Three explanations for the physics of materials

Three influential fifth Century figures in particular set the scene for Aristotle's discussion of physics, as, in different ways, they attempt to provide an explanation of change in the material universe. They are also key figures in the background of the intellectual ferment in Athens, as it rose to economic and military hegemony in the second half of the fifth century. It was their ideas and alternative explanations of reality that were promoted and discussed by the travelling rhetoric teachers (the Sophists), and provided an early example of the cultural clash between traditional faith and physical explanation of the world.

Anecdotes

Anaxagoras came to Athens and was a friend of Pericles, the most powerful figure in the democratic assembly in his day. However, he had to go into exile on the charge of impiety – though the likelihood is that the blasphemy charge had more to do with Pericles' political enemies than any genuine offence against the gods. He ended his days in Clazomenae, and (according to legend) asked for there to be a public holiday for schoolchildren on the anniversary of his death.

Democritus came from Abdera, originally a Phoenician town on the North Greek coast. Dionysius' somewhat legend-like account, has him educated by Persian mages and Chaldaean astronomers. There is also an attempt to associate him with Pythagorean thought, which is not stupid, given the importance of the unit as a basic building block of everything. Though some of his ideas are mocked in Aristophanes' play *The Clouds,* but, again according to Dionysius, one of his major works was very well received by his own townsmen, and won him a large sum of money and (eventually) a public funeral. According to some sources, Plato regarded him as a dangerous rival thinker and wanted to destroy all his books.

Empedocles came from Acragas (Agrigentum), a Greek colony in Sicily. He had a reputation for being a fierce democrat, denouncing potential tyrants – though also for having a very high opinion of himself. According to Dionysius, he had some successes in engineering and medicine that made a big impression on his contemporaries. He apparently liked to dress impressively and according to one set of

anecdotes, declared that he had been made a god – something which he then attempted to prove by climbing inside the crater of Etna. In spite of that his cause of death appears to have been an infection from a broken limb acquired when he was 77.

Explaining change and the origin of things in the material world

For Anaxagoras, the explanation rests on the idea that matter is infinitely divisible, and all the different forms that matter can take are present in some degree in every quantity of material. For Democritus, matter has a smallest indivisible unit. The combination of these indivisible units, or atoms, in different formations explains all the different properties of the materials that we see. For Empedocles, there are four fundamental elements which intercommute: earth, air, fire and water. This view would be taken up by Aristotle and dominate physics for the next 2000 years.

There was then the issue of the driver of change. Empedocles speaks of 'love' and 'hate' – perhaps a slightly more poetic variant of the earlier theory of Anaximenes, that it all came down to compression and rarefaction. For Democritus, the atoms, moving in an infinite void were driven by a 'whirl' which brought about the different combinations that made the different things. For Anaxagoras the driver of the combinations of things in the world was 'mind' – something that impressed Socrates and was taken up by Aristotle. Even though Socrates was disappointed at the small print of Anaxagoras' theory. This strand of thought has been central to the theologies (Jewish, Christian, Pagan, Islamic) that coalesced in and around the Hellenic tradition, and gives birth to the 'design argument' central to Stoic, Jewish, Christian, Platonic, and Islamic apologetics.

Anaxagoras (500 – 428: Clazomenae, Athens, Lampsacus)

Anaxagoras says that [homogenous substances] infinite in number separate out of one mixture, that is, all [kinds of thing] are in everything, with each individual entity marked out according to the dominant [homogenous substance]. He makes this point clearly at the beginning of his first book of the Physics:

"All things were together, infinite in number and in minuteness. For smallness was infinite too and when everything was together, nothing [distinctive] was visible because of the smallness. For air and aether controlled everything, both being

infinite, for these are the greatest among the totality of things, both in quantity and size."

(Simplicius VS 21)

Anaxagoras clearly states in the first book of the Physics that coming to be and passing away are a matter of mixing and separation, when he writes as follows: "The Greeks hold an incorrect opinion about coming to be and passing away. For there is no entity that comes to be or passes away, but there is mixture and separation of entities that already exist. So they should properly call coming to be 'being mixed together' and passing away 'separation out'" All of that and his claim "all things were together" and his claim that things are generated due to mixture and separation, indicates his belief that nothing can come into being out of what does not exist. But anything that comes into being, does so out of what exists.

(Simplicius VS 23)

All things find motion, and similar substances come together when they are moved by Mind. And everything under the heavens is ordered by the circular motion; anything dense and moist and dark and cold, and everything that is heavy comes together in the centre, and when these are compacted, earth is formed. The contraries of these, the warm, the bright, the dry and the light, rise up towards the aether.

(Hippolytus, VS 32)

He writes this about mind: "Mind is infinite, self-governing and is mixed with nothing else, but is alone by itself. For if it were not by itself, but mixed with something else, it would have had a share of all the entities if it had been mixed with anything: for in every thing, there is a part of every thing, as I have said earlier. And the things that were mixed in with it would impede it, so that it would not be able to control any entity, in the same way as it can being alone by itself.

"For it is the finest of all entities and the purest, and it has all understanding about everything and has the greatest power; anything that has soul, the greater or the lesser, mind masters them all. And mind controlled the whole of the circular movement, initiating its circular motion. At first it began the motion from the minute, then it circled more and will circle still more.

"And mind knows all the things which are being mixed and separated off and made distinct, what sort of things were going to arise, and what sort of things there were, and all that now is, and the sort of things that shall come into being. All these things mind has ordered, including this circular movement, in which the stars and sun and moon and the air and aether move, separated off. And it is the motion itself that made them separate out. And the dense is separated from the fine and the hot from the cold and the dark from the bright, and from the moist, the dry.

"And there are many parts of many things. Nothing is completely separated or distinguished from anything else apart from mind. For every mind is similar, both the greater and the less. Nothing else is like anything else, but whatever it has the greatest quantity of, this is what each single thing most distinctively is and was".

(Simplicius VS 38)

The earth is flat and broad in shape and remains in mid-air because of its size and because there is no void and because the air is strong enough to bear the earth floating on it. With regard to the watery entities on the earth, the sea arises from the waters within it, and as these turn to vapour, they thus leave salty deposits, and also the rivers that flow into it. The rivers take their origin from the rains, as well as from the waters within the earth. For it is hollow and holds water in its hollows. The Nile floods in summer when the waters flow down into it from the southern snows. The sun and moon and all the stars are fiery rocks, caught up in the circular movement of the aether. Below the stars there are bodies invisible to us which are carried around with the sun and moon. We do not feel the heat of the stars because they are at a great distance from the earth. Also they are not as hot as the sun because they are in a cooler space. The moon is below the sun and closer to us. The sun is bigger than the Peloponnese. The moon does not have its own light but receives it from the sun, the circuit of the stars goes beneath the earth. The moon is eclipsed when it is screened off by the earth and sometimes by things that are below the moon. The sun [is eclipsed] when a new moon screens it off. The sun and moon move to and from their turning points as they are pushed by the air. The moon turns more often, because it cannot resist the cold. Anaxagoras was the first to define eclipses and changes of phase. He said that the moon was of earth and had plains and valleys on it. The Milky Way was a refraction of light from stars that were not lit by the sun. Meteor stars were like sparks springing off, generated by the motion of the heavens. Winds came about as air was rarefied by the sun, and what was heated, withdrew and moved away towards the heavens. Thunder and lightning came about from heat falling on the clouds. Earthquakes took place when the air above struck the air below the earth; for when this was moved the earth that was floating on it was also shaken.

(Hippolytus *Heresies* VS 48)

Extracts taken from Jaap Mansfeld, *Die Vorsokratiker* (VS), (Reklam: Stuttgart, 1987)

Two sorts of fundamental infinite matter (Aristotle Physics 3 203a16 – 203b2)

Those who consider the elements to be infinite, like Anaxagoras and Democritus (for the former, homogeneous elemental parts, for the latter shapes that are the seeds of everything) claim that the infinite is continuous through contact. For Anaxagoras, any one of the parts is a mixture similar to the whole, because he observes anything coming into being out of anything. For it is from that observation he seems to claim that all things are together at some time, like

this flesh and this bone and so on for anything else; so this goes for everything and thus too at the same time. For there is a principle of separating out not only in each thing, but of all things too. For since that which comes into being comes out of such a body, and everything is generated, though not at the same time, and there has to be some principle for that generation, and this is one – as he calls it 'mind' - and mind thinks and acts from some origin, so it has to be the case that at some point all things are together and at some point begin to be set in motion. Democritus however says that none of the primary substances comes into being out of another; but, as for Anaxagoras, the common sort of body is the origin of all things, differing in its parts in size and shape.

Democritus (Abdera – on the Greek Thracian coast, 460-357?)

Aristotle on Democritus and Leucippus (Metaphysics 985b 4 – 22)

Leucippus and his associate Democritus say that the elementary things are massive bodies and the void [calling the one 'being' and the other 'non-being'] of these the solid mass they call 'that which is' and the void they call 'that which is not'. For that reason they say that 'that which is' exists no more than 'that which is not', because neither does void exist more than body), and these are the causes of things that exist, as matter. And just like those who consider underlying matter to be one thing, who generate everything else by modifications of it, making thinning and compression principles of those modifications, so too Democritus and Leucippus say that the differences [in the atoms] are the causes of everything else. Now they say there are three of these, shape, arrangement and position. For they claim that what is differs in form, contact and orientation. So form means shape, contact means arrangement and orientation means position. A differs from B in shape. AN differs from NA in arrangement and Z differs from N in position. With regard where it comes from or how it comes about in the realities, this question, like all the others they deal with carelessly.

Diogenes Laertius (vol II Loeb, p 453. Translation: Hicks)

His opinions are these. The first principles of the universe are atoms and empty space; everything else is merely thought to exist. The worlds are unlimited; they come into being and perish. Nothing can come into being from that which is not, nor pass away into that which is not. Further the atoms are unlimited in size and number and they are borne along in the whole universe in a vortex, and thereby generate all composite things – fire, water, air, earth; for even these are conglomerations of given atoms. And it is because of their solidity that these atoms are impassive and unalterable. The sun and the moon have been composed of such smooth and spherical masses, and so also

the soul, which is identical with reason. We see by virtue of the impact of images upon our eyes.

All things happen by virtue of necessity, the vortex being the cause of the creation of all things, and this he calls necessity. The end of action is tranquillity, which is not identical with pleasure, as some by a false interpretation have understood, but a state in which the soul continues calm and strong, undisturbed by any fear or superstition or any other emotion. This he calls well being and many other names. The qualities of things exist merely by convention; in nature there is nothing but atoms and void space.

Empedocles (Akragas – Sicily 484-424)

25 (Simplicius DK 31 B 17)

Empedocles relates as follows in his first book of the Physics:

I shall tell you a twofold tale: sometimes a thing grows to be one alone
out of many things, sometimes it dissolves to be many things out of the one.
For mortal things there is a twofold generation and a twofold decline.
For it is the coming together of everything that gives birth to and destroys the one,
the other, after being shattered, is nurtured as they grow apart.
This continuous exchange never ceases,
at one moment everything comes together as one in Love,
at the next once more everything is driven apart by the hostility of strife.
Thus insofar as one entity has learnt to grow out of many entities,
and again, as a single entity dissolves many things begin to flourish,
so entities come into being, and their lifespan is short.
Yet insofar as they never cease this continuous exchange,
in this way they ever exist, changelessly in a cycle.

But come, listen to my story – for learning will increase your understanding.
As I just said, setting out the main lines of my account
I shall tell you a twofold tale: sometimes a thing grows out of many things
to be one alone, and sometimes again, it dissolves to become many things out of one,
fire and water and earth and the boundless air above,
and baneful Strife apart from them, but of equal weight with all
and among them Love equal in length and breadth;
See love with your intellect, don't just sit there dazzled in your eyes.
This is what we believe is the inborn nature of even mortal limbs,
through this they are disposed to friendship and accomplish the acts that bind.
We give this the name of "Delight" and "Aphrodite".
But no mortal man has ever seen her whirling in the midst
of these things.

But just listen to the thrust of my argument – it does not deceive.
All these [ingredients] are equal and alike in origin.
But each as charge of a different office, each has its own character;
each rules in its domain in the course of rolling time.
Nothing then can be added to these things, and none of them can cease.
For if they were to perish, they would no longer exist, and forever.
And what could increase this whole? Where would it come from?
And where would any of these be annihilated, since there is nothing bereft of them?
No, these are all that is, and as they pass through each other
at different times, different things come into being, but at the same time they are continually the same.

55, 56, 58 (Aetius and Clemens) The Universe (DK 31 A 50, B 38, B40)

Empedocles says that the extent of the heavens is greater in breadth than in its height above the earth (it's distance from us). The heavens are more extensive in this way because the universe is laid out like an egg.

Come, I shall speak to you first how the sun dominates over all those
things from which everything before us becomes visible,
the earth, the sea with its many waves and the moist air,
and aether, the Titan which constrains all things within its globe.

According to Empedocles, there are two suns. One is the archetype, and consists of the fire in the other hemisphere of the universe, and which fills the hemisphere, and is always placed opposite its own reflection. The sun as it appears to us is the reflection in the other hemisphere, which is filled with air mixed with heat, arising by reflection (following the curve of the earth) in the crystal heavens, which moves around as the fiery sun [below] moves.

86, 87 (Simplicius (DK 31 B 96) Aetius (DK 31 A 72) Origin of Animals

He says in the first book of the Physics

The joyful earth in the forges of its lovely bosom
gained two parts to eight of bright water
and four of fire; these became white bones
marvellously constructed by the bonds of Harmony.

According to Empedocles, the first origins of plants and animals was not at all as wholes, but with individually growing parts separately. The second generation, where the parts had grown together were like images. The third were generated from the ones that had come together. The fourth were no longer generated directly from the elements but through each other. In the case of plants as their food became more available (so too for animals) and in the case of animals, as the attractiveness of females created the urge for the movement of seed.