SOCIALISM AND THE UNITY OF PHYSICAL FORCES

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In accepting the theory of the unity of physical forces or of the constancy of energy, we are also forced to admit that nothing can be *created*, in the strict sense of the word, through labor and that consequently, all the usefulness of labor, the goal for which it strives, can be nothing other than a transposition of a certain quantity of forces. What is the manner in which these transpositions are produced? What are the best ways to apply human labor to nature in order to render a greater fraction of its forces profitable for the satisfaction of human needs? These are the questions to which we shall attempt to respond in the present study.

According to the theory of production formulated by Marx and accepted by socialists, human labor, expressed in the language of physics, accumulates in its products a greater quantity of energy than that which was expended in the production of the labor power of the workers. Why and how is this accumulation brought about?

In order to respond, we must dwell for a moment on the general distribution of energy in the universe.

The total energy, the sum of all of the physical forces of the universe, is a constant quantity, but this is far from the case for the quantities of energy in the different parts of the universe. Certain heavenly bodies send to other bodies, across interstellar space, different kinds of physical forces in considerable quantities, and this permits us to say that the former of these bodies, the *suns*, possess a greater quantity of energy than both interstellar space and the latter celestial bodies, the *planets* and their *satellites*. These last heavenly bodies receive their energy from the nearest suns, in the form of light rays, calorific rays, chemical rays, etc. An exchange such as this, between bodies possessing a greater amount of energy and those with a lesser amount, must inevitably, after some time, lead to a universal equilibrium of energy.

It is thought that all of the transformations of physical forces, inevitable in their period of equilibration, are accompanied by a general tendency of certain kinds of physical forces to assume another form than that which they possess, and that there may be a determined form, that of *heat* uniformly distributed across the universe, that all forms of physical force accept, at least partially, in the course of each transformation.

The energy of the universe is thus transformed constantly, leaving behind forms that are not very stable in order to acquire others that are more stable. Consequently, the ease of the subsequent transformations always tends to diminish. After a long series of centuries the total energy should eventually acquire a form that is incapable of transformation, which would consist of a certain degree of heat uniformly distributed throughout the entire universe. When this occurs, every kind of mechanical movement perceptible to our senses, and consequently, every living phenomena familiar to our understanding, would not take place because a difference in temperature is *absolutely* necessary to bring about a transformation of heat into any other kind of physical force. This tendency of energy toward a universal equilibrium is called *dispersion of energy*, or according to Clausius's terminology, *Entropy*.[2] This last term expresses the quantity of energy transformed that cannot undergo additional subsequent transformations. These two principles of Clausius derive from it: *The energy of the universe is constant. The entropy of the universe tends towards a maximum*.[3]

Thus, in the strict mechanical sense of the word, the energy of the universe will certainly always and completely be conserved. But this equilibrated energy, that is, the heat uniformly distributed in the universe, will no longer be capable of provoking different presently observed phenomena in the inorganic world and in the living world, because a difference in temperature is absolutely necessary to bring about a transformation of heat into any other kind of physical force.

It is true that we continue to receive on earth from the sun enormous quantities of physical forces still capable of going through all of the transformations of which the physical and biological phenomena on our globe are faithful manifestations. According to Secchi, one square meter of the sun's surface furnishes 5,770,540 kilogrammometers in the form of 76,642 horsepower of work.[4] Several square meters of the sun's surface would be sufficient to set in motion all of the machines that exist on the earth. The total work of the sun is estimated at 470 quintillion horsepower. If we accept the widespread theory that explains the source of solar heat by the sun's own condensation, we find that it would take 18,257 years for the visible diameter of the sun to be diminished one single second, and 3,820 years for the sun's temperature to drop one single degree. This figure will not seem exaggerated at all, if one keeps in mind that the substance of the sun is found probably almost in that state of chemical indifference, which is produced by the raising of the temperature, that is known by the name of *disassociation*.[5,6]

Thus we see that the danger of one day lacking forces capable of being transformed on the earth's surface is still very distant, but at the same time, looking more closely, we would argue that the distribution of these forces is not always the most advantageous for the living world's needs in general and for the existence of the human race in particular. We believe, furthermore, that to a certain extent, it is within the power of humanity to produce certain modifications in this distribution of solar energy, in such as way as to render a greater portion profitable to humans.

In reality the major part of the physical forces that are found on the earth, and which are thus useful for meeting human needs, are by no means found in a form which would be the most advantageous for achieving this goal.

Humanity having above all a need for nutritive, combustible and mechanical forces for work, the most profitable forms of physical forces for it would be: first, the more or less free chemical affinity, represented in the form of nutritive substances of animal or vegetative origin, or in the form of combustible material; second, effective and available mechanical movement that can serve as an engine for the machines that work to the benefit of human beings.

Now, we observe that the earth, in itself, offers us relatively few physical forces that have these advantageous forms for humanity. If it is true that earth's interior is still in a state of incandescence [heating], which presumes that we would find there many dissociated chemical elements, and that thanks to the elevated temperature one would find a great quantity of virtual movement, we scarcely profit at all from this, and feel, on the contrary, the destructive effects during earthquakes and volcanic eruptions. We are, however, compensated for these disasters by the exceptional fertility of volcanic terrain and by a notable increase in the temperature in the vicinity of volcanoes. On the slopes of Mount Etna, says Eliceo Reclus,

> the land is so fertile, that its products are able to suffice for a population three or four times more dense than that of the other counties of Sicily and of Italy. More than three hundred thousand inhabitants are clustered on the slopes of this mountain, which from a distance is considered a place of terror and imminent danger, and from time to time this proves to be the case as it is uncovered to flood its countryside with a deluge of fire. At the base of the volcano the cities touch and follow one another like pearls in a necklace.[7]

But generally the surface layers of the earth's crust consist principally of chemical combinations which contain almost no free affinity, nor any noticeable mechanical movement. Such is also the case for the waters and the atmosphere that cover the surface of our planet and with which we are always in contact. All the movements of the air and water, the ebb and flow, the movement of waves produced by the wind, the river currents, the force of falling rain, the wind itself, take their force from the energy radiated from the sun, or are produced by the gravitational pulls of the moon and sun. The chemical affinity, accumulated in the form of coal in the bowels of the earth, is equally an effect of solar heat, a product of the sun's rays over the past centuries. Even free oxygen in the atmosphere, according to certain geological hypotheses, originated in combination with the carbon that now constitutes coal.[8]

All of these examples clearly demonstrate that the energy radiated from the sun is more or less the only source of all the forces profitable to humankind, which are found on the earth's surface.

But the quantity of energy radiated toward us from the sun would be, according to a very well known physical law, reflected into interstellar space, in the same proportion that it is received, if it did not undergo certain transformations which permit it to prolong its stay on the earth and to constitute there an accumulation of solar energy. This occurs when the rays which arrive from the sun, hot, luminous and capable of producing certain chemical modifications, are collected from material in such fashion as to transform them into free chemical affinity or into a mechanical movement.

In this last case, a part of the heat radiated from the sun is no longer reflected into interstellar space, according to the well-known law of Kirchhoff,[9] but is instead captured for a more or less long time on the surface of the earth, since it would take on forms that protect it from immediate dispersal. "Energy rises by degrees", is how this is expressed by the celebrated philosopher William Thomson. The words of Secchi may serve as the best illustration here:

> The sun's rays that fall on the plants are not reflected by them to the same degree as would be found for the desert or mountainous rock. They are captured by the earth's surface in a greater measure, and the mechanical force of the undulations of the particles is used to produce decompositions of oxygen with carbon and with hydrogen. The dissociation of the stable combinations, their dissolution so to speak, as in the familiar case of water and carbonic acid, is an inevitable consequence of the activity of the sun's rays on the plants.[10,11]

(End of First Installment)

Socialism and the Unity of Physical Forces: Continuation and End

What happens in this case? A portion of the solar heat, which seems to dissipate, is in reality captured by the earth's surface *without raising its temperature*, that is, without increasing its losses in space. The losses are equal, but the surface of the earth has received from the sun more energy, or rather, having received the same amount of energy it disperses it less. In whatever way we consider this process, we see under the influence of the plants an accumulation of energy. But it is not dispersed energy anymore, like heat, electricity, and light, but an energy of a higher degree that will still be preservable on the surface of the earth for hundreds of years, and will be capable also of all the other transformations. Thus, the plants in general and cultivation in particular are the most feared enemies of the dispersion of energy into interstellar space.[12]

But the ways in which the radiating force of the sun effects these transformations are not very numerous. They are above all:

1. The production of the *wind*, that is the impulse to movement given to the air by the modifications of its temperature.
2. The elevation of water through evaporation.
3. The dissociation of stable combinations, for example, of water, of carbonic acid, carried out by the growth of plants.
4. The muscular-nervous work produced by men and animals.
5. The work of machines constructed by men which, in a direct or indirect way, as with Monchet's solar machine, have as their only motor the sun's heat.

We will see that the quantity of solar forces converted into free chemical affinity and into effective mechanical motion is not always the same and that it can be modified, among other causes, by the efforts of humans. For *man, by certain acts of will, can increase the quantity of solar energy accumulated on the earth and diminish the dispersed energy.*

In cultivating vegetables in places where there were not any, or even where they existed in small quantities; by draining marshes, irrigating dry counties, and introducing a perfected system of cultivation; in applying machines to agriculture, and protecting cultivated plants and vegetables against their natural enemies; man can reach the first goal.

In driving away and exterminating animals that are harmful to the richness of the vegetation, he works to reach the second goal. In the two cases we have an absolute or relative increase of solar power retained on the earth.

Here are some examples, taken from agricultural statistics of France, which tend to prove the truth of our assertions as regards the decisive influence of the work of men, or of animals directed by men, on the quantity of solar energy accumulated by a given terrestrial surface.

France possesses now almost 9,000,000 hectares of forests that produce annually 35,000,000 stères or almost 81,000,000 metric quintals [1 metric quintal = 100 kilograms] of wood. The average production is then yearly 9 metric quintals for each hectare. Accepting the figure of 2550 calories[13] produced by the combustion of one kilogram of wood, we see that the 9 quintals of wood represent a value of 900 × 2,550 = 2,295,000 calories per hectare accumulated in the course of one year.[14]

The 4,200,000 hectares of *natural pastures* in France produce an annual average of 105,000,000 metric quintals of hay, or 25 metric quintals per hectare, which represent, given the same number of calories produced by combustion of hay as for wood, 2500 × 2550 = 6,375,000 calories accumulated per hectare.

Thus, in France, the accumulation of solar heat in the form of chemical affinity produced by the growth of vegetables in their natural state, fluctuates between 2,295,000 and 6,375,000 calories per hectare, under conditions where the natural vegetation is richest, that is, in the forests and on the pastures. Let us see now the effect produced by labor.

The *sown pastures* of France occupy a surface of 1,500,000 hectares and produce, on average, with a deduction made for the caloric value of the seeds, 46,500,000 metric quintals of hay or 31 metric quintals per hectare. This production gives 3,100 × 2,550 = 7,905,000 calories. In other words, the surplus compared to the natural pastures is 1,530,000 calories per hectare. Now in order to cultivate one hectare of sown pasture (once every four years) and harvest the hay every year, one must expend approximately 50 hours of a horse's labor and 80 hours of a man's labor, which altogether represents around 37,450 calories. Consequently, each calorie spent in work yields: 1,530,000:37,450 = 41 calories of accumulated solar heat.

The cultivation of *wheat* in France (taking a figure a little less than the actual average) extends over 6,000,000 hectares. The average production under the same conditions, after a deduction for the grain planted, reaches 60,000,000 hectoliters of grain and 120,000,000 metric quintals of straw, that is, 10 hectoliters or roughly 800 kilograms of grain and 20 metric quintals of straw per hectare. The 800 kilograms of grain contain almost 3,000,000 calories, using the figures for the combustion of albumens, starch, etc. The 2,000 kilograms of straw would produce through their combustion 5,100,000 calories, and altogether the harvest of one hectare gives 8,100,000 calories. The surplus over the natural pasture is 1,725,000 calories. This surplus is produced by 100 hours of horse labor and 200 hours of human labor, together representing a total value of 77,500 calories. Therefore, each calorie spent on labor, during the cultivation of a field of wheat, accumulates 1,725,000:77,500 = 22 calories on the earth's surface.[15]

The effects produced by irrigation also show the importance of the influence of human work on the quantity of solar energy stored in the earth. The average product of one hectare of wheat on the non-irrigated lands of the Spanish provinces of Valencia and Murcia only yields 6 times the quantity of planted grain, while in the fields traversed by innumerable canals, diverted from Gibraltar, from Jucar, from Segura and from the other rivers of the eastern coast of Spain, the yield is 36 times the weight of the seeds.[16]

What then is the real cause of this increase in the quantity of solar energy, which remains on the earth's surface, in the form of nutritive substances or combustible materials, instead of being immediately reflected, according to the simple law of temperature differences, into frigid interstellar space? It is the *useful work* that we can define in this way: *every expenditure of muscular work of humans or of animals that has as a result an increase in the solar power accumulated on the earth*.

The increase of force can be carried out in two ways: by the immediate conversion of a certain quantity of solar energy into motion or into a nutritive substance, or, just as well, in a mediated way, through the conservation of a quantity of energy existing on the earth, which without the intervention of labor would be inevitably dispersed. In this last category belongs, for example, the useful work of artisans, such as shoemakers, tailors, tool and machine inventors, etc.

It is clear, according to this definition, that useful work can be attributed only to men and certain animals that, like domestic animals, are guided by men, or that, like ants, are busy with cultivation and the raising of domestic animals, driven by their own instincts.

The motion of the air, the wind, can never be categorized as useful work in the true sense of the word, because, left to its own free course, it does not ever produce with the expenditure of its energy a new accumulation of energy on the earth. The same reasoning is applicable to the moving force represented by water currents.

Plants, which in fact accumulate energy in the substance of their own organisms, cannot put it in motion by themselves in the vast majority of cases, neither can they expend it in a useful way, that is, in a way that may increase the quantity of accumulated energy that exists on earth.

Machines constructed by the work of men, left to themselves, even if they could remain for a long time in motion, would not give any useful work, because it is still impossible to imagine an artificial construction that, without any intervention of the work of men's muscles, could produce a continuous increase of solar energy accumulated on the earth.

Finally, the nervous work of men, also intellectual work, that can contain the *possibility* of an immense accumulation of energy, does not really become useful work for the human race before having been applied to a specific muscular labor, *because we are not acquainted with any means (method) to achieve with intellectual work the goal of all useful work, that is, the absolute or relative increase of the energy that is found at the disposal of humans*.[17]

How animals contribute to increasing the accumulation of energy on the earth's surface is very difficult to establish. Nourishing themselves with vegetables, they make them diminish, but they also make them increase indirectly by accumulating their products in an indirect manner, for example the guano and other products of the digestion of vegetable substances, etc., that serve to make plants grow. The same thing happens with the animals that serve in the nourishment and clothing of humans, animals which, although certainly formed from the vegetable kingdom, supply it at the same time with a surplus of energy. It is known that certain species of animals accidentally or instinctively produce useful work. Thus, the bees that make honey or wax, many insects and birds that fertilize plants and increase in such a way the production of seeds (Darwin, *Origin of Species*), show us clearly that plants and insects adapt to their conditions of mutual coexistence and at times help each other in their struggle for existence.

It would be impossible indeed to establish mathematically the usefulness or harmfulness of different animals, by which we should mean their usefulness for the welfare of the human race.

In sum, strictly speaking, only in the cultivation of the earth is our definition of work best exemplified, since it is evident that a hectare of uncultivated land or of virgin forest, without the influence of humans, produces less nutritive materials, but this quantity can be multiplied by ten or even more. Certainly, man can create neither material nor energy. All the material existed in the earth, in the seeds and in the atmosphere; all of the energy was given by the sun. But thanks to the activity of human work, one hectare of land can accumulate in its vegetation ten times or more energy than without this influence. It is not necessary to believe that this energy is only diffused into space by the work of humans. This would not be correct, since agriculture does not exhaust the soil unless it is carried out in an unscientific and wasteful manner. On the contrary, a perfected agriculture gives better results precisely in the countries where it has flourished for a longer time, in Egypt, China, Japan, Lombardy, France, Belgium and England, etc.

We believe we are right then in affirming that scientific agriculture is the best example of useful work, that is, of work that increases the quantity of solar energy on the earth's surface.[18]

We now attempt to apply this theory to the satisfaction of human needs. We assume as demonstrated that the satisfaction of any need is accompanied by an exchange of physical forces between the organism and the external environment. A certain quantity of energy indispensable to the satisfaction of our needs is offered to us without efforts on our part and is in a matter of speaking a gift of nature, for example, oxygen in the air, etc. We have not worried ourselves about this part of the energy necessary for our existence. But all the rest must be acquired through work. Now we have seen that the only useful work, the only kind that really increases the quantity of energy that is available to humans, is the work done with the muscles. All intellectual work, even that of the man of genius, *does not in fact* increase the accumulation of energy on the earth if it does not increase the productivity of the muscular labor of the worker who adapts himself to the forces of new inventions, to the perfected tool, to the machine, to a new system of agriculture and industry. Without this essential expenditure of muscular force, the most splendid invention would be useless. There exists only one way for work to increase the quantity of energy on earth, and that is to make the muscular labor of the workers more productive with the help of machines and of perfected processes, etc. Sensing this truth, Adam Smith specified the necessary work in production, in the wider sense, in the historical sense of the word, as the only measure of the value of things.[19]

From the experiments of Hirn and Helmholtz, we now know that a relationship exists between the quantity of oxygen inhaled during work and the quantity of work supplied. It turns out that estimating the quantity of work accounted for by the combination of breathed-in oxygen with the elements of our bodies, and comparing this quantity with the work supplied by the muscles, we have an almost constant relationship which does not stray far from the ratio of 5:1. For this reason, the fraction 1:5 is considered to be the *economic coefficient* of the human machine, whether measured in terms of the quantity of oxygen inhaled, or, almost equivalently, by the quantity of food ingested.[20]

But in reality one should reduce considerably the fraction which represents the economic coefficient of the human machine, because nutrition combined with respiration, is not the organism's only indispensable need. As an approximate calculation, the value of the food may be considered to represent half of the work demanded for the satisfaction of our needs. For the whole, then, it is necessary to allow double the amount of work and thus to reduce the economic coefficient of humans by two times, that is to put it at 1:10, rather than 1:5. This means that the satisfaction of all of our needs, presently considered as indispensable, represents a quantity of work almost ten times greater than the human muscular labor. This surplus must be accounted for by the greater productivity of human muscular labor, guided by intelligence, by the muscular power of domestic animals, or finally, by inanimate forces both natural and artificial.

It is easy to see that the economic coefficient of the human machine is in no way a constant quantity. It varies considerably through the centuries and from place to place. The savage who satisfies his own needs in large part from the free bounty which nature offers him, without much productive work on his part, and whose needs are limited almost to nourishment, apparently possesses an economic coefficient that is higher than civilized man. But, on the other hand, if the work produced by the muscular system of the civilized man is a smaller fraction of his expenses than that of the savage, then the usefulness of his work is much greater, because his work satisfies a greater quantity of needs and satisfies them on average much better than with the savage primitive or during the intermediate stages of civilization.

Production, which is equivalent to the possibility of satisfying our needs, increases in the civilized countries by reason of their progressive movement, and this increase proceeds, in the majority of cases, more rapidly than the growth of population. Let us take the example of France.

France in:[21]

1820	had	29,700,000	inhabitants;	wheat production was	44,000,000 hectoliters
1830	“	31,500,000	“	“	52,000,000 “
1850	“	35,000,000	“	“	87,900,000 “
1860	“	36,100,000	“	“	101,000,000 “
1868	“	37,300,000	“	“	106,000,000 “

According to other calculations,[22] the consumption of wheat per inhabitant in France was:[23]

In	1821	1.53	hectoliters
“	1835	1.59	“
“	1852	1.85	“
“	1872	2.11	“

The yields of the hectares cultivated in cereals have greatly increased in average numbers of hectoliters harvested. In 1840,[24] the average yield of:

Wheat was . . .	12.28	hectoliters per hectare;	in 1866 it was	15.70	hectoliters
Rye was . . .	10.79	“	“	13.83	“
Barley was . . .	14.00	“	“	18.91	“
Oats was . . .	16.30	“	“	24.50	“
Corn was . . .	14.27	“	“	17.61	“

All of these figures, even if they are not perfectly exact in their particulars, still reveal that in France, human work has shown a clear tendency to become more productive over the course of the present century, and that its usefulness has grown in an indisputable manner.

The statistics furnished by Switzerland provide more detailed evidence. Comparing the increase in the population with the export of cereals, because Switzerland exports grain in larger quantities than it imports, we see that in spite of the continuous increase in the well-being, and consequently in the consumption in this country, the exportation of grains increased much faster than the population:[25]

In 1840,	the population was	3,100,000;	cereal exports were	1,500,000	metric feet
" 1850	"	3,500,000	"	4,500,000	"
" 1860	"	—	"	8,500,000	"
" 1875	"	4,400,000	"	17,500,000	"

Sweden in:

1830	possessed	1,857	factories with production valued at	13,000,000	kronen
1850	"	2,513	"	37,000,000	"
1870	"	2,183	"	92,000,000	"
1875	"	2,719	"	173,000,000	"

Finally, Spain, which is usually not considered to be a country following a path of rapid progress, shows us examples according to which, under good conditions for the increase in population, the increase in agricultural production took place at a still more rapid pace. It has now been one hundred years since in the Basque Country the annual harvest was 200,000 bushels (a Spanish measure a little larger than a hectoliter) of wheat and 400,000 of corn, and at that time there were resources sufficient for a population of scarcely 100,000 souls. Since then the population has doubled, but the crops harvested have increased in a greater proportion: The Basque Country today produces annually 600,000 fanegas of wheat [one fanega equals 1.58 bushels], more than one million fanegas of corn of which a portion is exported to England and to Germany, and 80,000 fanegas of dry vegetables.[26]

We thus see that useful work can accumulate energy in greater proportion than the population increase, but certainly, this is not the general case. In the majority of countries, especially where unbridled luxury reigns from developed capitalist production, a great part of the work is, contrary to its purpose, almost exclusively directed to the production of luxury objects, that is, to the gratuitous dispersion of energy rather than to its accumulation.[27]

What is the cause of this apparent contradiction? Since the economic coefficient of primitive man is greater, it is necessary to consider his body as a better organized machine than the body of civilized man; still, the latter produces more with his work. To find the solution to this problem it is necessary to return to the noted considerations of Sadi Carnot on *thermal machines*, that is, machines that transform heat or other forces into mechanical motion.[28] Man is also a thermal machine.

According to Sadi Carnot, in order to be able to judge the degree of perfection of a thermal machine, one needs to know not only its economic coefficient, *but also its capacity to recycle the heat spent at work*. A machine having the capacity to reheat itself, making the heat spent at work rise toward its fire-box, would be a *perfect machine*, and only such a machine could provide a true conception of the transformation of heat and *vice-versa*. Now, no machine constructed by the hands of men possesses this faculty. No machine heats its own fire-box with its own work alone, and no machine works on a *reverse cycle*, that is, the transformation of work into heat is unknown. As a consequence, the true laws of these transformations cannot be found with the aid of inanimate machines. The plant world, producing almost no effective mechanical motion, also cannot even be remotely considered as an example of a *perfect thermal machine*.

But, observing the work of humans, we see in front of us just exactly what Sadi-Carnot calls a *perfect machine*. From this perspective, humanity would be a machine that would not only transform heat and other physical forces in work, but that would also produce the *complete reverse cycle*, which converts its work into heat and other forces essential for the satisfaction of its needs, that is to say it would recycle to its fire-box the heat produced by its own labor. In reality, a steam engine, even admitting that it will run an entire year without the intervention of muscular human labor, could never produce all the elements necessary to sustain its work in the following year. The human machine, by contrast, will have created a new crop, will have raised young domestic animals, will have constructed new machines, and will still be able to continue with success its new work in the following year. The reason is evident: the human machine is a perfect machine, whereas an inanimate machine never achieves the conditions of perfection that Sadi Carnot requires.

The degree of perfection of the human machine is determined not only by its economic coefficient, but above all by its capacity to carry out the reverse cycle, that is, to convert its work into an accumulation of the physical forces necessary for the satisfaction of human needs. This is how we should explain that primitive man, with his coefficient of almost 1/6, is less perfect as a machine than civilized man with his coefficient of only 1/10. It is that primitive man profits only from the free gifts of nature, while the civilized man satisfies almost all of his needs with the help of his work and produces in this way an accumulation of solar energy on earth, whose quantity surpasses ten times the force of his muscles.

The essential conditions for the continuation of work by an imperfect inanimate machine do not depend on its work, nor on its qualities, because we know that a steam engine, for example, cannot by itself renew the heat of its fire-box. All of these machines depend on human labor to furnish them with the substances that produce this heat. By contrast, the conditions of labor, i.e., of the existence of the human machine, can be rigorously established.

As long as muscular labor supplied by the human machine is converted into an accumulation of energy necessary for the satisfaction of human needs, which represents a quantity in excess of the sum of the muscular work of the human machine, by as many times as the denominator of the economic coefficient exceeds the numerator,—the existence and the possibility of the labor of the human machine are guaranteed.

Every time that the productivity of human labor falls below the inverse coefficient of the human machine, there will be misery and perhaps a decrease in the population. Every time, instead, that the usefulness of labor surpasses this number, there will be an increase in well-being and probably an increase in the population.

The considerations that we have set forth lead us to the following conclusions:

1. The total quantity of energy which the earth's surface receives from its interior and from the sun tends to diminish. The amount of energy accumulated on the earth's surface tends to increase.
2. This increase of accumulated energy (beyond the limited quantity produced by the increase of non-cultivated vegetation) has as its only cause the muscular work of man and of certain animals. Every expenditure of mechanical

work by humans and by any other organized beings, which is accompanied by an increase in the overall quantity of energy that exists on the earth, should be qualified with the name of useful work.

3. The economic coefficient of humans tends to diminish as their needs increase.
4. The usefulness of muscular work tends instead to increase, because, at the present time, a certain expenditure of muscular labor makes the accumulation of energy on the earth increase more than it did during the primitive era of civilization.
5. As long as humans have on average a quantity of free chemical affinity and of mechanical work at their disposal, in the form of nutritive substances, of mechanical power of the animals and of mechanical motors, which together surpass the mechanical force characteristic of humans so many times as the denominator of his economic coefficient exceeds the numerator, — the existence of humans is materially assured, because in this case the entire human race presents an example of a perfect thermal machine, according to the conception of Sadi Carnot.
6. The principal goal of work should be, consequently, the absolute increase of the quantity of solar energy accumulated on the earth, not simply the transformation into work of a greater quantity of solar and other forms of energy already accumulated on the earth. Yet in the latter kind of transformation, the increased amount of energy — for example, the work done by means of the burning of coal — is accompanied so much more by inevitable losses through dispersion [of energy] into space, that it reaches a higher percentage of heat and of the other physical force used in the work.[29]

We have reached the second question posed at the beginning of our study: what are the forms of reproduction that are most advantageous for the satisfaction of human needs? We may respond: *those that produce the greatest accumulation of solar energy on the earth*.

Clearly, this is not primitive cultivation. This cultivation, in truth, is not yet cultivation, because it is not based on the accumulation of energy, on useful work, but only on the utilization of forces previously accumulated from the vital processes of nature. Primitive man, nourishing himself with fruit and with roots, hunting wildlife, fishing, only disperses into interstellar space the solar energy accumulated on the surface of the earth.

Neither is it production under slavery. This social form, based on perpetual warfare, excludes a considerable proportion of workers from all participation in the labor which accumulates energy on the earth, i.e., from the work which is really useful for the satisfaction of social needs. Without speaking of the number of workers killed and injured during the continuous wars, we mention only *the standing armies*, *the owners of slaves* and their *multitudes of guards*, as completely unproductive elements of humanity, during the entire era of the reign of slavery.

Feudalism already contains several elements of progress. The serf owns a plot of land that he can cultivate without fearing the eye of the master, without feeling the whip of the overseer.

But how restricted this element of progress is! The small plots of the serf are but parcels in comparison to the fields of the seigneur, which extend as far as the eye can see, and the time allowed for free work is but a brief recreation after the hard days labor done for the lord. It is not necessary then to marvel at the fact that the productivity of labor during serfdom never reached even the average of its present day usefulness.

We now arrive at the capitalist production of today's society. This form of production knew how to utilize the division of labor, and, as this division no longer sufficed, it applied the machines of industry and agriculture on a large scale. It obtained unhoped for results and it takes pride in this. But let us look more closely. All of these results were obtained not from capitalism, but from the *accumulation of the labor of generations of workers in the past*, or of the *present day workers' associations (cooperatives)*. Capitalism, on the contrary, does nothing more than throw, in times of crisis generated by it, thousands of workers onto the street, and it operates this way in a manner analogous to wars, slavery, to epidemics, that is, it disperses a portion of the energy at the disposal of humanity, instead of increasing its accumulation on the earth's surface.

The relation between labor and capital is analogous to that which exists between the human machine and an imperfect machine. An imperfect machine, a steam engine for example, is *absolutely incapable* of transforming work into heat, of producing a *combustible, nutritive substance*, without the intervention of human muscular and intellectual labor. And even the intellectual work of humans does not become productive until it induces a certain amount of muscular work. In the same way, capital, the product of the accumulated labor of ancient times, left to itself, would produce *absolutely nothing*, would not carry out *any new accumulation of energy* on the earth, without the indispensable co-operation of the expenditure of a certain amount of presently existing muscular labor. With the progress of industry this quantity of absolutely indispensable muscular work will probably fall to a minimum difficult to define, but we strongly doubt that this quantity could ever be completely eliminated. This is why we think that *only work, and indeed muscular work, should ultimately serve as the basis for the definition of the value of production and that as a consequence it will enter as the preponderant element in every socialist theory of the correct* (or, which is the same, a *precisely* egalitarian) *distribution of products*. This deduction is a death sentence for all systems of production other than socialism. It remains only for us to demonstrate that socialism is precisely the mode of production capable of carrying out the greatest amount of accumulation of energy on the earth, the mode which, in other words, serves to satisfy most easily and agreeably all the needs of humanity. It is also that which gives us the best chance for the continuous progress that fosters more and more along its way a harmonious and peaceful path.

We can limit ourselves to several examples.

It goes without saying that labor and production in common, through the association of the work forces, are more advantageous, regarding the accumulation of energy, than is individual work. Apart from the fact that the egalitarian association of the workers is the best means to profit in a reasonable manner from all the advantages of the division of labor, avoiding its deadly influence on the health of the workers and on their intellectual development, it is also the only system through which the machines become real organs for social organisms, instead of being, as occurs frequently under capitalism, destructive weapons in the hands of the privileged few that direct them against the proletarian majority. With the current system, every new improvement in the big industries deprives a certain number of workers of work, and as such causes a certain number of workers to die of hunger. Instead of increasing the accumulation of energy on the earth, it accelerates the gratuitous dispersion of the force of the workers excluded from production. Under the socialist system, by contrast, every mechanical or other improvements will have as an immediate consequence a decrease in the number of hours of work of all the workers and it will furnish them with time for new production, or indeed for education, for art, etc.

If the influence of the future socialist order is already very clear in that which concerns production, it is still more decisive in reference to exchange. The entire class of idle and rapacious businessmen will simply be eliminated.

A higher level and a more equal distribution of the quantity and quality of food will inevitably lead to an increase in the muscular and mental power of the immense majority of individuals comprising the human race. Hence, a new growth in production, a new accumulation of solar energy on the surface of the earth.

A precise and conscientious system of accounting, in which the figures are neither hidden nor distorted, will certainly have a considerable role to play in a more egalitarian, which is to say more just, distribution of the efforts of production and of the enjoyment accompanying the satisfaction of our needs.

Rational public health, and the possibility for everyone to adapt their private hygiene to the demands of science, will quickly raise the life-expectancy and, in parallel fashion, the productivity of the human organism to a level that is currently found only in exceptional cases.

We can no longer deprive ourselves of the advantages in the accumulation of energy which the socialist system offers to us, for the sake of the security of all existing persons, also for the sake of the assistance that could be offered to the elderly, the sick, and the infirm. But we must also indicate the immense advantage that socialist education will offer, insofar as muscular labor, and the habit of undertaking it without great toil, will be taught to all, no one excepted. In our opinion, such a pursuit of integrated instruction will tend not only to raise the productivity of the social organism, but will serve above all to prevent any foolish ambition on the part of a selfish minority for the reestablishment of the oligarchical order under which we now live.

Such are, in the form of a brief and very general outline, the relations that exist between the theory of the accumulation of energy and the different forms of production. We hope to be able to revisit this issue soon in a more extensive and better illustrated work.

—*S. Podolinsky*
May 1881

NOTES

1. This article was originally published in *La Plebe* in 1881 (Vol. XIV). The first installment appeared in issue number 3, on pages 13 to 16. The second installment appeared in issue number 4, on pages 5 to 15. Editorial notes were compiled by Paul Burkett (Indiana State University) and John Bellamy Foster (University of Oregon) [Editorial note].

2. Clausius, *Théorie mécanique de la chaleur*, t. I, p. 411, Paris, 1863 [Footnote in original]. R. Clausius, *The Mechanical Theory of Heat*, translated by Walter R. Browne. London: Macmillan, 1879, pp. 106-107, 195-197 [Editorial note].

3. This paragraph does not appear in the French version of Podolinky's article: "Le Socialisme et l'Unité de Forces Physiques," *La Revue Socialiste*, No. 8, June 20, 1880, pp. 353-365 [Editorial note].

4. Secchi, *Le Soleil*, II, p. 258. Parigi, 1875 [Footnote in original]. Angelo Secchi, *Le Soleil*, Second Edition. Paris: Gauthier-Villars, 1875-77 (two volumes) [Editorial note].

5. H. Sainte-Claire Deville, *Leçons sur la Dissociation*, Paris, 1862 [Footnote in original]. Henri Sainte-Claire Deville, *Leçons sur la Dissociation: Professées Devant la Société Chimique le 18 Mars et le 1 er Avril 1864*. Paris: Lahure, 1864 [Editorial Note].

6. This sentence and Note 5 do not appear in the French version [Editorial note].

7. Popalazione chilometrica dell'Italia, 94; della regione dell Etna, 550 (Elisée Reclus, *Nouvelle Géographie Universelle*, I, 538, Paris, 1875) [Footnote in original]. *Elisée Reclus, Nouvelle Géographie Universelle: La Terre et les Hommes* (19 volumes). Paris: Hachette, 1876-1894; Elisée Reclus, *The Earth and Its Inhabitants* (19 Volumes), edited by E.G. Ravenstein and A.H. Keane. New York: D. Appleton & Co., 1882-95, Volume I, p. 315 [Editorial note].

8. Sterry Hunt, *Congresso della Società Britannica*, 1878 [Footnote in original]. See Thomas Sterry Hunt, *Chemical and Geological Essays*, Third Edition. New York: Scientific Publishing Company, 1891, pp. ix-xi, 40-47 [Editorial Note].

9. Kirchhoff's Law can be expressed as: The quantity of radiated heat is directly related to the difference between the temperature of the heat-source and the environment that surrounds it [Footnote in original]. Gustav Kirchhoff, *Researches on the Solar Spectrum, and the Spectra of the Chemical Elements*, Part 1, translated by Henry E. Roscoe. Cambridge and London: Macmillan, 1862-63, p. 17; Gustav Kirchhoff, "On the Relation Between the Emissive and the Absorptive Power of Bodies for Heat and Light," in *The Laws of Radiation and Absorption: Memoirs by Prévost, Stewart, Kirchhoff, and Kirchhoff and Bunsen*, translated and edited by D.B. Brace. New York: American Book Company, 1901, pp. 75-76 [Editorial note].

10. Secchi, *Le Soleil*, t. II, p. 300 [Footnote in original].

11. This paragraph and Notes 9 and 10 do not appear in the French version [Editorial note].

12. This paragraph does not appear in the French version [Editorial note].

13. The *calorie* is a unit of measure of heat which represents the quantity of heat necessary to raise the temperature of a kilogram of water by one degree [Footnote in original].

14. In the French version (p. 357), a short paragraph follows which does not appear in the Italian. It is restored in the present text [Editorial note].

15. Veggasi Ch. Laboulaye, *Dictionnaire des arts et de l'agricolture*, 4.[a] edizione, articoli: "Agricolture" e "Carbonification"; *Statistique de la France*, 1874, 1875, 1878; Pelouze et Frémy, *Traitè de Chimie*; Hermann, *Grundzüge der Physiologie*, 5.[a] ed. 1877 [Footnote in original]. Charles Laboulaye, *Dictionnaire des Arts et de l'Agricolture*, Fourth Edition. Paris: Librairie du Dictionnaire des Arts et Manufactures, 1874; Théophile Jules Pelouze and Edmond Fremy, *Traité de Chimie Générale*, Third Edition. Paris: V. Masson, 1865-66; Ludimar Hermann, *Grundriss der Physiologie des Menschen*, Fifth Edition. Berlin: Hirschwald, 1874; Ludimar Hermann, *Elements of Human Physiology*, Fifth Edition, translated and edited by Arthur Gamgee, M.D. London: Smith, Elder, & Co., 1875 [Editorial note].

16. This paragraph does not appear in the French version [Editorial note].

17. Compare Marey, *Du mouvement dans les fonctions de la vie*, pagina 205, Paris, 1868 [Footnote in original]. *Etienne-Jules Marey, Du mouvement dans les fonctions de la vie*. Paris: G. Baillière, 1868 [Editorial note].

18. The preceding four paragraphs do not appear in the French version [Editorial note].

19. Smith, *Ricerche sulla natura e sulle cause della riccessa delle nazioni*, Collezione dei principali economisti, V. 1 [Footnote in original]. Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Book I. New York: Modern Library, 1937 [Editorial note].

20. Verdet, *Théorie mécanique de la chaleur*, II, pag. 216 [Footnote in original]. Oeuvres de Émile Verdet, Volumes VII-VIII. Paris: Imprimerie Impériale, 1868-72 [Editorial note].

21. Gustave Heuzé, *La France agricole*, atlante N. 18, 1875; e *Annuaire du Bureau* [Footnote in original]. Possibly referring to the following: Gustave Heuzé, *Les Jardins de*

Versailles et l'École d'Horticulture. Paris: Société Centrale d'Agriculture de France, 1875 [Editorial note].

22. Maurice Block, *Statistique de la Francé*, t. II, pag. 389 [Footnote in original]. Maurice Block, *Statistique de la Francé*, Second Edition. Paris: Guillaumin et cie, 1875 [Editorial note].

23. This sentence and the immediately following figures do not appear in the French version [Editorial note].

24. Gustave Heuzé, loc. cit., pag. 27 [Footnote in original].

25. Elis Sidenbladh, *Royaume de Suède — Exposé statistique* 1878, pag. 40 [Footnote in original]. Elis Sidenbladh, *Royaume de Suède; Exposition Universelle de 1878 à Paris*. Stockhom: 1878; Elis Sidenbladh, *La Suede: Expose Statistique*. Paris: K. Nilsson, 1876 [Editorial note].

26. Louis-Lande, *Basques et Navarrais*, pag. 205, Paris, 1878 [Footnote in original]. Lucien Louis-Lande, *Basques et Navarrais*. Paris: Disier et cie, 1878 [Editorial note].

27. The preceding four paragraphs and Notes 25 and 26 do not appear in the French version [Editorial note].

28. *Réflexions sur la puissance motrice du feu*, pag. 20, Paris, 1824 [Footnote in original]. Sadi Carnot, *Réflexions sur la Puissance Motrice du Feu et sur les Machines Propres a Développer cette Puissance*. Paris: Chez Bachelier, 1824. *Reflections on the Motive Power of Fire By Sadi Carnot*, translated and edited by E. Mendoza. Gloucester, Mass.: P. Smith, 1977, pp. 11-13 [Editorial note].

29. This entire set of six conclusions does not appear in the French version [Editorial note].

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