, not the whole appropriation, but only one particular part at a particular place, and of a particular kind. But even within a specific product it was not the whole of the kind, not all the barley, not all the corn which was the object of appropriation but only the surplus part of it, the other part of the same product remained in the possession of the producers and played quite a different role in the total order of existence. In short, nowhere in this order is a generality reached which is applicable to all its objects or subjects. The objects of appropriation certainly possess an identity as value; of this their accounting, the economy of the system, offers direct proof – but this economy has no generality in substance nor in function.

However, it is important to understand that precisely those factors which prevent a generalisation of value and of form determination make it possible for the total order to be controlled, comprehended and governed. The thought of the system's functionaries lacked rationality in theory to the same degree as the system possessed rationality in practice. This is only the converse of the observation already made that the 'autonomous intellect is an effect of the exchange mechanism through which man loses control over the social process'. Ancient oriental economy was a planned economy, its irrationalities were not of a kind to make its order uncontrollable.

Thus the results of our survey are twofold. First, the intellectual development which took shape in the Bronze Age occurred in that sphere of social formation based on appropriation separated from production. Second, this intellectual development had not yet achieved any intrinsic division from manual labour because appropriation controlled only a part of the social product and therefore did not constitute the general form of the social synthesis. The division between intellectual and manual labour can only occur when appropriation assumes the reciprocal form of private exchange when the object of appropriation takes on commodity form; or, alternatively, when individual small-scale production spreads to include primary as well as secondary production. This did occur in the epoch of iron metallurgy when cheap metal tools became available to the primary producers, making them independent of the cumbersome and extensive collective irrigation economy of the alluvial river valleys. Incidentally their individual labour became more productive than the communal economy of any previous epoch.

14

The Classical Society of Appropriation

The new iron metallurgy which emerged onwards from around 1000 B.C. brought about the civilisations of the Phoenicians and then of the Greeks, the Etruscans and the Romans. These civilisations required far less space for food production than their predecessors; they could populate hilly country, coastal strips and islands and gain advantages from their mobility. In order to produce a surplus of their primary production with iron implements they were no longer dependent upon the cultivation

of alluvial river soils. The legends of their heroic early phase prove that they waged raids of destruction, plunder and abduction in the fabulously wealthy territories of the ancient oriental Bronze Age civilisation. In the process they acquired the superior craftsmanship and techniques of these older civilisations. They soon caught up and even overtook their predecessors in secondary production and particularly in the making of weapons and building of ships.

The individualisation of production that now emerged is reflected in the fact that these adventurers indulged their deeds of robbery and pillage on their own account and at their own risk; they were no longer in the service of theocratic rulers or backed by the power of a whole State. They acted as heroes, independent individuals, with whom their people and State could identify, devoting themselves in this way to their particular function, the appropriation of existing alien wealth. Their mythological frame of reference is still related to that of the Bronze Age civilisations except that the gods are transformed from what were, in effect, legitimations of the appropriators in the image of a higher power into deities guarding the destinies of the heroes themselves. Here one sees the nucleus of private wealth and of commodity exchange before this exchange leads to the emergence of money.

The social revolution brought about by the development of the iron technique is summed up by George Thomson in the following words: 'by increasing productivity and so rendering possible new divisions of labour, the use of iron carried still further the process of transforming collective production and appropriation into individual production and appropriation. Hence it marked a new stage in the growth of commodity production. The village commune, resting on common ownership and surrendering its surplus in the form of tribute, was succeeded by a community of individual proprietors, each producing independently for the open market. Such was the Greek *pólis*, based on the use of iron.'[8]

Engels follows Lewis Morgan in seeing developed commodity production as synonymous with the first stage of civilisation, which he describes as follows: 'The first stage of commodity production with which civilisation begins is distinguished economically by the introduction of (1) metal money, and with it money capital, interest and usury; (2) merchants, as the class

of intermediaries between the producers; (3) private ownership of land and the mortgage system; (4) slave labour as the dominant form of production.'[9] I would also add that the first stage of civilisation is not only distinguished economically, but that the division of intellectual and manual labour becomes a factor of prime importance.

The chief difference between ancient and capitalist commodity production was that the producers remained owners of their means of production. When, in fact, they lost this ownership they fell into slavery, and became the means of production themselves in person, *possessed* by their slave-owner. The wealth acquired by slave-owners and by the landed aristocracy was either by unilateral appropriation by means of tributes, rents, war booty and loots, or by such methods in addition to commerce. Thus occurred a more or less violent redistribution of possessions and property, with a disruptive impact upon the traditional communal and tribal forms of society. The formation of wealth, all of it in terms of substantial riches of jewellery, precious objects, palaces and so on took place through *external* relations between 'barbarian' or other Greek communities by means of trading, warfare or colonisation. Only when the commercial element grew so dominant that it resulted in the first invention of coinage on the Ionian side of the Aegean around 680 B.C. did the disruptive effects transfer themselves to the *internal* order of the home community. Engels's description of this process is so powerful and so instructive that it is worth quoting at some length:

> Towards the end of the upper stage of barbarism, . . . through the sale and purchase of land, and the progressive division of labour between agriculture and handicraft, trade and shipping, . . . the smooth functioning of the organs of the gentile constitution was thus thrown so much out of gear that even in the heroic age remedies had to be found. [There followed the division of] the entire people, regardless of gens, phratry or tribe . . . into three classes: nobles, farmers and artisans. . . . The power of the nobility continuously increased, until about the year 600 B.C. it became insupportable. And the principal means for suppressing the common liberty were – money and usury. The nobility had their chief seat in

> and around Athens, whose maritime trade, with occasional piracy still thrown in, enriched them and concentrated in their hands the wealth existing in the form of money. From here the growing money economy penetrated like corrosive acid into the old traditional life of the rural communities founded on natural economy. The gentile constitution is absolutely irreconcilable with money economy; the ruin of the Attic small farmers coincided with the loosening of the old gentile bonds which embraced and protected them. The debtor's bond and the lien on property (for already the Athenians had invented the mortgage also) respected neither gens nor phratry, while the old gentile constitution, for its part, knew neither money nor debts in money. Hence the money rule of the aristocracy now in full flood of expansion also created a new customary law to secure the creditor against the debtor and to consecrate the exploitation of the small peasant by the possessor of money. All the fields of Attica were thick with mortgage columns. . . . The fields not so marked had for the most part already been sold on account of unpaid mortgages or interest, and had passed into the ownership of the noble usurer; . . . and that was not all. If the sale of the land did not cover the debt, . . . the debtor had to sell his children into slavery abroad. . . .
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> The rise of private property . . . led to exchange between individuals, to the transformation of products into *commodities*. And here lies the seeds of the whole subsequent upheaval.
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> But the Athenians were soon to learn how rapidly the product asserts its mastery over the producer when once exchange between individuals has begun and products have been transformed into commodities. With the coming of commodity production, individuals began to cultivate the soil on their own account, which soon led to individual ownership of land. Money followed, the general commodity with which all others were exchangeable. But when men invented money, they did not think that they were again creating a new social power, the one general power before which the whole of society must bow. And it was this new power, suddenly sprung to life without knowledge or will of its creators, which now, in all the brutality of its youth, gave the Athenians the first taste of its might.[10]

There is no doubt that this complete social revolution must have been associated with its own appropriate form of thought. We have explained how the exchange abstraction can become the basis of a complete mode of thinking when exchange assumes the role of the social nexus. George Thomson has not only confirmed and supported the study of Engels, but has carried the enquiry to greater depths and new results. 'From Ionia the new medium spread across the Aegean to Aegina, Euboea, Corinth, Athens, and a little later to the Greek colonies in Italy and Sicily. Thus Greek society was the first to be based on a monetary economy. The significance of this development has seldom been appreciated.'[11] George Thomson, like myself, links the rise of commodity production in Greece with the rise of Greek philosophy.

I make a differentiation between primitive exchange on the one hand and private commodity exchange on the other. The former was contemporary with the various forms of 'communal modes of production' and evolved chiefly in the external relations between different tribal communities. Its beginnings preceded the development of the exploitation of man by man and in fact helped to promote the progress of the productive forces preconditional to the rise of such exploitation. In its initial stages, as we have described by the example of ancient Egypt, exploitation took the shape of systems of direct lordship and bondage. When the productive forces developed further by the transition from Bronze to Iron Age communal food production was superseded by individual production combined with an exchange of a new kind, the private exchange of 'commodities'. 'Commodities' then answered the Marxian definition as 'products of the labour of private individuals who work independently of each other'.[12]

This kind of exchange – commodity exchange properly speaking – is the one which is characteristic of Greek antiquity. It leads to a monetary economy and to a system of social synthesis centred on private appropriation. Whereas in the system of direct lordship and bondage, as in Egypt, appropriation is public and relates to production, here appropriation is private in such a way that one act of appropriation relates to a reciprocal counteract, both linked under a postulate of equality. This constitutes a network of social synthesis entirely in terms of property. Production is done by chattel slaves who are owned by their masters as their personal property and who themselves do not take part in that network of property, having no access to money.

Here we have the social system of reification governed by the anonymous rule of the exchange abstraction. The contrast between the proto-intellectual labour of the Bronze Age and the real intellect is vividly stated by Benjamin Farrington

> with the Greeks a new and most important element did enter science. This is the element of speculative philosophy, which constitutes the specific quality, the real originality, of Greek science; . . .
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> The organised knowledge of Egypt and Babylon had been a tradition handed down from generation to generation by priestly colleges. But the scientific movement which began in the sixth century among the Greeks was entirely a lay movement, it was the creation and the property, not of priests who claimed to represent the gods, but of men whose only claim to be listened to lay in their appeal to the common reason in mankind. The Greek thinker who advanced an opinion stood behind the opinion himself. He claimed objective validity for his statements; but they were his own personal contribution to knowledge and he was prepared to defend them as such. Consequently with the Greeks individual scientists begin to emerge, and the specific quality of scientific thinking begins to be recognised.
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> To put the matter in another way, the world-view of the Egyptians and Babylonians was conditioned by the teaching of sacred books; it thus constituted an orthodoxy, the maintenance of which was in the charge of colleges of priests. The Greeks had no sacred books, . . .
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> Thales [born about 630 B.C., who founded the Early Ionian School] is the first man known to history to have offered a general explanation of nature without invoking the aid of any power outside nature.[13]

Too little is known of the historical details of the beginnings of the conceptual mode of thinking for us to be certain of the social class of its main protagonists. Significant, however, is its place of origin. Miletos, on the Ionian coast of the Aegean Sea was the foremost centre of the commercial activity and colonial expan-

sion of the Greeks in the eastern Mediterranean down to Nauplia in Egypt, north to the Black Sea and as far west as Massalia, the present Marseilles. Thales himself was, according to Herodotus, partly of Phoenician descent and belonged to an ancient family of priest-kings, as also did his contemporary Anaximander, perhaps the greatest of the Ionian philosophers. Thales, in addition to his interests in science, technology, philosophy and geometry, was also reputed to have organised a corner in oil and pursued other commercial activities.

By the end of the eighth century, as George Thomson records, the Greeks had broken the Phoenician monopoly of the Aegean carrying-trade and were challenging them in the Levant.[14] From the same century chattel slavery developed, and the Milesian merchants were selling slaves from the northern colonies to Egypt and Syria in the seventh century. Early in the eighth century the traditional rule of the landed aristocracy had been overthrown, following which Miletos itself was shaken by political upheavals and alternating regimes of tyranny and democracy. From the end of the seventh century the city-state suffered two generations of civil war.

George Thomson sums up ancient Greek history in these words:

> The truth is that, just because they were based on small-scale production, the Greek city-states, having grown up in conformity with the new developments in the productive forces, especially iron-making and the coinage, were able, under the democracy, to insinuate slave labour surreptitiously into all branches of production, and so create the illusion that it was something ordained by nature. It was then that 'slavery seized on production in earnest' [Marx]. This was the culmination point in the evolution of ancient society, to be followed by a long decline, in which the limitations inherent in the slave economy asserted themselves on an ever-increasing scale, obstructing the further development of the productive forces and diverting the energies of society from the exploitation of nature to the exploitation of man.[15]

15

Mathematics, the Dividing-line of Intellectual and Manual Labour

In Chapter 13 we illustrated the proto-intellectual character of the mental work in the Bronze Age by describing the Egyptian geometry of the rope. We found it to be a highly efficient and multivariant art of measuring attaining useful and indeed astonishing grades of approximation. But it was in the character of a skill rather than of a science even though it depended on extensive geometrical interpretation and instruction as indispensable accessories to manual practice.

Admittedly, from my perspective, I would not place traditions handed down from the Bronze Age or even earlier on the same level as the mathematics created by the Greeks. They replaced the rope by ruler and compass and thus transformed the previous art of measurement so fundamentally that something completely new grew out of it – mathematics as we understand it. The geometry of the Greeks is of a purely intellectual character and detached from the practice of measurement. How could the change in the implementation achieve such a difference, or, rather, what transformation occurred to bring this change about?

The art of the rope was a manual skill which could only be carried out by those apprenticed to do it and practised in it and only at the particular spot where the need for measurement arose. Divorced from this it had no point. Neither did it leave behind any detachable demonstration of its geometric content. After each action of measurement, each 'measure', the rope was moved on from one position to another so that such a thing as a direct 'geometrical demonstration' never came into question. The

geometry inherent in the task at hand extinguished itself in the practical result, which was only ever applicable to the case in point. To be sure, the 'harpedonapts' in the course of their training had to be taught and shown the constantly recurring elements in their techniques and with Ahmes much of this is presented in the guise of geometric rules. But it must surely be nothing but a reflex of our own conceptions when mathematical historians (including Moritz Cantor, Sir Thomas Heath and D. F. Smith) conjecture that a theoretical manual must have existed serving as a foundation to Ahmes's book of practical exercises – a manual which has never been found.

The Greeks, however, invented a new kind of geometric demonstration. Instead of stretching ropes, they drew lines by ruler which remained on the sheet underneath, and together with more straight lines, formed a permanent figure from which could be recognised geometric laws. The combination of lines were tied to no particular location, and their size was infinitely variable.

The geometry of the measurement thus became something quite different from the measurement itself. The manual operation became subordinated to an act of pure thought which was directed solely towards grasping quantitative laws of number or of abstract space. Their conceptual content was independent not only from this or that particular purpose but from any practical task. In order, however, to detach it from such application a pure form abstraction had to emerge and be admitted into reflective thought. We reason that this could result only through the generalisation intrinsic in the monetary commensuration of commodity values promoted by coinage.

It goes without saying that this radical transformation from the Egyptian art of measuring to the geometry of the Greeks did not occur at one stroke, but only over hundreds of years and mediated by incisive developments to the productive forces and by corresponding changes in the relations of production. For proof of this one need go back no further than to the beginnings of Greek geometry. The invention which bears Thales's name is traditionally connected with the measurement of distance of ships from the coast; here the art of the rope would clearly have been useless. This one example illustrates the world-wide difference between the Bronze Age mainland economics of

Egypt and Mesopotamia based on agrarian exploitation, and the Greek city-states based on sea-voyaging, piracy and trade. The Greek forms of production were peasant agriculture on a small scale, and independent handicrafts. The new monied wealth of the Greeks emanated solely from the circulation nexus, an achievement effected, as Lenin says, by merchants' and usurers' capital. It did not spring from the land or from the workshops of manual producers, at least not before these were replaced by slaves, who themselves became the source of commodities for exchange.

An essential point regarding the 'pure mathematics' of the Greeks is that it grew to be the unbridgeable dividing-line between mental and manual labour. This intellectual significance of mathematics is a central theme with Plato. Euclid, in his '*Fundamentals of Geometry*', created an imperishable monument to it at the threshold of Hellenistic culture. This work seems to have arisen for the sole purpose of proving that geometry as a deductive thought structure was committed to nothing but itself. In the synthetic quality of thought no account was taken of the material interchange of man with nature either from the point of view of the sources and means involved, nor from that of its purpose or use. Into this glasshouse of Greek thought went 'not a single atom of natural matter' – quite parallel with commodities and their fetish identity as 'value'. It was the pure formalism of 'second' or 'para-'nature and suggests that in antiquity the form of money as capital, in other words the functionalism of second nature, finally remained sterile. Although it had indeed freed labour from slavery it had failed to lower the reproduction cost of human labour power in any noteworthy way, if at all. We can conclude this to be true in retrospect from the fact that development after Euclid by Archimedes, Erastosthenes, Apollonius, the legendary Heron and many others, in whose mathematical elements of abstract dynamics were already noticeable, consequently achieved technical application limited only to military or other wasteful ends.

16

Head and Hand in Medieval Peasant and Artisan Production

We can sum up by saying that the salient feature of antiquity in our context is that the social category of value as money and as capital – capital operating solely as merchants', usurers' and predatory capital – failed to communicate its social character to labour. Labour was not human labour; it was slave labour, a variant of animal function. Any co-operation performed under the whip of the slave-driver ceased when the slaves were freed. As a freed man the individual dropped out of any co-operation, both the one involved in slavery and also the co-operation within the tribal community to which he belonged before his enslavement. The end-result of the ancient forms of commodity production was the final dissolution of the numerous forms of communal production which preceded it or were initially coexistent with it. The description we quoted from Engels of the dissolution of the Athenian gentile society only exemplifies the process which took place throughout the length and breadth of the Roman Empire until it reached its own dissolution. In fact, ancient commodity production economically fed on the very process of dissolving primitive tribal economies and came to an end of its monetary economy when there were none of these left to dissolve. Rome then became a place inhabitated by an atomised mass of about two million individuals living on unemployment benefit and social security, as we would say today, to supply them with '*panem et circenses*' – food and entertainment – rather than using the payment to organise production – capitalist production as it

would have been. Production was supplied by the enormous latifundia run on slave labour and owned by the senators and '*equites*' ruling the Empire. As the economy lost its character of a monetary and slave economy it transformed into feudalism which represented the final legacy Rome bequeathed to its medieval successors.

The negativity of the Roman decline, the disintegration of the ancient formation of commodity production, brought forth a positive result of great importance: the humanisation of labour. By this I mean that productive labour lost its incompatibility with the human quality of man and could be undertaken without the risk of enslavement. 'Christianity with its religious cult of man in the abstract'[16] was a plausible ideological exression of this innovation. The serf and the villain were baptised the same as the feudal lord, and from the very start this religion sought its converts partly among the slaves and the freedmen, but mainly among people of the labouring and the artisan status.

The economic development in European feudalism started again with 'peasant agriculture on a small scale and production of independent artisans, both of which, on the one hand, form the basis of the feudal mode of production' as they had also formed 'the economic foundation of the communities of classical antiquity at their best, after the primitive oriental system of common ownership of land had disappeared and before slavery had seized on production in earnest'.[17] It is almost as though history was making a restart after the communal modes of production had been cleared out of the way and labour freed from slavery. We shall note later (p. 110) how this restart led on to a road which took mankind in a direction diametrically opposed to that of the first start.

The advantage that feudalism offered to the humanised labour of the small-scale peasant and artisan producers lay in the fact that the means of labour was made available to them notwithstanding that they were dependent on the lords who owned the land. The individual production proceeded on the lines of a division of labour within the economic framework of the medieval manor. In the undivided possession of their physical and mental capabilities and left to the freedom of their inventiveness for the sake of lightening their work these small-scale producers achieved an enormous increase of productive capacity

through the massive utilisation of the natural forces of water, wind and beasts of burden.

The draught-power of horse and ox was revolutionised by the invention of the breast-strap harness, making possible the use of the heavy plough; stirrup and iron horseshoes were developed and means of transport increased and improved so as to bring corn, wood, wool, dyer's woad, etc., to the watermills and later to the windmills for processing. These mills were used in a multitude of ways and were connected with the invention and improvement of new tools and methods of work. No room is available here for the relevant and interesting details. A good indication of the development, however, is contained in the Domesday Book of 1086 which enumerates no fewer than 5624 watermills south of the Trent and Severn. Of outstanding importance for subsequent developments was the progress in animal rearing and particularly of sheep breeding for wool processing.[18]

This general growth of the productive forces available to the individual peasants and artisans, between the ninth and thirteenth centuries, gave rise to a change in the mode of feudal exploitation. The appropriation of the surplus assumed forms which, while more successful in enriching the feudal exploiter, were at the same time more apt to give greater mobility and scope of initiative to the exploited. It was the era of the formation of towns and of growing expansion of monetary relationships. It was followed in the next two centuries by a mounting trend towards the emancipation of economic developments from the tentacles of feudalism. In the words of Rodney Hilton: 'the history of the English agrarian economy in the 14th and 15th centuries illustrates very well the consequences of successful peasant resistance to the lords' pressure for a transfer of surplus. In fact, it must be regarded as a critical turning point in the history of the "prime mover". [of the social change in progress – S-R] The long period of the successful and multiform exploitation of peasant labour ended, at any rate in most Western European countries, between the middle and the end of the 14th century.'[19]

However, the era of a free peasant and artisan economy was not long-lived. It did not survive the fifteenth century. To the degree to which the emancipation succeeded, the direct producers retained their technical independence of choosing what and how to produce, but by no means their freedom from

economic exploitation. They exchanged the bonds of feudal tyranny for the entanglement of the ever-tightening net of the merchants' and usurers' capital. Again to quote Rodney Hilton: 'Moneyed wealth, which was not based on the possession of landed property, came from trade, which was in the hands of monopoly companies of merchants like the Merchant Adventurers and the Merchants of the Staple.'[20]

The developments described here with special, although by no means exclusive, reference to England took place much earlier in Flanders and Italy, particularly in Florence which is, of course, of primary importance from our point of view. In the thirteenth century the struggle for urban independence and emancipation from the forces of rural feudalism was led everywhere by merchant capitalists and bankers. But in the towns this went hand in hand with the growing exploitation and impoverishment of the producers whose character as artisans gradually deteriorated to that of mere cottage labourers.

Feudalism has grown out of the declining Roman economy; now the rise of merchant capital led to the revival of a monetary economy, thereby linking up, so to speak, with the point where the economy of antiquity had given up. Proof of this is found in many places, but nowhere with greater clarity than in England. Here, around A.D. 900 monetary economy had already begun, not as a result of such pervasive trade relations as that of Italy with Byzantium and the Levant but for the very different and more local reason that the Danes, on their second invasion of England's east coast, had imposed upon the king the payment of a tribute in money. As a consequence the king was forced to establish a monetary accountancy. By the twelfth century one finds detailed instructions for the running of the royal exchequer and the collection of tax in cash, thereby enforcing monetary thinking upon the taxpayer. Some two hundred years later, in Oxford, manuals were compiled with exact and varied material for teaching bailiffs, reeves, accountants and other administrators of feudal domains from the perspective of loss and gain. These have recently been published in an admirably painstaking edition by Dorothea Oschinsky under the title *Walter of Henley and other Treatises on Estate Management and Accounting*.[21]

The earliest of these texts is by Robert Grosseteste (died 1253), bishop of Lincoln, who advises the Countess of Lincoln on how to

make bigger gains and fewer losses on her very numerous manorial estates. In 1214 the same Grosseteste became the first Chancellor of the colleges of Oxford, and thus founder of the university. His significant achievements as an academic make him the earliest in that succession of great Oxford scholastics, whom one might even call English Aristotelians, including such names as Roger Bacon (1214–95), Duns Scotus (1270–1308), Thomas Bradwardine (1290–1349) and William of Occam (1295–1350). These scholastics maintained a constant exchange of ideas and comings and goings between Oxford and Paris.

The close ties between the monetary and the scholastic developments are obscured by a peculiar state of affairs. The educational books for the profitable administration of feudal estates had to be written in the French of that time instead of in Latin so as to be understood by the Norman overlords, and for this reason were excluded from the records of the university, although this whole branch of teaching took place in Oxford. The historians of the university know nothing of it, and in most cases it is not even known who were the authors of the manuals. But scholasticism's connections with its economic background can be recognised on quite a different level: from the perspective of money on the one hand and from that of labour and production on the other. The first new mathematical developments took place from 1202 onwards when Leonardo da Pisa published his *Liber Abaci*. This innovation in mathematics was again associated with a change of implementation. The Greeks excelled in geometry but not in arithmetic and algebra although they possessed and used the abacus. The Indians, the Chinese and later the Arabians combined the technique of the abacus with a rational numerical notation which took them far ahead of classical antiquity.

About Leonardo of Pisa's *Liber Abaci* Moritz Cantor writes: 'Despite its total mathematical clarity and discipline, it was offputtingly difficult. On the other hand it dealt with things which the merchant could use in the demands of daily life and sometimes had to.'[22] Cantor tells how Leonardo's father, himself a merchant of Pisa, demanded that his son 'devote several days to the study of the abacus'. He was introduced to this discipline by the help of the Indians' nine numerals, found pleasure in it, and on trade journeys which he later undertook to

Egypt, Syria, Greece, Sicily and Provence learnt everything there was to know about this practice of counting. But this 'everything', together with Algorism and the segments of Pictagoras [*sic*], 'seemed to me as so many errors compared with the method of the Indians'. And he had specialised in the Indian method, added things of his own, enriched the geometrical art of Euclid by new subtleties and so published his work in fifteen sections – all 'so that the race of Latins' (meaning the Italians) 'should no longer be found ignorant in these matters'.

The 'demands of daily life' of the merchants was that of great international trade which, at the time of the Crusades, joined together European feudalism with the Arabian and Byzantine empires. It was a trade for which Leonardo and others taught methods of calculating the purity content of precious metals since the international standard coins such as the gold florin, the ducat, the sequin and the guilder went into circulation only when feudal domination had collapsed after the death of Frederick II in 1250. From that date the independence and rise of the towns depended only on the towns themselves and on their internecine rivalries. This dating may be too precise since the developments depended on the uneven progress, not only between North and South, but, more important, of the manufacture of cloth (the principal commodity of international trade) centred in Flanders and northern Italy on the one hand and the wool-producing countries of England, Spain, France and Saxony on the other.

By 1350 (a hundred years later) the commercial activities of merchant capital had already developed so extensively that the production relations were rapidly changing. The supplying countries and particularly England began their own cloth manufacture. Up to then the Italian and Flemish buyers, for example, had negotiated most of the wool deliveries with the domain managements; now, however, the greater part of the wool-supplies was contracted by individual, direct producers who gained their independence from the domains, enlarged their flock of sheep, and began to enjoy a growing monetary income, the feudal lords leasing them the necessary pasture land. In England wool became the commercial equivalent for money, and Edward III (1327–77) frequently accepted tax payments in wool in lieu of money. (Hence the Woolsack of Parliament.) The historical events leading to the later Enclosure Acts date back to

this time. There occurred the transference of monied wealth to a growing middle class of agrarian and artisan stock who themselves had changed from the labourers employed by feudalism to employers of labourers producing for merchant capital. The end of the fourteenth century sees the transition from artisan modes of production to the pre-capitalist epoch – the epoch of the Renaissance with which the history of the development of natural science begins.

Here the development, moving in a diametrically opposite direction to ancient commodity production, of which we spoke at the opening of this chapter, started to take shape. Whereas the originally social character of labour with which human history begins reached the point of absolute dissolution in the decline of the Roman Empire when its slave economy changed to feudalism, now, as medieval feudalism ends, the trend of renewed co-operation of labour in production occurs under the impact of the merchant-capitalist developments. This trend inaugurates the epoch of pre-capitalism from around 1300 onwards until two and a half or three centuries later the situation is rife for merchant-capitalism to turn into production-capitalism; that is to say, into capitalism proper. But the important difference of the renewal of the socialisation of labour from its primitive counterpart is that the modern form feeds entirely on the resources and incentives of the second nature and no longer on those of primary nature. It no longer depends on the standards and the capacities of the direct material interchange of man with nature, but on the subordination of labour to capital.

17

The Forms of Transition from Artisanry to Science

Medieval handicraft began with the personal unity of head and hand; Galilean science established their clear-cut division. In this chapter we are concerned with the transition from artisanry to science from this viewpoint. The causes of the transformation can be found in the change from one-man production to production on an ever-increasing social scale. This occurred, as we have seen, mainly as a result of the commercial revolution.

The formation of towns as urban communities started in the era of late feudalism. With their development sprang the need for communal walls, communal defences, communal town halls, cathedrals, roads and bridges, water-supplies and drainage systems, harbour installations and river control, monuments and so on. These were all due to the activities of capital, commercial and monetary, 'antediluvian forms of capital', as Marx calls them. The social character of all this development is the direct outcome and manifestation of the originally social power of capital. Under this power the great mass of the artisans were ruthlessly exploited. They still retained the status of producers owning their own means of production, but the bulk of them did so as impoverished cottage labourers, hopelessly indebted to the capitalist for whom they produced the merchandise. They were downgraded and depressed to the standard of proletarian labour long before they actually assumed the status of mere wage-labourers. Production taking place in artisan workshops, on the other hand, increased in volume and changed in labour methods. The employment of more *and* more semi-skilled workers resulted in class divisions within the workshops.

From our viewpoint, however, these economic and sociological changes are not the main focus of interest. They are not the ones that can explain the logical and historical steps leading to the formation of science. Parallel to the economic developments making for the eventual dissolution of the artisan mode of production go technological changes caused by the increasingly social scale of the order of life as a whole exemplified by the town developments.

Construction and production tasks of such dimensions and novelty stretched the craftsmen to the limits of their resources and inventiveness. By the necessity to tackle the problems there rose from the ranks of ordinary producers the great Renaissance craftsmen, the 'experimenting masters', artists, architects, and also engineers of the fifteenth and sixteenth centuries. The main qualification which the craftsmen lacked in their capacity as artisans for solving the problems facing them can be named in one word – mathematics. We have defined mathematics as the logic of socialised thought. Capital and mathematics correlate: the one wields its influence in the fields of economy, the other rules the intellectual powers of social production.

We must be clear about the limits that are set to the capacity of work tied to the personal unity of head and hand. The artisan or individual manual worker masters his production, not through abstract knowledge, but by practical 'know-how' and by the expertise of his hands. In terms of 'knowledge', it is the knowledge of how one *does*, not of how one *explains* things. This practical knowledge can be conveyed by demonstration, repetition or words, depending on practical understanding of the task involved. Cookery books are a clear example. This is, moreover, not only true of human functions. Let us suppose we deal with working a pump, a threshing-flail or a water mill, irrespective of whether they replace human labour or whether man cannot perform their task. In speaking to manual workers one could not express oneself in any other way than by treating these things as if they took the part of human agents. The language of common usage (devoid of special technical terms) cannot articulate a division of intellectual and manual labour. The only symbol language which rends itself free from this tie-up with human activity is that of mathematics. Mathematics cuts a deep cleft between a context of thought and human action,

establishing an unambiguous division of head and hand in the production processes.

It is no exaggeration to say that one can measure the extent of division of head and hand by the inroad of mathematics in any particular task. More than any other single phenomenon it was the development of firearms which imposed the use of mathematics on artisanry. Needless to say, the technology of firearms did not cause the dialectic of the precapitalist development, but from the second half of the fifteenth century it intensified and accelerated technological developments enormously. The use of firearms was confined to guns for artillery, and in this capacity created problems completely new and alien to artisan experience and practice – problems such as: the relationship between the explosive force and the weight of cannon and range of fire; between the length, thickness and material of the barrel; between the angle and the resulting path of fire. Metal-casting assumed new proportions, as did the mining of ore, the demands of transport, and so on. Special importance accrued to military architecture for the defence of cities and harbours. From the fall of Constantinople to the Turks in 1453 well into the sixteenth and even seventeenth century the Turkish menace hung over Europe like a nightmare. After the fall of Otranto in the Adriatic in 1490 Venice felt under the threat of immediate assault and in 1532 the Turks laid siege to Vienna.

To gauge the strain and stresses which the urgency of this turn of events laid upon European artisanry would demand a study beyond our scope. We can, however, gain an illuminating insight into the contradictions of the epoch by drawing upon the writings of Albrecht Dürer (1471 – 1528) as a master in both the arts and mathematics. My remarks are based on *Instructions of Measurement with Compass and Ruler* (1525)[23] and on the *Instruction as to the Fortification of Town, Castle and Hamlet* (1527). Here the unique attempt is made to refashion mathematics to make it a fitting discipline for the use of artisanry. This means, of course, to attempt the impossible. Nevertheless his venture was so significant that it occupied mathematicians and military architects of the whole of the sixteenth century and to some extent up to the eighteenth century.

Dürer had studied mathematics at the highest academic level of that time with his learned friends in Nuremberg, Willibald

Pirckheimer and Johann Werner. Instead, however, of using this knowledge in its scholarly form he endeavoured to put it to the advantage of the craftsmen. The work is dedicated to 'the young workers and all those with no one to instruct them truthfully'. It aims to change geometry by modifying its implements; he replaces the ruler by the set-square and alters the use of the compass by restricting it to a fixed aperture. According to generally accepted surmise Dürer, for this, drew on the tradition of workshop practice and in particular of that of the mason lodges. What is novel in his method is that it tries to combine workmen's practice with Euclidean geometry, and to reconcile these two seemingly incompatible elements by aiming at nothing more than approximate results sufficient for practical needs. He writes: 'He who desires greater accuracy, let him do it *demonstrative*, not *mechanice* as I do it.'

As Moritz Cantor points out: 'Albrecht Dürer is the first to apply the principle of approximation with full awareness.' Only in his construction of the pentagon does Dürer neglect this distinction, presumably because he takes it to be accurate, albeit erroneously. 'The fact that he otherwise makes such a clear distinction between what is correct and what is of practical use places him on a plane of science reached by hardly any other geometrician of the 16th century.'[24]

On the subject of Dürer's construction of the pentagon Leonardo Olschki writes:[25] 'The construction of the regular pentagon by this method [the fixed-compass aperture – S.-R.] exercised the wits of such mathematicians as Tartaglia, Cardano, G. del Monte, Benedetti and others, until finally P. A. Cataldi devoted a special dissertation on it which appeared in Bologna in 1570.' He was a member of the Florentine Accademia del Disegno, where twenty years later Galileo also taught. Galileo too dealt with Dürer's construction in his lectures on military architecture of 1592–3, and even Kepler, in his *Harmonices Mundi* (1619), still discussed Dürer's construction of the septagon.[26]

What Dürer had in mind is plain to see. The builders, metal workers, etc., should, on the one hand, be enabled to master the tasks of military and civil technology and architecture which far exceeded their traditional training. On the other hand, the required mathematics should serve them as a means, so to speak,

of preserving the unity of head and hand. They should benefit by the indispensable advantages of mathematics without becoming mathematical brainworkers themselves; they should practise socialised thinking and yet remain individual producers. And so he offered them an artisan's schooling in draughtmanship, permeated through and through with mathematics (not to be confused in any way with applied mathematics). Nothing can illustrate the inner paradox of the pre-capitalist mode of production more clearly than this attempt of Dürer's; nothing can so illuminate the interrelationship of the intellectual form development with the economics of the conditions of production than its fate. It met with failure on both counts.

To do justice to the inner nature of this achievement of Dürer is impossible here. Two or three quotations must suffice to illustrate it. His stereometric constructions in the Fourth Book of the *Instructions of Measurement* end: 'Here I have drawn up everything quite openly after which I closed it, laid it on the ground and opened it up once more.'[27] In numerous constructions he points out ways in which they could prove useful to his work-mates; here, for instance, with the doubling of the cube: 'In this way they could duplicate, triplicate and infinitely increase and augment the cube and all other things. Now as such an art is of great use and serves the end of all workmen but is held by all the learned in the greatest secrecy and concealment, I propose to put it to the light and teach it abroad. For with this art, firearms and bells can be cast . . . barrels, chests, gauges, wheels, rooms, pictures and what you will, enlarged. Thus let every workman heed my words, for they have never, to my knowledge, been given in the German language before this day.' From the squaring of circle: 'Mechanice, that is approximately, so that at work it will fall short of nothing or of very little, and could be put by comparison as follows. . . .' Regarding approximation: 'Now I shall change a previous triangle into a septangle through a common trick which we need to speed up a job of work.'

But, in fact, Dürer's intentions came to nothing because he demanded far too much in the way of mathematical understanding from the apprentices and craftsmen of his time despite all the painstaking efforts he had taken to be sufficiently explanatory. Moreover, his aims to save the unity of head and hand were frustrated by the response that his writings evoked from the

subsequent mathematicians mentioned above. They never considered, for instance, the geometry of fixed-compass aperture as a means of helping the craftsmen. Their main effort was directed towards demonstrating that this geometry could cope with the entire body of the Euclidean geometry, its principles, theorems, problems and all. Hence Dürer's was not a particular artisan geometry; indeed, such a geometry does not exist and cannot be invented.

This re-establishment of mathematics as the dividing-line between head and hand is all the more conclusive as Tartaglia himself copes with artisan problems. In his book of 1537 and the first eight books of the second one of 1546 as well as in a number of his 'risposte' (replies) to Ferrari he deals with questions of ballistics, harbour fortification and cannon-casting which the highly skilled craftsmen of the Venice arsenals had put to him as their mathematical consultant. And in parts of his own work Tartaglia also uses the geometry of fixed-compass aperture. In his case it is as difficult, as in Dürer's, to be sure where this geometry, attracting such wide interest throughout the sixteenth century, had its origin. The most likely assumption is that it answered the requirements of the Venetian craftsmen as Dürer's did the demands of those of Nuremberg. Tartaglia, however, charged a fee to the workmen for the answers he gave them – indeed it was the main source of his living – and showed no sign of wanting to bolster up their education.

Tartaglia and his pupil Benedetti and their enemies Cardano and Ferrari, as well as Cavalieri and the other Italian mathematicians of the sixteenth century, already trod upon early capitalist ground. They worked for the steady deepening of the cleavage between head and hand and groped towards the science whose methodological basis is the completed severance of the one from the other.

18

The Capitalist Relations of Production

The Italian mathematicians we mentioned were the immediate forerunners of the scientific revolution. It is our endeavour to understand the historical and logical genesis of the exact sciences as an essential part of the capitalist relations of production. Our first need to this end is a clear conception of what exactly is involved in the relational change from the artisan mode of production to the capitalist.

The artisan producer owned his means of production, but in the fifteenth and sixteenth centuries his economic independence had been so undermined that it became all but fictitious that they were his own property. However, so long as his means of production had not actually been taken from him, no matter how heavily they were pledged to the capitalist, we still move in the era of the production relations of artisanry. The artisan nominally sold his finished product to the merchant. As long as this was the case the responsibility for the process of production, the quality, the quantity, the manner and date of delivery rested with the artisan producer. As a consequence the manner of production and of its physical conditions were still conceived in terms of artisanry and these were basically terms of the unity of head and hand of the artisan in person. He performed small-scale production on the basis of personal skills, and, like an artist, judged things by his senses.

Now let us assume for argument's sake that the merchant capitalist, who had hitherto been satisfied to 'buy' his wares from the artisan producers, decides instead to seize the means of production, the workshop, implements and materials and to carry on production by employing the artisans as wage-

labourers. There is nothing to stop him legally, materially or economically from doing so, since financially these things have long been forfeited to him already. Thus the capitalist acquires the direct control of the labour process and assumes the status of 'producer' or, as we say by an even worse misnomer, the status of 'manufacturer'. By this change of production relations the responsibility for the production process in all its material aspects and conditions has shifted from the direct producer to a social power which does not partake in the process of production by one single physical function of its own. In what terms have we, then, to conceive of the responsibility of the capitalist for the process of production under his control? This question allows for a concise answer: the control of capital over production must be entirely in terms of second nature, and of second nature in both representations – the real abstraction in the economic field and the ideal abstraction in the intellectual field of science. On both levels the terms of the second nature are, we have seen, totally 'abstract' from the empirical realities of use, either consumption or production, and they are alienated from all contact and interchange with the first nature. Our main concern in this study is the shaping of the ideal abstraction, but we cannot broach our subject adequately before making a brief characterisation of the material basis.

How does the capitalist perform his role of 'producer'? He performs it not by way of labour, not with his hands, not by tools or machines which he operates. He performs it with his money which he uses as capital and with nothing else. To exercise his role of 'producer' the capitalist must be able to buy everything on the market; materials, land, services, labour and know-how, which, correctly assembled under his command at the right place and time, constitute a labour process in which he himself, the capitalist, never need lay a hand. 'The labour-process is a process between things the capitalist has purchased,' says Marx, 'things which belong to him.'[28] If, indeed, he should have to put his hand to the wheel it would merely prove that he had failed in his function as a capitalist and entrepreneur, and, strictly speaking, he should pay himself for his own manual labour. In other words the role of producer now falls on a person who does not perform a single productive function in the labour process. From the perspective of the capitalist entrepreneur the essential characteristic of the production process for which he is responsible is that it must operate itself. The controlling power of the capitalist hinges on this postulate of the self-acting or 'automatic' character of the labour process of production. This all-important postulate of automatism does not spring from any source in the technology of production but is inherent in the production relations of capitalism.

However, a postulate is not necessarily a reality. It becomes a reality only when the appropriate conditions exist for its practical realisation. The change from the handicraft to the capitalist mode of production did not occur suddenly in the sharply defined manner our description might suggest. Even during the actual period of transition in the sixteenth century the change took place gradually and in a great variety of ways. Marx has given an unforgettable picture of the violence, cunning and ruthlessness of its methods in his account of the so-called primitive accumulation. Our presentation has been reduced to a formalisation only for theoretical purposes.

In its initial stage the capitalist mode of production suffered from many imperfections. By rights the capitalist should find the factors he needs for his production process available in the market. But throughout the sixteenth, seventeenth and eighteenth centuries this was far from the case. The capitalist had therefore to be his own inventor, his own engineer and master craftsman and often enough even his own labourer. The workmen available for employment were originally the same artisans who had worked for the craftsmen of the pre-capitalist workshops. Although they still worked with hand-tools they differed from the producers of the preceding era by becoming increasingly subject to such close division of labour that they were crippled artisans and mere 'detail labourers' as Marx calls them. It was only under the pressure of the severest managerial authority that they were forced to act as pawns to the capitalist producers instead of remaining producers themselves.

In few other parts of *Capital* does Marx discuss the phenomenon of capitalist management in such detail as in the chapter on the manufactural stage of capitalist production, concluding his analysis of Manufacture with the following:

During the manufacturing period proper, i.e. the period in

which manufacture is the predominant form taken by capitalist production, the full development of its own peculiar tendencies comes up against obstacles from many directions. Although . . . manufacture creates a simple division of the workers into skilled and unskilled at the same time as it inserts them into a hierarchical structure, the number of unskilled workers remains very limited owing to the preponderant influence of the skilled. . . . Since handicraft skill is the foundation of manufacture, and since the mechanism of manufacture as a whole possesses no objective framework which would be independent of the workers themselves, capital is constantly compelled to wrestle with the insubordination of the workers. 'By the infirmity of human nature', says our friend Ure, it happens that the more skilful the workman, the more self-willed and intractable he is apt to become, and of course the less fit a component of a mechanical system in which . . . he may do great damage to the whole.' Hence the complaint that the workers lack discipline runs through the whole period of manufacture. . . . During the period between the sixteenth century and the epoch of large-scale industry capital failed in its attempt to seize control of the whole disposable labour-time of the manufacturing workers, and . . . the manufactures are short-lived, changing their locality from one country to another with the emigration or immigration of workers. . . . At a certain stage of its development, the narrow technical basis on which manufacture rested came into contradiction with requirements of production which it had itself created. . . . This workshop, the product of the division of labour in manufacture, produced in its turn machines. It is machines that abolish the role of the handicraftsman as the regulating principle of social production. Thus, on the one hand, the technical reason for the lifelong attachment of the worker to a partial function is swept away. On the other hand, the barriers placed in the way of the domination of capital by this same regulating principle now also fall.[29]

Once the dominion of capital finds an objective basis in the employment of machinery the previous ambiguities in the position of the labourers are swept away and Marx explains:

> Every kind of capitalist production, in so far as it is not only a labour process but also capital's process of valorization, has this in common, that it is not the worker who employs the conditions of his work, but rather the reverse, the conditions of the work employ the worker. However, it is only with the coming of machinery that this inversion first acquires a technical and palpable reality. Owing to its conversion into an automaton, the instrument of labour confronts the worker, during the labour process in the shape of capital, dead labour, which dominates and soaks up living labour-power. The separation of the intellectual faculties of the production process from manual labour, and the transformation of those faculties into powers exercised by capital over labour is . . . finally completed by large-scale industry erected on the foundation of machinery.[30]

Judging from our experience with contemporary industry the 'conversion into an automaton' not only seizes upon the single instruments of labour, but affects entire factories as integrated complexes of machinery and labour. To reiterate the chief point: the tendency which I described as the 'postulate of automatism' presents itself as a feature of technology. But it does not spring from technology but arises from the capitalist production relations and is inherent in the capital control over production. It is, as it were, the condition controlling this control.

This postulate of automatism clearly stands in diametrical contrast to the principles of handicraft and to the whole manner of thinking associated with the artisan's mode of production. As long as handicraft plays any essential role in the capitalist labour process, as during the seventeenth, eighteenth and even the early nineteenth centuries, automatism will not take full command. Handicraft acts as a stop-gap, if not as a hindrance to capital, exercising its own specific kind of control. During the Industrial Revolution, when machinery came to play a more and more predominant part, all important machine tools were inventions of craftsmen, even though their work shows a tendency to science, and so does the production process itself. As Marx expresses it:

> This subjective principle of the division of labour no longer exists in production by machinery. Here the total process is

> examined objectively, viewed in and for itself, and analysed into its constitutive phases. [Disregarding the remaining elements of handicraft] A system of machinery . . . constitutes in itself a vast automaton as soon as it is driven by a self-acting prime mover. . . . As soon as a machine executes, without man's help, all the movements required to elaborate the raw material, and needs only supplementary assistance from the worker, we have an automatic system of machinery. . . . An organised system of machines to which motion is communicated by the transmitting mechanism from an automatic centre is the most developed form of production by machinery.[31]

However, this fully developed form of the capitalist factory was not realised before the second half, or even the last third, of the nineteenth century after the technique of producing machines by machines had been well mastered. Thus the introduction of machinery in the second phase of development of the capitalist mode of production, the phase marked by the Industrial Revolution was not only motivated by the drive for a higher rate of exploitation and a lowering of production costs, but also by the need for 'a framework apart from the labourers themselves' for the control of the labour process. The postulate of automatism as a condition for the capital control over production is even more vital than its economic profitability – it is fundamental to capitalism from the outset.

A capitalist enterprise may survive a lowering of its profits and even a temporary lack of profits in a general slump, but if the automatism of the labour process breaks down, the very basis of the production relations of capitalism is in jeopardy. The capitalist control over the labour process of production can only operate to the degree to which the postulate of automatism functions. The stages in the development of capitalism can be seen as so many steps in the pursuit of that postulate, and it is from this angle that we can understand the historical necessity of modern science as well as the peculiarity of its logical and methodological formation. As pointed out earlier in this study, the mathematical and experimental method of science established by Galileo secured the possibility of a knowledge of nature from sources other than manual labour. This is the cardinal

characteristic of modern science. With a technology dependent on the knowledge of the workers the capitalist mode of production would be an impossibility. Needless to say, however, the self-acting property of the labour process presents itself from the point of view of the capitalist; from that of the workers it looks different indeed!

It is thus not science but ideology in the sense of one-sided class consciousness when, in the seventeenth century, philosophers like Descartes and Hobbes looked upon the outer world as a whole and in all its parts, organic no less than inorganic, as self-operating mechanisms. Marx considers the mechanistic mode of thinking as characteristic of capitalism in the epoch of manufacture. Indeed, so long as this functional self-activity of the labour process had not yet materialised in the technology of machinery it reigned in the mind of the capitalist class, only to lose its imaginative grip when the postulate gains palpable mechanical reality.

However, if the postulate of the self-operating production process had remained nothing more real than an ideology, not far removed from the dream of perpetual motion, the capitalist mode of production could not have materialised. The postulate had to be given reality, and to achieve this was the business of modern science.

19

Galilean Science and the Dynamic Concept of Inertia

The break with tradition resulting in the foundation of exact science occurred when Galileo extended the concept of inertia to

movement and thereby initiated the science of dynamics. Until then inertia had always been understood as rest, and rest only, so that movement had required an effort or *impetus* to bring it about or to sustain it. This effort did not reside in things but had to be supplied in the last resort by a human being, handicraftsman or peasant, independent producer or slave or serf or wage-labourer; and even when the movement occurred in nature outside the human range the effort imagined to be causing it was of material forces acting as if with an agency analogous to that of man.

These assumptions of a static inertia and of the need of an impetus to account for movement are in keeping with a handicraft mode of production. Their rational use is limited to the solving of tasks lying within the scope of human strength and skill. They become irrational and fail when applied to problems transcending this scope by a substantial margin, as was notably the case with the ballistics of gunnery which in turn governed the entire range of military engineering and architecture when Europe was gripped by the fear of the Turkish menace (from the fall of Constantinople 1453 and of Otranto 1490).

The calculation of the trajectory of cannon balls was among the foremost problems on which Galileo brought to bear his concept of inertial movement and which he was the first to solve successfully. He proved it to be an exercise of pure mathematical analysis consisting of the combination of two geometrical principles, that of a straight line with a horizontal or an upward tilt and that of a vertical fall involving an even acceleration of known arithmetical measure. The combination yielded a parabola and the actual trajectory of cannon balls proved experimentally to conform with this rule advanced by way of hypothesis, while making allowance for air resistance. We know that Newton later repeated on an astronomical scale in his calculation of celestial orbits the feat which Galileo performed in terrestrial mechanics.

The Galilean assumption of inertial motion opened the applicability of mathematics to the calculation of natural phenomena of motion. This calculation carries scientific reliability, providing that the phenomena can be isolated from uncontrolled environmental influences and then tested experimentally. This briefly epitomises the guiding features of the mathematical and experimental method of science which, in

turn, signifies the epistemologically most telling part of the Scientific Revolution associated with the name of Galileo. Our aim in this study is to show that the rise of modern science is not only outwardly coincident but inherently connected with the rise of modern capitalism. In order to do that we must give a historical-materialist account of the origin and inner possibility of the method of modern science.

For a fuller description of the salient characteristics of this method I draw on Alexandre Koyré, whom I regard as one of the most distinguished exponents of the history of science as an internal history of ideas. His is an idealistic witness, but one which I intend to turn to advantage as an added test of the materialistic interpretations here proposed. I quote from his essay on 'Galileo and the Scientific Revolution of the Seventeenth Century', which is a good summary of his extensive Galilean investigations.[32]

> Modern physics, which is born with and in the works of Galileo, looks upon the law of inertial motion as its basic and fundamental law. . . . The principle of inertial motion is very simple. It states that a body, left to itself, remains in a state of motion so long as it is not interfered with by some external force. In other words, a body at rest will remain eternally at rest unless it is 'put in motion', and a body in motion will continue to move, and to persist, in its rectilinear motion and given speed, so long as nothing prevents it from doing so.

It is true that Galileo did not formulate this definition himself, although in his scientific work in terrestrial mechanics and physics he put it into practical effect. His research did not extend to astronomy, and his interest in the controversy around the Copernican system was in the main ideological. In the *Discorsi* of 1638,[33] the last of his dialogues on these issues, he touches upon inertial motion and describes it, by way of illustration, as the movement of a body persisting in a continuous course of uniform speed running parallel to the earth's surface. Thereby he creates the confusing impression that he conceived inertial motion as circular, and, even more misleading, as a notion gleaned from observation and therefore of empirical status. And yet, nothing could be further from the truth. Inertial motion such as Galileo

applies in his research is in empty space and strictly rectilinear, which makes it unmistakably non-empirical. Space, empty of air, is no object of perception in the terrestrial sphere, and in outer space, where we may claim to see it, none of the observable phenomena moves in rectilinear but all in orbital fashion.

The immediate successors to Galileo, Descartes and Torricelli, are quite clear on the non-empirical character of Galileo's novel dynamic principle. Newton gave it the final acknowledgement under the name of 'the first law of motion'. There is thus no possible doubt that Galileo's own description in the *Discorsi* must be discounted and that the correct interpretation is the non-empirical one of 'the uniform motion in a right line' – to use Newton's phrasing. Koyré is well justified in emphasising this true aspect of the principle which does not always receive its due attention.

> 'The principle of inertial motion', he continues where we quoted him before, 'appears to us perfectly clear, plausible, and even, practically, self-evident. . . . The Galilean concept of motion (as well as that of space) seems to us so "natural" that we even believe to have derived it from experience and observation, though, obviously, nobody has ever encountered an inertial motion for the simple reason that such a motion is utterly and absolutely impossible. We are equally well accustomed to the mathematical approach to nature, so well that we are not aware of the boldness of Galileo's statement that "the book of nature is written in geometrical characters", any more than we are conscious of the paradoxical daring of his decision to treat mechanics as mathematics, that is to substitute for the real, experienced world a world of geometry made real, and to explain the real by the impossible.
>
> 'In modern science motion is considered as purely geometrical translation from one point to another. Motion, therefore, in no way affects the body which is endowed with it; to be in motion or to be at rest does not make any difference to, or produce a change in, the body in motion or at rest. The body as such is utterly indifferent to both. Consequently, we are unable to ascribe motion to a determined body considered in itself. A body is only in motion in its relation to some other body, which we assume to be at rest. We can therefore ascribe it to the one or to the other of the two bodies, *ad lib*. All motion is relative. Just as it does not affect the body which is endowed with it, the motion of a body in no way interferes with other movements that it may execute at the same time. Thus a body may be endowed with any number of motions which combine to produce a result according to purely geometrical rules, and vice versa, every given motion can be decomposed, according to the same rules, into a number of component ones. . . .
>
> 'Thus, to appear evident, the principle of inertial motion presupposes (*a*) the possibility of isolating a given body from all its physical environment, (*b*) the conception of space which identifies it with the homogeneous infinite space of Euclidean geometry, and (*c*) a conception of movement – and of rest – which considers them as states and places them on the same ontological level of being.'[34]

With his usual brevity Bertrand Russell summarises:

> Galileo introduced the two principles that did most to make mathematical physics possible: The law of inertial motion, and the parallelogram law.[35]

The vital importance of the principle of inertial motion is that it has the element of motion in common with innumerable phenomena of nature and at the same time it is co-extensive with mathematics and can be treated like Euclidean geometry 'made real', as Koyré puts it. It thus opens the door through which mathematics can establish itself as an instrument of the analysis of given phenomena of movement and yield a mathematical hypothesis which can then be tested experimentally. The concept of inertial motion is the methodological key to exact science. The crucial question is – from what origin does it spring?

We face the contradiction that concepts which are incontestably non-empirical – that is, not gleaned or reflected from nature – can nevertheless give such invaluable service in the investigation of nature. Whether or not the knowledge achieved is proved valid by experiment or by industrial or social practice is, of course, the vital question. But our concern is the possibility of such knowledge which, in order to be available for practical confirmation or refutation, depends on whether the concepts

bear the necessary reference to nature at all. And how such reference is possible of concepts which are not taken from nature is the pivot of our enquiry. It can, without exaggeration, be called the particular epistemological riddle of exact science. It was asked by Kant as an enquiry into 'the possibility of pure mathematics and of pure science'. He saw no possible answer other than the one given in his 'transcendental idealism', that, since our knowledge depends on concepts *a priori* not depicting nature as it really is, we can only understand nature as it corresponds to those concepts of ours. In Part I of the present book we have, however, laid the foundation for a different answer, a materialistic one, while changing Kant's ahistorical question to the historical one, to read: How is knowledge of nature possible from sources other than manual labour? or: How is mathematical physics possible given the fact that it cannot be derived from manual labour? How does man acquire an intellectual capacity of knowledge of nature that far exceeds the standards accessible to handicrafts?

Our explanation of the principle of inertial motion is that it derives from the pattern of motion contained in the real abstraction of commodity exchange. This motion has the reality in time and space of the commodity movements in the market, and thus of the circulation of money and of capital. The pattern is absolutely abstract, in the sense of bearing no shred of perceptible qualities, and was defined as: abstract linear movement through abstract, empty, continuous and homogeneous space and time of abstract substances which thereby suffer no material change, the movement being amenable to no other than mathematical treatment. Although continually occurring in our economic life the movement in this description is not perceivable to our private minds. When it does indeed strike our minds it is in a pure conceptual form whose source is no longer recognisable; nor is the mechanism to which it owes its abstractness.

The derivation of Galileo's principle of inertia from the exchange abstraction thus explains the reference of the principle to natural movement. Moreover, it has to be borne in mind that 'the concepts which result from the identification of the elements (the elements of the exchange abstraction) are in origin concepts of nature'.[36] It is necessary to affirm these points in order to counter the impression which might easily arise to a superficial

observer that, by tracing the categories of science to a root in social history, we had simply replaced Kant's subjective idealism by a sociological idealism and added historical relativism into the bargain. I recognise that this misapprehension constitutes a danger, because in order to avoid it, an effort must be made to plumb the depth of an argument laden with considerable epistemological complexity.

To bring the right idea to bear on my theory it is advisable to turn to the Afterword to the second German edition of *Capital* where Marx quotes with approval a Russian review of his book and in particular of its method:

> Marx treats the social movement as a process of natural history, governed by laws not only independent of human will, consciousness and intelligence, but rather, on the contrary, determining that will, consciousness, intelligence. (p. 27)

And in the Preface of the first edition Marx speaks of

> My standpoint, from which the evolution of the economic formation of society is viewed as a process of natural history . . . (p. 21)

Thus my derivation of the concepts *a priori* of science is a natural one, not relating, it is true, to the external nature but to the historical nature of man himself.

We must now explain the different concepts of inertia – static in the ages of pure commercial and slave-holding capital in antiquity, and in the Middle Ages and the Renaissance, but dynamic from the start of capitalist production. The first remains as long as the exchange processes are confined to the sphere of circulation as is the case of merchant and monetary capital until the sixteenth century. But as society enters upon a state where the direct producers are without their own means of production then these means of production, both material and men, are brought together by way of the market. Then production does not take place merely as production but as exchange, and exchange no longer signifies only exchange but production. This mingled unity of exchange and production, production and exchange, constitutes a constant and continuous process functioning as an

economically self-compelling system. Production here is of larger volume and

> Capitalist production only really begins . . . when each individual capitalist employs simultaneously a comparatively large number of workers, and when, as a result, the labour-process is carried on on an extensive scale and yields relatively large quantities of products. . . . [This] constitutes the starting point of capitalist production. This is true both historically and conceptually.[37]

In other words capital is a social power which takes over production where it has outgrown the economic and technological capacities of the direct producer controlling it himself. While in the economic field the social power is capital, in the field of technology it is science, or, more accurately, the methodical operation of the human mind in its socialised form, guided by its specific logic, which is mathematics. This socialised mind of man, we have seen, is money without its material attachments, therefore immaterial and no longer recognisable as money and, indeed no longer being money but the 'pure intellect'. In its form as money it is capital ruling the labour process by the identity of labour with value and postulating the process to be cast in a framework in which it operates in an automatic manner enforcing the embodiment of the labour employed into values containing a surplus. In its form as the scientific intellect the socialised mind applies itself to physical phenomena on which the automatic working of the labour process of the various capitals is found to be depending. I turn once more to Bertrand Russell's *Human Knowledge*[38] to illustrate this context. The first sentence of the book reads:

> Scientific knowledge aims at being wholly impersonal, and tries to state what has been discovered by the collective intellect of mankind. (p. 17)

On page 30 we find the statement:

> This principle [of inertial motion] led to the possibility of regarding the physical world as a causally self-contained system.

The establishment of natural laws we can understand as resulting from a combination of mathematical hypotheses and experiments. How this is helped by, and indeed founded on, the principle of inertial motion, or, let us say, how this was done in classical physics can be further clarified by considering the following statements, one by Engels, the other by Bertrand Russell: In *Anti-Dühring* we read:

> Motion is the mode of existence of matter. Never anywhere has there been matter without motion, nor can there be. Motion in cosmic space, mechanical motion of smaller masses on the various celestial bodies, the motion of molecules as heat or electrical magnetic current, chemical combination or disintegration, organic life – at each given moment each individual atom of matter in the world is in one or other of these forms of motion, or in several forms of them at once.[39]

And in his *History of Western Philosophy* Russell states:

> The theory that the physical world consists only of matter in motion was the basis of the accepted theories of sound, heat, light, and electricity.[40]

The association of matter with motion stems from Galileo's definition of inertia. This definition, we have seen, was the finishing touch enabling Galileo to work out the mathematical and experimental method and to become the founder of modern science. In the light of Galileo's definition of inertia the pattern of the exchange abstraction assumes the meaning of the absolute minimum of what constitutes a physical event. Any event that can be constructed as a composite of this minimum is therefore *ipso facto* conceivable in terms of pure theoretical categories and amenable to full mathematical treatment. This is, in fact, how modern science proceeds. Theoretical hypotheses in conceptual form and mathematical formulation are worked out and tested by confrontation with nature or with that carefully isolated part of nature of which the hypothesis contains the definition. This confrontation represents the experiment. The experiment is carried through with the help of instruments adapted to the hypothesis and are, in fact, part of it. The phenomenon tested is

safeguarded from any touch by human hand and made to register specific measurements which are then read as indicated by the instruments, and which must be in answer to the questions advanced by the hypothesis. The act of reading these values is the only direct contact the experimenter is allowed with the piece of nature under investigation. These precautions are indispensable for ascertaining the identity of the tested phenomenon with the mathematical hypothesis; in other words indispensable for clinching the experimental isolation. Owing to this isolation a phenomenon can be subject to investigation only torn out of the context within which it occurs. It is clear, therefore, that modern science is not aimed at helping society in her relations with nature. It studies nature only from the viewpoint of capitalist production. If the experiments yield a reliable verification of the hypothesis the latter becomes an established 'law of nature' in the shape of a law of recurrent events. And this is the result the capitalist may utilise for technological application in his factory. Not infrequently the technological installation closely resembles a large-scale replica of the successful experiment. It can be said that objects over which capital can exercise control must be cast in the form of a commodity. It is the exact truth of exact science that it is knowledge of nature in commodity form.

20

Bourgeois Science

Is it correct to class science as we know it, or rather as we knew it until the end of the nineteenth century, as bourgeois science? Can we expect a major transformation of science if socialism were to supersede capitalism? It all depends what we understand by 'science'. The science that we have is a product of intellectual labour divided from manual labour. For that reason alone it

cannot represent our possession of nature, our true relation to nature. By adhering to a concept of science which keeps to this intellectual one-sidedness we should not judge it capable of essential alterations, for instance, major alterations in method and in the use of mathematics. In his Parisian *Economic and Philosophical Manuscripts of 1844* Marx is more outspoken than in his later work about his demands on science and there are two passages which I shall quote. The one has regard of the notion of 'labour' which we ought to keep in mind, the other shows us what conception of 'science' animated Marx's ideas.

> The outstanding thing in Hegel's *Phenomenology* and its final outcome – that is, the dialectic of negativity as the moving and generating principle – is (thus) first that Hegel conceives the self-genesis of man as a process . . .; that he grasps the essence of *labour* and comprehends objective man – true, because real man – as the outcome of man's *own labour*. The *real* active orientation of man to himself as a species being (i.e. as a human being),* is only possible by his really bringing out of himself all the *powers* that are his as the *species* man – something which is only possible through the totality of man's actions, as the result of history – is only possible by man's treating these generic powers as objects: and this, to begin with, is again only possible in the form of estrangement.[41]

It is clear that 'labour', here, to Marx means the comprehensive unity of man's mental and physical powers and that only when this unity is achieved can man possibly assume control of his destiny and become master of his social history and his relationship to nature. When we distinguished 'societies of production' and 'societies of appropriation' we made the point that on the basis of primitive communal modes of production, as they preceded commodity production, the social practice was rational but the theory was irrational (mythological and anthropomorphic), while on the basis of commodity production the relation was reversed; namely, the social practice has turned irrational (out of man's control) but his mode of thinking has assumed

* Marx later replaces this anthropological Feuerbachian notion of 'species being' (Gattungswesen) with that of the social being and social essence of man.

rational forms. What Marx has in his mind's eye in the passage we quoted is man's historical potentiality of achieving a rational practice and a rational theory combined, which is simply another way of speaking of communism. In the following passage we find Marx evolving a conception of 'science' corresponding to this complete rationality of man, the only real one that can be intended.

> It will be seen how the history of industry and the established objective existence of industry are the *open book of man's essential* powers, the exposure of the senses of human *psychology*. Hitherto this was not conceived in its inseparable connection with man's *essential being*, but only in an external relation of utility. . . .
>
> A *psychology* for which this, the part of history most contemporary and accessible to sense, remains a closed book, cannot become a genuine, comprehensive and *real* science. What indeed are we to think of a science which *airily* abstracts from this large part of human labour and which fails to feel its own incompleteness. . . . [Marx is thinking here chiefly of the humanities and in the idealistic and romantic manner of his time of writing – S.-R.]
>
> The *natural sciences* have developed an enormous activity and have accumulated a constantly growing mass of material. Philosophy, however, has remained just as alien to them as they remain to philosophy. Their momentary unity [in Hegel's *Encyclopedia* presumably – S.-R.] was only a *chimerical illusion*. The will was there, but the means was lacking. Even historiography lays regard to natural science only occasionally. . . . But natural science has invaded and transformed human life all the more *practically* through the medium of industry; and has prepared human emancipation, however directly and much it had to consummate dehumanisation. *Industry* is the *actual*, historical relation of nature, and therefore of natural science, to man. . . . In consequence, natural science will lose its abstractly material – or rather, its idealistic – tendency,[42] and will become the basis of *human* science, as it has already become the basis of actual human life, albeit in an estranged form. . . . All History is the preparation for '*man*' to become the object of *sensuous* consciousness, and for

> the needs of 'man as man' to become his needs. History itself is a *real* part of *natural history* – of nature's coming to be man. Natural science will in time subsume under itself the science of man, just as the science of man will subsume under itself natural science: there will be *one* science.[43]

Needless to say this is no longer a conception of science which fits the one-sided intellectual science which we have today and which stands out as bourgeois science when confronted with Marx's conception. However, there are signs that our twentieth-century science which has achieved the enormous advance to atomic and nuclear physics has left bourgeois science behind and has assumed a state where it no longer fits the 'rationality' on which capitalism relies for its continuance. In any case, if it possesses the same and even a higher degree of rationality, it does not occupy the place in our present-day capitalist society which nineteenth-century science held, for it has unleashed natural powers which capital fails to control. Thus if we remain in the clutches of capitalism we are threatened with the loss of the social rationality of science which capitalism formerly possessed and may find ourselves with the irrationality of our social practice combined with no less an irrationality of our theory. If we are not mistaken, man has reached a crossroad where he is faced with the alternative either of taking the socialist road and perhaps achieving a rationality of both social practice and theory or continuing on the capitalist road and forfeiting both.