Lecture 7. Atomic theory and biology

(Notes on an informal talk to a group in the Medical School)

Analogy between organisms and atoms

The individuality problem is common to the organism and the atom.

- The stability of the individual is one of the most fundamental problems in biology. In the atom you have the same quality, stability; but also the property that this stability can be disturbed, e.g. by a light stimulus. The stability is only relatively disturbed by a not too great stimulus, but it can be killed with too great a stimulus. The fundamental idea of atomic theory is that there are a number of possible states that the atom can take, i.e. there is a discreteness of orbits close to the nucleus, but further from the nucleus the discreteness becomes diminished and disappears. The problem of [atomic] individuality is the problem of stability. Similarly, it is likely that the problem of an organism's individuality is the problem of the stability of the organism.
- Probability is very closely connected with the stability problem of the fundamental atom. Experimenting on individual atoms is sometimes possible, but in a large number of experiments on populations of atoms one is just investigating total behaviour. One is also forced in biology into the statistical method because, although one may be able to produce controlled extra-organismal conditions, one can't be sure of intra-organismal conditions, and so the statistical approach is essential for biological investigation. The intra-organismal conditions are dependent on the adaptation of the organism, and hence on its life history.

Counter-arguments

- The atomic analogy is progressively lost as you ascend the molecular scale. The simple molecule is like an atom. The larger the molecule the less it is like an atom. The statistical character of the atom is lost if you come to heavy molecules, i.e. the atomic statistical character disappears with molecules having hundreds of atoms, and this is still more so with the simplest virus, i.e. the analogy is superficial and cannot be carried through rigorously.
- The various stable states of the atom – eigen-states – may exist in the organism analogously, but it is extremely unlikely that they are closely related to atomic states. Thus the discrete character of the organism may have something to do with stable states, but it is unlikely that it is in any way connected with the stable states of atoms.
- As you move further out from the nucleus of the atom, you have a merging of the discrete characteristic orbits into the outer continuous state, i.e. at is gets larger it merges into classical physics. There is apparently nothing analogous to this with the organism.

In accordance with the laws of atomic physics one can never get a series of elementary particles in identical states, i.e. with the same spatio-temporal coordinates. The nearest one can get to a pure state is illustrated by a monochromatic light beam of infinite width. Here there is a statistical distribution of photons. You cannot get a monochromatic parallel beam through a hole because of diffraction.

There may be a real parallelism here with populations of biological individuals, for example with a series of individuals not sexually reproduced, where you could have a pure type. We have no idea whether processes in which biologists are interested are essentially of atomic dimensions. Are they instead of molecular character only?

Effect of X-rays and γ-rays on living tissue

- 'Hit theory': How do γ-rays work on living cells? Is there a valid comparison of the inside of an atom to the inside of some atoms of the living cell? Does the hit inside the atom of a cell lead to a change in the whole cell? This is the 'hit theory', that is, it resembles the Bohr concept [of complementarity, see below].
- Another theory is that all rays are ionising rays (electromagnetic waves), and hence they produce electrical and therefore chemical changes.

  There is no decision between these two theories.

An alternative possibility is quasi-hits; for example, there are susceptible spots where ionisation happens to be of great consequence, e.g. in chromosomes, but it looks like hits, for a high degree of localisation is essential for action.

It would be possible by investigating the statistical character of effects to distinguish between these hypotheses, because one should find a different character in the statistics. One would give a simple statistical relationship (ionisation), the other two superimposed statistical processes. It is likely that both happen. There is no doubt that ionisation happens particularly with mutation, but is seems also that hits happen.

Bohr has interesting ideas on the subject of atomic theory and biology. He operates with the principle of complementarity. There is also the principle of correspondence. The complementarity principle is that you can't have your cake and eat it. Complementarity means for Bohr not only an analogy with complementary angles, but also an exclusiveness. You can get one answer or another, but not both. The reason is that the questions are determined from macro-experience. In the micro-world we are asking too much; just as for example, in the optical plane of a microscope you see only a narrow optical layer, not the great depth of your macro-field of vision.

The Heisenberg principle of indeterminacy is one example of the principle of complementarity. Bohr even says that we get the application of this principle of indeterminacy of the macro-world, but he would agree that peculiar problems are created there. He even applies it also to linguistic problems; for example, it is impossible at the same time to use a word and discuss its meaning, but logic has an alternative explanation. Similarly, the principle of complementarity holds for power and knowledge.

In biology, Bohr is worried by the relationship of the vitalism-versus-mechanism controversy to the free will problem. He sees free will as a relationship between them, and thinks it may be an example of the complementarity principle.

Bohr is not a vitalist methodologically, for he is not interested in the problem of what is just physics and chemistry and what is not. He says that there is something unique about life and something unsatisfactory in considering organisms as just physical and chemical machines. It is possible that this unsatisfactory character will never be removed, as something always escapes us.

If we would like to give a complete description of a machine (how it works) we would have to break it up and put it together again. This would kill an organism, and hence complete knowledge of it is impossible; hence a part escapes us, and hence we can only describe an organism as a machine. I find this idea interesting, but would criticise it in the following respects.

- There is not good evidence that one must kill an organism to find out how it works, e.g. this is not so with investigation with X-rays, or with our electrical investigations, etc. Thus it may not be necessary to kill in order fully to investigate, i.e. the organisms may be so robust that they will stand full investigation.
- I question whether disturbance of an organism on the one hand and of an atom on the other is of the same significance. There may be a disturbance of a cell on quite a crude level.
- If Bohr is right, is it impossible to produce life artificially in a test-tube? The question of production of life is independent of vitalism and mechanism. The origin problem is independent of the functional problem, i.e. we may do things that appear to us miraculous. For example, Beethoven writes a symphony, but he can't explain how it acts on one, i.e. the musical appreciation.

How would this individuality problem appear if Bohr is right? We should be unable to formulate a set of laws of how an organism functions. What if we now have a set of procedures? Whenever A exists, we find B (where B is an actual living organism). In other words, if we can really produce a living organism systematically, would vitalism be defeated? If Bohr's point of view is right, we would have a statistical population distribution curve, with perhaps always a time variable.

Bohr's views on indeterminacy and free will were developed by Pascal Jordan, his pupil – the Bohr amplifier theory of indeterminism. Bohr said that, according to the principle of complementarity you can't will and observe at the same time, but free will would imply that you actually could.

Jordan says that, if complementarity is involved, it must be due to some atomic indeterminacy, i.e. the will is indeterminate in the same way as the atom is indeterminate. In fact, it may have the same basis as atomic indeterminacy with the 'hit theory' – the electron jumping to new orbits. In other words, he thinks that big changes could be produced if only you have amplifiers, hence the name, the amplifier theory.

Personally, I consider that this is an outrageous theory : partly on account of the great size of a body relative to atomic magnitudes, but also because free will is too vague, and too diverse for amplifier theory, which would give a statistical population distribution curve for behaviour.[1]

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[1] *Editor's note: In 1977, in the first Darwin Lecture, Natural Selection and the Emergence of Mind (http://www.informationphilosopher.com/solutions/philosophers/popper/), Popper said:*

> *The selection of a kind of behaviour out of a randomly offered repertoire may be an act of indeterminism; and in discussing indeterminism I have often regretfully pointed out that quantum indeterminacy does not seem to help us; for the amplification of something like, say, radioactive disintegration processes would not lead to human action or even animal action, but only to random movements.*
>
> *This is now the leading two-stage model of free will.*
>
> *I have changed my mind on this issue. A choice process may be a selection process, and the selection may be from some repertoire of random events, without being random in its turn. This seems to me to offer a promising solution to one of our most vexing problems ... .*