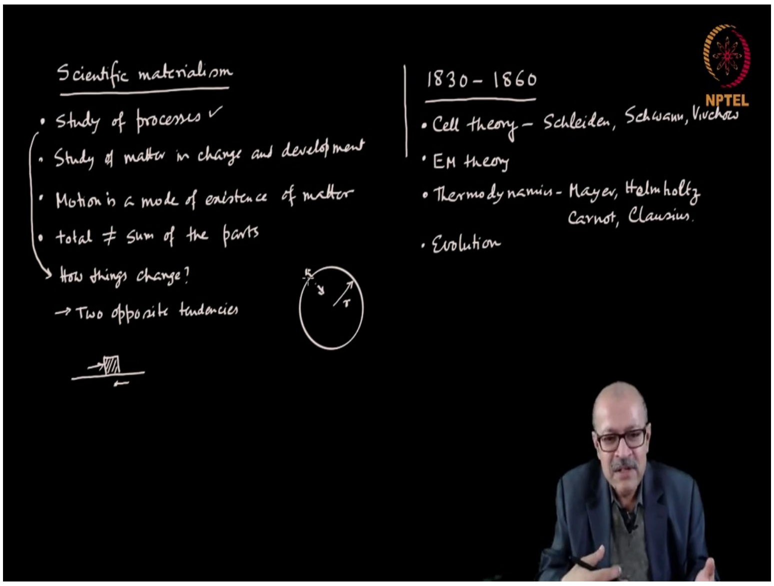
Research Methodology
Prof. Soumitro Banerjee
Department of Physical Sciences
Indian Institute of Science Education and Research, Kolkata

Lecture - 20
Historical Perspective: The Advent of Scientific Materialism Part 02

(Refer Slide Time: 00:17)



When we realized that mechanical materialism, metaphasics, and formal logic are not going to serve the purpose of the science of the 19th century, then a new viewpoint developed which is called scientific materialism. The basic point made by scientific materialism was that, everything is in a flux; everything is going through changes.

And if everything is continuously going through changes, it would not be *things* that we should study, rather *processes* that lead to the changes that should study. The focus changed from study of things to the study of processes. So, the main point was the study of processes.

What kind of processes? Everything is going through change; everything is going through evolution; and things come into being, evolve, and go out of being. Therefore, if everything is so transient, there is no point in studying things. Rather we should focus on studying the process that lead to something coming into being, something evolving and something going out of being.

So, the *processes* came to the centerfold, and you will find that later, in the later half of the 19th century, the developments more or less focused on the study of processes. It was the study of matter in change and development.

We studied matter. Earlier we were studying matter as they are, things as they are. But now we were studying matter in change and development. The focus changed. We realized that cells come into being, evolve, and go out of being. Every individual comes into being and evolves and goes out of being. And if that is so, then that should be true for everything. That means things that we do not yet know about, that they are also changing. People started projecting that idea.

For example, the stars. Stars twinkle just like that, and they have been twinkling since eternity. We have seen that. But still, following this line of argument, people argued that they also must be changing. People started exploring whether or not they really do change, and people found that they do. They do change in position. People tallied the positions of the stars from the ancient chronicles with the presently observed star charts and found that the stars have also moved, though very slowly, but still, they have moved.

And people found that stars also do evolve. By then some evidence had accumulated that stars do explode: things that are called nova or supernova; these things happen. So, we have situations where stars change, stars evolve. Then people came to the realization that it is not only the stars, but stars conglomerate into galaxies and the galaxies also evolve. So, the point is that, the idea came in a general way: things that we earlier studied as ‘things’, now the focus came to the study of their change and evolution.

The things which we earlier thought as fixed, those also came under scrutiny. Are they really fixed? Are they really unchanging? Then people realized that, no, they are also changing. So, the world, in this viewpoint, was no longer seen as a complex of things, but it was viewed as a complex of processes. Not a complex of things, but a complex of processes in which things are coming into being, evolving, and going out of being.

But the world, the universe, is a complex of processes. So, it is the processes that we have to understand. The way of metaphysics was to study things in abstraction, abstracted from its condition of existence. Now the understanding was, no, we have to study everything based on, dependent on, their condition of existence.

If we talk about the iron being hot, iron being hard, then you have to talk about at what temperature it is hard. If we heat it to a high temperature, it no longer remains hard. This is a simple example I gave, but it is applicable to everything. So, the idea was that, whenever you are talking about the property of something, it has to be related to its condition of existence.

Metaphysics studied everything as isolated separate entity, with a fixed property. But scientific materialism started studying things in their interaction with the surrounding things, as a part of a whole. So, it is interaction and inter-connection.

There are connection with things around. The property, character, motion everything, of each entity, is dependent on its interconnection with the rest, and interaction with the rest. So, interconnection and interaction came under very strong scrutiny in the picture of scientific materialism.

Mechanical materialism considered mass as inert mass, to which motion has to be imparted from outside by force. Force is applied from outside, due to which things, their state of motion, changes. Force always was from outside. So, the motive force of any change was from outside. That was the picture of mechanical materialism. But the understanding of thermodynamics and and other topics gave us the idea that energy that we see in various forms—these are nothing but different forms of motion.

Heat is a form of motion of the molecules, sound is another form of motion of the molecules, light is another form of motion. So, all these are effectively motion, matter in motion, and one form of motion can be converted to another form of motion. That is what is the idea of conversion of one form of energy into another.

So, motion can be converted from one form to another. But there can be no matter without motion. Matter always exists in motion in some form or other. And so the idea came, that motion is a mode of existence of matter. Matter always exists in motion. It does not exist like inert mass on which motion has to be imparted from outside.

So, whenever there is motion, we do not have to look for a reason for that, because matter, by itself, cannot exist without motion. So, motion is a mode of existence of matter. This idea also came from scientific materialism.

So, there can be no matter without motion. By then, what is known as Galilean relativity had developed, by which we got the idea of relative motion. We understood that, when we see something as fixed, it is actually not fixed; we are both sitting on the surface of the Earth and the Earth is going around the sun, so on and so forth. Therefore, there is no point saying that the things that are apparently static around us, are really static. So, there is nothing that is really static.

And then the idea came that, the totality of anything is not the same as the sum of the parts. The totality is not the same or totally not the same as the sum of the parts. As I have said, in the cell it is evidently clear.

Similarly, consider a man. If you want to study the character and behavior of a man, you should not really talk about the man being composed of innumerable molecules and atoms and therefore, if I understand each molecule, each atom, and how they are interacting with each other, I will be able to understand the behavior of that man, character of the man, thoughts of that man. No. The whole is quite different from the sum of the parts and therefore, at every emergent level of matter you have to study the processes at that level. That was another assertion of scientific materialism.

The most important point was that, it was focusing on the study of processes. How do things change? Now, when we talk about how things change, let me illustrate this point here. How do things change? The general idea was obtained by studying various different specific processes of change. Then, by the idea of induction, people came to a general idea that, in everything, whatever you are studying, whatever process you are studying, in that process there are always two opposite tendencies.

So, in order to study the process you have to identify and study the opposite tendencies. Let me give you a couple of simple examples. For example, suppose there is a plane on which a body is resting, and you give a push. It will not initially move, and if you explore why is it not moving, then you will realize that there is a frictional force acting in the opposite direction.

So, what is the process going on? Its a body in which there are two opposite tendencies, presently balancing each other. If they are balancing each other, then you have to write an equation equating this equal to that. That is the methodology. Right?

And if you keep on pushing with a larger force, at some point of time the static friction will be overcome and it will move. When it moves, you can still write an equation equating two opposing tendencies: one, its inertia tries to keep it where it was, and two, the force, the resultant force, this minus this, tries to move it. And therefore, when it is moving, there are still two opposing tendencies, and again you have to equate these two opposing tendencies. You have to write the equation: force is equal to mass times acceleration.

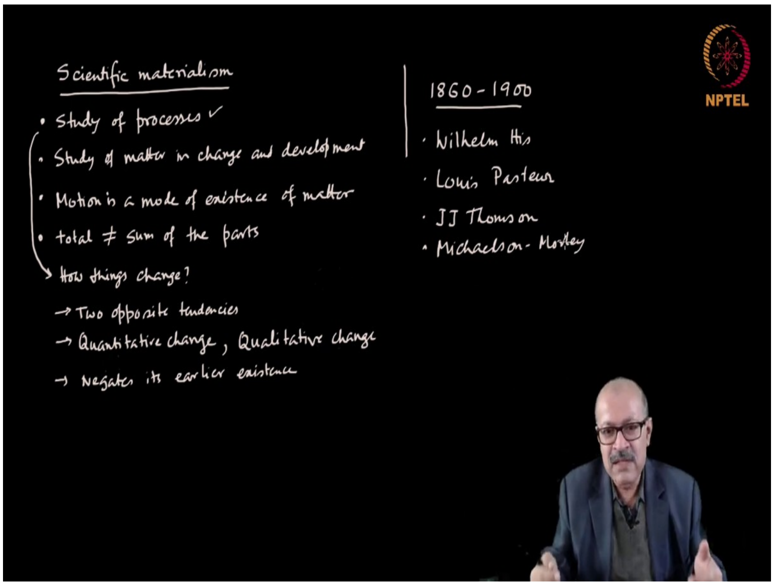
Let me give a somewhat modern-day example. Suppose there is the sun or a star like the sun. The star like the sun has a certain radius. Right? What determines the radius and what determines the stability of the star?

You notice that every particle in the star feels two opposing forces. One is the gravitational force that that pulls it towards the center. At the center there is a thermo-nuclear reaction going on, and that fusion reaction will produce a lot of heat, and that heat will expand the star. So, there will also be a force that acts in the opposite direction. And the star actually remains in balance of these opposite forces.

And so, if you want to find out why the star is in a stable situation, you have to understand and equate these opposite forces. When this balance is broken, for example, something that happens when the hydrogen stock in the interior of the star depletes, and the hydrogen reaction producing helium can no longer continue. Then this force dominates over the other, and the star collapses.

So, all that understanding has to be developed by actually looking for the two opposite tendencies and studying them elaborately.

(Refer Slide Time: 15:43)



Now if you look at the evolution of anything, then it was found that things do not proceed in a linear fashion. There are two types of changes that can happen in anything. One is called quantitative change. Quantitative change means, for example, if you are heating a glass of water, its temperature increases: the temperature is the quantity which changes. So, it is just a quantitative change. But there are also qualitative changes when 100 degrees centigrade is reached, then the water turns into a gaseous state.

So, it changes its quality, qualitative character. Both kinds of changes are there. For example, in biological evolution you find that, for a long time a species changes very slowly. But at some point of time there is a sudden, relatively faster, change that completely changes the species. One species changes into another: an event called speciation. An emergence of a new species out of an earlier species: that is a qualitative change.

Similarly, any change from a state of energy to another is a qualitative change of one form of motion into another form. Therefore, that is a qualitative change. So, on and so forth. A cell is born: it is a qualitative change. A seed germinating into a plant is a qualitative change.

So, there are both kinds of changes and whenever you want to study any quantitative change you have to look for the opposite tendencies and when it goes into a qualitative change, that is also the result of the opposite tendencies.

But when it becomes another entity through a qualitative change, then it negates its earlier existence. So, qualitative change means, it negates its earlier existence. That is a result of a qualitative change. That means, whenever a seed germinates into a plant, it is no longer a seed. When a star becomes, say, a neutron star, it is no longer a main sequence star.

So, whenever there is a qualitative change, it negates its earlier existence. It becomes something new, and when that happens, you have to find the new opposing tendencies that will determine its course of development.

Further development of science actually happened over the next 50 years or so, following these prescriptions. As we will see, quite a lot of developments happened in the later part of the 19th century following these prescriptions of scientific materialism.

So, in the period between 1860 and say 1900, around this period, a lot of developments happened. For example, earlier there was a belief that whenever a embryo develops, that development goes through the earlier phases of evolution. For example, at some stage people said animals were in the sea, then it became amphibian, etc. An embryo goes through all these stages. That was an idea that was there.

Wilhelm His, a German scientist, actually studied the process of development of embryos. By studying various stages, he showed that the idea was wrong and hence the subject of embriology was born.

Earlier there was an idea that whenever there is an infectious disease, that happens because of something called ‘miasma’. Miasma means some kind of ‘bad air’ that emanates from rotting matter. People believed that epidemic or pandemic happens because of that.

Louis Pasteur showed that, that is not quite true. He proposed the Germ theory. That means, there are microorganisms that can be born only from microorganisms through infection through the microorganisms, and he showed that the microorganisms, the germs, are responsible for most of these diseases. Thus the Germ theory of diseases was born.

In the area of physics interesting developments happened. For example, people discovered what is known as the cathode ray. In an evacuated tube in which there are positive and negative terminals, and people saw that there is a discharge between the two electrodes and that was cathode ray. And studying the cathode ray, J J Thomson showed that it is actually a flow of particles and the particles have negative charge.

And he could measure the e/m ratio: the charge to mass ratio of these particles. And he proposed that these are new particles. It came to be known as the electron. Around 1897 he made the announcement. Photoelectric effect was also discovered sometime back. It was probably Heinrich Hertz who first observed that, but other people then explored it further, but it was unexplained at that time.

There was a belief that the electromagnetic waves, which was proposed by Maxwell, travel through a medium called ether. It was a belief that ether is there. The idea of ether, the substance of the sky, came from Aristotle again, but the belief was very influential. Michaelson and Morley did an experiment: you know about that so, I am not explaining. They did an experiment by which they showed that ether does not exist. So, electromagnetic waves actually travel through the vacuum.

Becquerel discovered what today is known as radioactivity and Madame Curie later would develop that further.

So, all these developments were happening in the field of various areas of science. In the areas of technology, in this period the internal combustion engine was developed by Daimler. Nicholas Tesla and Edison developed modern electrical engineering. Edison was working with DC electricity while Tesla experimented with AC and ultimately discovered the transformer, induction motor and things like that, through which everything became alternating current based power supply system.

And in this period, as I said, internal combustion engine was developed. Cars were coming into the market. So, a lot of developments were happening. But as we shall see in the next class, there was also something that was blocking the development of science. I will come to that in the next class.