



# A Hierarchy of Consciousness from Atom to Cosmos

*Marilyn Monk*

Before I begin let me confess that the study of consciousness is not my field. I am a molecular biologist. In over 60 years of my research of life at the subcellular and cellular level, I have been concerned with DNA replication and repair, cell signalling, epigenetics and regulation of gene expression in development, Lamarckian inheritance, regenerative medicine, early diagnosis of genetic disease and embryo/cancer genes. So why now consciousness?

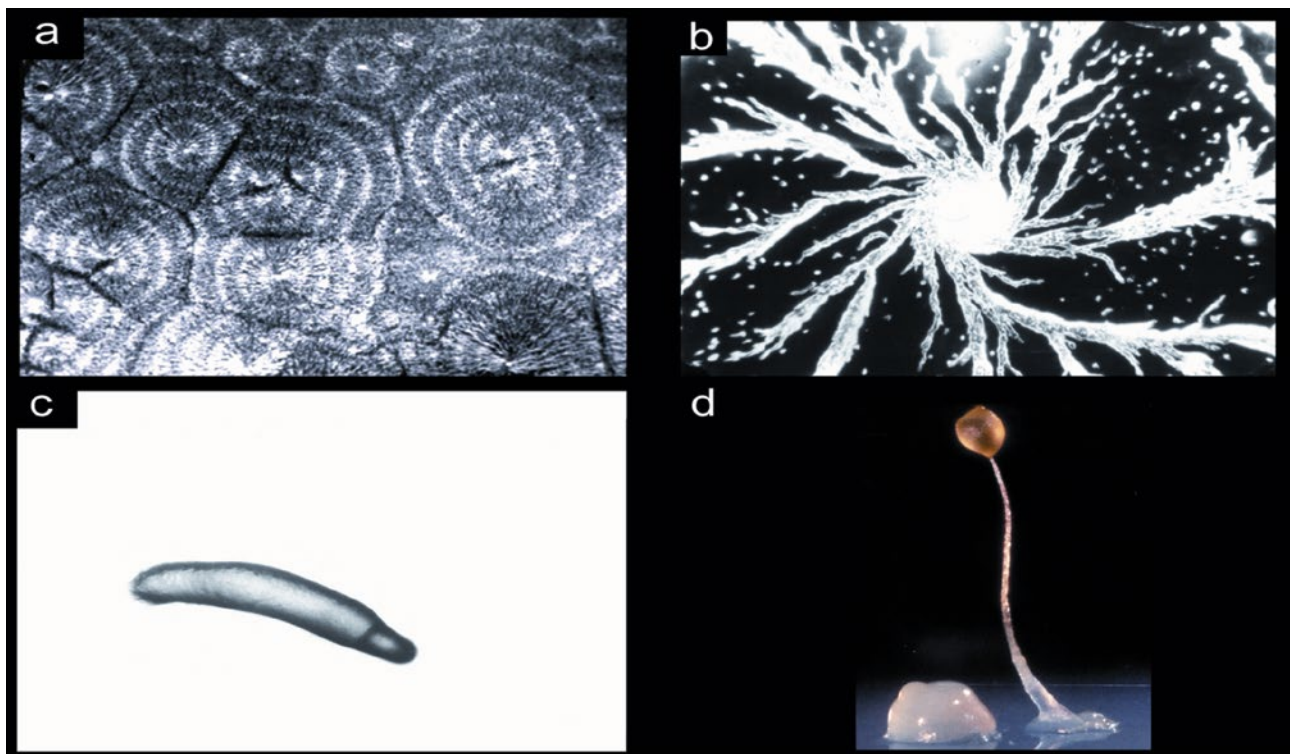
Over the last year I have found presentations of consciousness studies very confusing. Is consciousness in the brain (as Francis Crick expounded), or not just in the brain but pervading all existence (as in panpsychism)? Does consciousness use material mechanisms in its operation or is it non-material? Is consciousness a human phenomenon or is all life, and perhaps non-life too, conscious? So, first of all, I asked myself where is consciousness for me? Experimentally, I know in everyday activities I have consciousness. But then, in times of meditative experiences of wonder and beauty, when I am aware of being aware, I feel strongly that consciousness has me. As one who has always happily embraced paradox I think both are true. But

is the mechanism of consciousness in either sense material? I decided to start with the definition of consciousness from the Oxford Living Dictionary, which is “*The state of being aware of and responsive to one’s surroundings*’.

People who talk about consciousness studies are mainly concerned with human consciousness and may use definitions that are human centred - indeed, the Cambridge Dictionary definition of consciousness is “*The state of understanding and realizing something*”. Certainly that has been the main focus since Descartes who confined consciousness and mind to humans, but more recently there has been much debate about consciousness in animals - even in plants - and I have observed in my research, and in my love for all creatures on this earth, that all life is aware and responsive to surroundings. The term ‘aware’ is certainly more of a human concept and may be taken to include a huge range of consequences of awareness - sensations, feelings, self reflection, memory and imagination and so on. But, as a biologist, when I consider the simple definition - aware of and responsive to surroundings - I see that consciousness extends outside of the human realm, though in

lower life forms, or even non-life forms, we see awareness more simply as detecting and sensing surrounding environment.

Consistent with my usual approach to scientific exploration, I began without investigation of the vast literature on the topic of consciousness. In this way I hoped to avoid being overwhelmed by the myriad of ways of thinking about the topic. During my early studies I was mentored by a wise scientist (Professor Bob Pritchard), and then later by my spiritual teacher (Rajneesh or Osho), to approach my work of exploration with an open mind. Bob said to me don’t read the literature before you begin - you will be indoctrinated and think it has all been done already. Similarly, Rajneesh said to me that there should be no *a priori* hypotheses, no preconceived ideas guiding my research. So I decided to start thinking about consciousness at the level of the atoms, molecules, cells and tissues of my laboratory research and found myself working my way up from the micro- to the macro-cosmos, looking for the mechanisms of consciousness (sensing environment and responding to change) at each level of increasing complexity.



**Figure 1.** Aggregation, movement and fruiting body of *Dictyostelium* after the amoebae detect they have run out of food. a) Amoebae in the field emit a signal of cAMP triggered by starvation and those with the highest periodicity form territories with amoebae relaying the signal outward and making a movement step inward towards the source. b) As they approach the centre, amoebae are attracted to each others' cAMP signal and the streams form spirals. c) The slug, measuring several centimetres, has receptors that detect heat and light, and so can detect, and move the distance, to the soil surface. d) At the surface the slug transforms into a fruiting body. A third of the amoebae in the slug sacrifice their lives to form stalk to bear the spores aloft (Alcantara and Monk, *J gen Microbiol* 81;321-334, 1974).

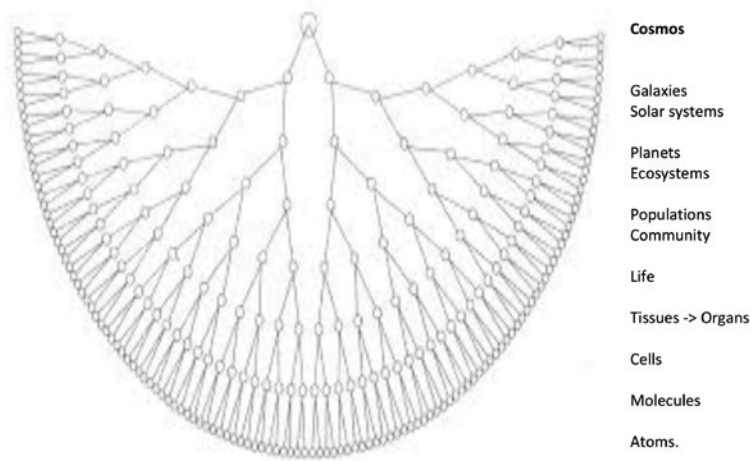
My starting rules for this analysis were views I had already - specifically, that everything is interconnected and everything is in service to its own higher order structure. These principles came from influences in Edinburgh University in the early 70s; Henry Kacser taught the concept of interconnectedness as metabolic flux in the metabolome - the intricate interconnected biochemical pathways within a cell - and Conrad Waddington taught the concept of service as epigenetic programming of different cells in the body to serve their higher order structure - the tissues and the organs. My scientific approach was to look for material mechanisms of consciousness at each level. And, indeed, I found that material mechanisms were known at all levels, with a few exceptions

that might require a greater knowledge of quantum theory and entanglement. Surprisingly, with such a materialist approach throughout, I ended up with a model encompassing a sense of belonging, meaning and purpose throughout evolution.

Just starting with consciousness as a state of being aware (or sensitive) and responsive to surroundings, it is clear to me that my experience that I have consciousness relies on my senses of sight, hearing, touch, smell and taste. I also get messages from my body to my brain if I am hungry or tired or in pain, and messages from my brain to my body for different emotions I experience. And indeed messages from within the environment of my self as I am conscious of my mental functions of memory, imagination and the machinations of mind. These are

functions of human brain/body communication and a lot (but not all) is known about material mechanisms involving transmission of signals between body and brain via informational molecules binding to special cell receptors. However, it is evident to me that all forms of life have consciousness but at different levels of sophistication and with very different range of consequences of their consciousness. A worm is conscious - it detects and responds to changes in its environment. A bacterium can detect a gradient of sugar involving special receptors on its surface and responds by transferring the information to its means of movement - its flagellae - to swim towards a food source.

As an example of consciousness in a lower life form we can look at an area of my own research in



**Figure 2.** A diagrammatic representation (an ancestry model, published by Gregoire 2014, which I have inverted) of an interconnected hierarchy of increasing complexity. This is a binary model for simplicity - the number of atoms making a molecule, or molecules making a cell, and so on, is greater than two. It also shows a path of increasing complexity going through animal life forms familiar to the author (my own expertise is at the level of molecules and cells and differentiating tissues). Clearly there are many other intermediate life forms between the atom and mammals which are not included here. A similar hierarchy could be created for non-life - e.g., starting with grains of sand - or for flora rather than fauna.

the early 70s, namely, how slime mould amoebae (*Dictyostelium discoideum*) become aware of changes in their environment, and how they respond. Aggregation of the individual free-living amoebae into a multicellular structure is triggered by their awareness that they have run out of food. The individual amoebae detect the change in environment (starvation) and start to emit a signal (pulses of cyclic AMP), which diffuses out into the territory (see Figure 1). The fastest signalling amoebae establish and take control of the territories. Amoebae in a territory, detecting the gradient of cyclic AMP, make movement steps towards the source and emit their own signal to attract amoebae further out to join the aggregation. So the signal is relayed out and bands of amoebae move inwards. They move towards each other as they come closer to the centre to make amazing spirals looking like galaxies. The aggregate formed in the centre of the territory forms a multicellular slug capable of movement over a greater distance

than the individual amoebae could manage. The slug develops phototactic and thermotactic receptors at its tip so that it moves towards the light and heat at the soil surface where it forms a fruiting body. A third of the amoebae in the slug sacrifice their lives to create a stalk which bears the spores aloft so that they will be distributed to better feeding grounds. I worked on the material mechanisms and parameters of aggregation in the early 70s and it was amazing to understand how really clever this organism can be when triggered by the need to move to new pastures. It is a good example of a lower organism sensing and responding to environment at several levels and the material mechanisms are known.

This example demonstrates also how consciousness can operate at the level of whole populations of individuals. What about lower and higher levels of complexity - atoms, molecules, cells and tissues, or ecosystems, solar systems and galaxies? Does it make sense

to say that the mechanisms of consciousness are still material throughout?

In the following model of a hierarchy of consciousness, I propose that mechanisms at all levels of complexity depend on interconnectedness of the parts serving their higher order structure. A model of interconnectedness applied to increasing orders of complexity is shown in Figure 2. This is illustrated as a binary interconnected model for simplicity and to link all parts at all levels of increasing complexity into one unified structure. Analysis of this hierarchy of interconnectedness will show that, at each level, the parts are in service to their higher order structure - the electrons to the atom, the atoms to the molecule, the molecule to the cell, and so on. The parts in service at each level are conscious in that they detect and respond to their environment. In fact, service of parts to their whole is essential for survival of the whole in evolution. The mechanisms are material at all levels as we will now examine - starting with the atom.

Atoms consist of a balanced number of neutrons and positively charged protons in the nucleus and negatively charged electrons in their orbits - e.g., a carbon atom has six electrons and six protons, an oxygen atom has eight protons and eight electrons. When the balance of protons, neutrons and electrons is disturbed, the atom decays. The components or parts of the atom are in service to their higher order structure - the atom.

Next, we have the molecules which consist of several atoms joined together by covalent bonds formed by a sharing of electrons in their outer orbits. The stability of molecules is variable depending on the strength of bonding between the atoms and the possibility, or not, of their bonding with another atom or molecule. One could say that the atoms are in service to the molecule and the mechanisms by which they bond and form the molecule are understood.

Molecules interact in an interconnected way to form cells. There are approximately 3000 biochemical pathways, with their associated enzymes and cofactors, interconnected in every cell. This is called the metabolome. As students in the 60s and 70s we would have a Boehringer chart attached to a door or wall somewhere as a sort of biochemical bible. I developed many single cell enzyme assays to monitor gene transcription changes in early embryonic development from studying my Boehringer chart. Interconnectedness means that a change in any biochemical pathway affects all the pathways in the cell. The interconnected changes in all pathways is called metabolic flux, which can be observed by mass spectrometry. For instance one can distinguish a starvation metabolome, from an addiction metabolome, from a sugar eating metabolome, and so on. Metabolic flux shows the interconnected pathways detecting and responding to a changing environment - our definition of consciousness. The molecules are serving their higher order structure - the cell.

Referring back to Figure 2 we see that the next items in increasing levels of complexity are tissues and organs. In the case of humans, all cells in the body have the same 20,000 genes. The differentiation into over 100 different cell types in the body is directed by signalling from the different environments of the cells in the developing foetus to programme their genes to be on or off, up-regulated or down-regulated. The programming is by epigenetic mechanisms - modifications superimposed on the DNA of the genes to regulate their expression. In computer language the genes are the hardware and the programming is the software. The cells detect information from their environment in the developing foetus and respond by differentiating into cells with the required function (bone, muscle, blood, skin, nerve, and so on). In this sense they are conscious and serving the tissues and organs of the body. Maybe even more incredible is that all mammalian embryos

have 90 per cent of their genes in common yet differential epigenetic programming from the species-specific environments of ovary, testis and uterus, determines the differential development of species. The material mechanisms of service of cells to tissue and organs is the same throughout life so at this level of complexity we could list a bee, a frog, a fish, or a bird, and of course other mammals. I do not specify 'human' here as this might divert the reader to start to think about the huge range of consequences of consciousness that emanate from the human brain and the human mind.

We have been looking so far at two rules - interconnectedness within and between levels of increasing complexity and service of parts to their higher order structure at each level. It is time to observe two further rules. The third rule is that, even though the parts are in service to their higher order structure at each level, the parts do not know what they are serving. However, if they do not serve correctly the higher order structure will not survive. The fourth rule is that the whole is looking after its parts at each level. Perhaps this is more easily seen at our own level in the hierarchy - our organs do not know who or what they are serving but we look after our organs.

Referring back to Figure 2, we see the next level I have included is populations. Populations of different species can form a higher order structure - for example the beehive, or the Portuguese Man O' War jelly fish. Here we have a colony of organisms working together for the sake of the greater whole. One can see this too in simultaneous movement in flocks of birds and shoals of fish - all moving as one. And indeed in humans sharing a common event - like football crowds moving as one in response to events on the pitch. I do not know the mechanisms of communication between individuals in flocks and shoals and football crowds. However, the material mechanisms of service are known in other populations of individuals in service, e.g., in the beehive. The

genes of different worker bees - nurse, farmer, forager, warrior - are epigenetically programmed to differentiate them to perform their specific tasks. If they do not serve their higher order structure, the beehive will die and so will the bees. Anarchic behaviour in worker bees causes destruction of the beehive. Throughout we see that service of parts to their higher order structure through consciousness - aware of their environment and responsive to change via interconnectedness - ensures material survival at every order of complexity. One could argue that consciousness is primary and that matter is derivative from consciousness? Indeed, evolution can be seen as a model of interconnectedness and service ensuring harmonious survival at each level of complexity.

The next level of complexity I have included in my hierarchy is the ecosystem. An ecosystem is an interconnected biological community of interacting organisms and their physical environment. It will have the right pastures for the herbivores, the correct herbivore to predator ratio, it will have rivers (and maybe ocean) and mountains and forests. The parts are in harmonious interconnected service to the whole for survival of the ecosystem. The mechanisms are known. As we know, if the forests are destroyed, if a river is diverted, if the top predator is removed (e.g., the wolves in Yellowstone Park) - these disturbances can unbalance the whole system leading to death and destruction of the ecosystem.

And the case is the same with the next level - our solar system. Although we trust that our planet earth will safely look after us in the future, a glimpse at the past is not so re-assuring as it contains inhospitable ice ages and a meteor that wiped out the dinosaurs. And now our planet is threatened by climate change, and the melting of the ice caps, or possibly a solar flare. Indeed only this year in June, Nature published a report that 'astronomers may have spotted a distant star spitting out a giant flare that packed 100,000 times more energy than any seen from Earth's

sun'. (Argiroffi. Nature Astronomy 3:742-749, August 2019). This is 'the first clear detection of a remote star emitting a kind of eruption known as a coronal mass ejection that were until now only seen from our sun. Such explosions may wreak havoc on surrounding worlds.'

We have reached our galaxy and the cosmos, and we can summarise the preceding arguments in the following key points:

1. A view of a hierarchy of interconnectedness through, and within, levels of increasing complexity from atom to cosmos.
2. At each level the parts are conscious - aware of, or detecting, or sensing, their surrounding environment, and responsive to change - in service to their higher order structure. The material mechanisms of service are established and known.
3. The parts do not know what they are serving.
4. The higher order structures are caring for their parts.

Some important consequences flow from the above model:

- a. Interconnectedness means that reverberation (or flux) can move through whole system top down or bottom up or middle out. For example, a solar flare might disrupt ecosystems, scattering populations to new environments, leading to cellular adaptation and reprogramming of genes. Or the human race could become extinct leading to recovery of ecosystems.
- b. Flux through the system leads to events that do not seem to have a material mechanism because consciousness - awareness and response to change in surroundings - is happening across several levels of complexity. This leads me to wonder whether aspects of the paranormal might be explained in this way - certainly in space (e.g., remote viewing). However, it is not so clear to me how paranormal events happen across

time. Here, connections made between individual aspects in the interconnected system due to flux must be recorded in some way and recoverable later. What could be the mechanism of recording previous events in time and re-membering?

- c. Service of parts to their higher order structure to which they belong is essential for survival at all levels of complexity, and ensures development in evolution. However, it is important to note that this is not an imperative because it is essential that there is turnover - the replacement of the old with the new. Extinction is equal to creation - for all species that exist on earth today an equal number have become extinct. The rule is that death equals birth. One wonders whether birth and death apply to our whole cosmos.
- d. This scheme of things establishes consciousness as the unity of everything, and the belonging to the unity of all things in service to their higher order structures. It suggests that matter is derivative from consciousness. It fits with my experience that I have consciousness at my particular level of the hierarchy and that consciousness has me though my interconnection to everything else. It celebrates *belonging*, and *meaning*, and *purpose*, for everything on planet earth and beyond. My scientific approach is material - an understanding of the material mechanisms throughout and perhaps showing how aspects of the paranormal might be understood. My current scheme based on interconnectedness and service shows that consciousness is all pervasive and its material mechanisms at each level of complexity are known.
- e. There are still many mysteries however. We do not have an understanding of mechanisms of memory through time (e.g., telepathy) And, importantly, we do not know the nature of interconnectedness itself. What is the nature of the

interconnecting lines in Figure 2? Could interconnectedness be non-material? Could interconnectedness be the all-powerful non-existent 'inbetween' of things. Like love. What is the material nature of love between the lover and beloved - where is it? Is this greatest power in existence non-material?

- f. And finally - this whole scheme looks like love itself. Service is love. Unconditional service in humans is an evolutionary selectable in that it activates the pleasure centres of the brain and, beyond that, unconditional love for all beings and every thing works to support the flourishing of all. Anarchy, abandonment, neglect and abuse lead to loss or - in this scheme - extinction.

So now, do we draw a line at the top of this hierarchy? Remembering that parts cannot know who or what is being served at all levels, and that the higher order structures are looking after their parts, we cannot know the next higher order structure beyond cosmos. It is plausible to argue that beyond this entire scheme of all that exists, beyond cosmos, there may be a yet higher power caring for everything.

---

*Professor Marilyn Monk is Emeritus Professor of Molecular Embryology at University College London. She researched life at a subcellular level - at the level of molecules - and at a cellular level. Her work as a laboratory scientist over 60 years has been involved with DNA replication and repair, with the genetics of bacteria and their viruses, with amoeboid cell signalling and aggregation, with single cell molecular biology and preimplantation diagnosis, with deprogramming in development to stem cells and regenerative medicine, with gene transcription and its epigenetic regulation in embryonic development, and with embryofcancer genes towards development of a prophylactic cancer vaccine.*

---