Consciousness and Knowing:
What can be known?

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Introduction

In an earlier essay (Young, 2016), we proposed a new way of thinking about consciousness that postulates that all matter has awareness as an attribute (similar to spin or charge). We further proposed that every physical change of state of matter is a change of awareness or consciousness. We then asked "what states of consciousness/awareness would you expect elementary matter, plants, and animals to experience"? We review that model in the next section.

There seems to be a very significant difference between elementary matter (i.e., elements of the periodic table) and living organisms (plants and animals). In particular, living organisms create "walls" (e.g., cell membranes) that enable them to create complex structures inside the organism, seemingly in violation of the second law of thermodynamics. Most importantly, some of the internal structures appear to represent knowledge about the external world which the organism uses in choosing behaviors.

In this essay, we are going to explore in greater detail the role of the "inner world" from an information processing perspective. Specifically, we will consider the role of aggregated matter in enabling more complex states of consciousness to arise and neuronal architectures in determining what aspects of the universe an organism can experience and know. We will use the three worlds framework proposed by Popper (1979, 1982) as an aid to clarify some of our positions.

A Theory of Consciousness

Elsewhere[2] we have put forward a theory that argues that all matter has an attribute that is awareness. We provide key points from that proposal below.

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[2] Much of the material in this section is from Young, 2016.

At the core of our proposal is the belief that all matter has an attribute that can be called awareness. It is important to state up front that basic matter, by which we mean here elements of the periodic table, does not posses minds nor does it have a sense of self. Further, basic matter is not aware of a world. In essence, we argue that awareness can exist *per se* (in and of itself), without any entity being aware. It is only when you combine, or configure, it (matter-*cum*-awareness) in certain ways does it make sense to talk of an "entity" that is aware.

To understand subjective experience there are four terms that must be clearly comprehended: awareness, consciousness, mind, and aggregated matter. We propose that all matter has an attribute that is awareness; organisms (flora and fauna) take this property and use it to construct consciousness; and animals take it one step further to create a concept of mind and self identity. Further, the complexity of conscious experience depends upon how the matter that comprises the entity is aggregated: More aggregated or complex matter equals more complex subjective experience. We expand on these ideas below.

Starting with basic matter, there is a fundamental state of awareness for each element. Physical changes to the element such as heating or cooling the element, and interactions with other physical forces, such as gravity, can modify this state. Consequently, for each element there is a multi-dimensional continuum it can experience, based upon physical changes in the surrounding environment. Further, when an element combines with another and forms a compound, we believe that the awareness aspects of the elements merge. It is not clear how this happens, but we suspect it has to do with sharing material elements (e.g., electrons). This means that each chemical compound is a unique state of awareness.

It is important to stress that basic or fundamental matter is not alive, does not have feelings or emotions, and does not have sensory or motor systems. It is just matter. To have emotions, or the ability to see, or to move about, or to think, requires additional levels of complexity in the way matter is bound or aggregated together resulting in the presence of neuronal architectures, as are found in plants and animals.

Next we consider the world of plants. There is a significant difference between basic matter and plants: Plants are alive. They use self-production and metabolism to create and maintain complex structures during the time they are alive. Plant structures separate the plant from the rest of the universe. They provide what can be considered a "wall" that separates the inside from the outside (i.e., plants are comprised of cells, and the cells work together in a fashion to create a wall like structure). Within the walled-offed area, plants create structures that seem to violate the law of entropy. Instead of becoming simpler over time, they become more complex over time (as long as they are alive).

From an information perspective, the existence of a wall enables the creation of an inner world embodying intelligence and meaning. The state of matter within the walled-off area (e.g., cell membrane) becomes more complex, and its complexity represents information. This complexity enables the plant to sense and respond (Ferris, 2010) to the environment, and adapt its behavior accordingly. Plants do not think, nor do they have a self that knows what they are doing, but they do sense aspects of the world around them and respond by altering their growth and behavior (e.g., plants orient their leaves towards the light, or adjust leaves to maximize water intake, or absorb extra energy to use when sunlight is unavailable) (E. Volkenburgh, quoted in Ferris, 2010).

Plants are considerably more complex, from a physical perspective, than elementary matter. They use metabolic processes to create many complex configurations of matter to include DNA, proteins, cellular components (cell wall, amyloplast, ribosomes, etc.) and larger structures (leaves, cotyledon, roots, etc.). This complexity of matter, which we refer to as aggregated matter, enables more complicated reaction chains to be set off by transduced information. Consequently, plants can experience significantly more states of consciousness and more complex states of consciousness than elementary matter; i.e., there are more potential configurations of matter in a plant, which means there are more potential states of consciousness that it can experience.

Note that in discussing plants we introduced the term consciousness. Our proposal is that when internal plant matter-*cum*-awareness is organized in a fashion where the structure or configuration of matter represents knowledge about the external world, that the term consciousness becomes the appropriate term to characterize this relationship. Plants possess rudimentary consciousness; they are more complex from an information perspective than elementary matter. They do not have a sense of self, but they do have the ability to sense select aspects of a world around them (e.g., location of sun, water, and nutrients) and to use that information to their advantage.

As plant matter becomes organized into structures such as proteins and ribosomes, and then leaves and roots (on a higher level) we postulate that each structure has awareness, which, in turn, gets merged with other higher level structures with which it is combined so that there is only one consciousness (i.e., subjective experience) per plant.

We believe that potential changes in consciousness percolate up from smaller structures to larger in plants, in a manner that mimics the way a neuronal action potential occurs. Neurons are constantly receiving signals to fire from many sources. However, for an action potential to occur, it has to receive a certain number of signals within a given time period to fire (because the stored potential to fire is constantly decaying). Analogously for plants, a particular change at a lower level might or might not be sufficient to produce a change at the next level. If a change at a lower level produces some type of "behavioral change" at a higher level, then the consciousness has changed at that higher level. What counts as a behavioral change depends on the structures involved. For a protein, it might be a change in configuration (e.g., folding in some fashion). For higher structures it could be the rotation of a leaf, for example. Finally, all lower level changes may not make an impact at a higher level; they might just die out without producing a change in consciousness. We believe that plants experience an integrated consciousness that only changes slowly.

Next we consider the world of animals. Animals, like plants, are living organisms: They use metabolic processes and self-organization to create and maintain a physical structure that separates their internal processes from the environment. Like plants, animals represent internally information about the external world, so they posses consciousness. Where animals are meaningfully different from plants is that animals are mobile. They can change their environments. This creates much greater need for information, and opportunities to use information to enhance fitness. Animal mobility creates a huge opening for the evolution of new classes of information-processing capabilities such as the creation of advanced sensory, perceptual, cognitive, and motor systems, all of which provide information that can potentially be used to enhance fitness.

We contend that the most critical piece of information that came to the fore with the advent of mobile organisms was a sense of *I,* or *I*-ness. We believe that the sense of I-ness developed from the ability of the organism to move about, the need to integrate information from different motor and sensory systems, and the opportunity to learn from experience. For a mobile organism, knowing where your physical boundaries are is a critical piece of information. You would also want to know if you could fit in somewhere, before you tried to enter a place, and it would be very advantageous if you could remember previous attempts to perform some action, or recall information you acquired about an environment from an earlier visit.

Whereas plants primarily process information locally via chemical and electrical changes, animals use both local chemical and electrical changes, and electrical transmission over significant distances within the organism to manipulate information (Ferris, 2010). A second major difference between plants and animals is that animals have a central nervous system, to include large brains in higher animals. Comparing plants to animals, plants can be described as a collection of functions that run when a situation (usually chemical) activates them; and there is minimal, if any, central control. Conversely, animals have a nervous system that is similar to a modern computer. It is fast, has several types of memory, and integrates data from across the enterprise.

With their complex nervous systems and their higher metabolic rates, animals consist of more complex, or aggregated matter than plants (i.e., more complex proteins, more sophisticated structure such as muscles, and sensory systems). Consequently, there are more states of consciousness that they can be in. Further, the use of electrical signaling combined with methods like synchronized firing of neural assemblies enables animals to change from one state of consciousness to another much more quickly than plants.

While the consciousness of animals thus differs from plant consciousness in several ways, we still have not ascribed to animals the possession of minds. From our perspective, mind is an undefined colloquialism used to "explain" why the content of consciousness (i.e., subjective experience) changes. Dictionary definitions of mind (e.g., Dictionary.com) describe it as a process that reasons, thinks, feels, and wills. From our perspective, what that definition describes is the subjective experience of changes in brain states. The concept of mind could become useful if it were used to characterize the role of *I*-ness in information processing (Young, 2016).

The Physics of our World

In this section and the next we explore how properties of matter determine what aspects of the physical world we can experience. The lowest level of matter that we currently know of is made up two classes of particles, those that contain mass (fermions) and those that carry forces (bosons) (Economist, 2015). There are two basic varieties of mass particles: leptons and quarks, each of which has six types (total twelve). In addition there are four force particles (photons, gluons, gravitons, and intermediate vector bosons).

Quarks and leptons are packets of energy that have parameters that vary such as mass, spin, and parity (i.e., quantum numbers) associated with them. Quarks and leptons in combination form atomic particles, such as electrons and neutrons, which have these parameters rolled-up and associated with them. These varying parameters provide the basis for the attractions that cause matter to bind together and form the universe we know.

Of the complete set of mass-containing particles, only a small subset (4 of 12) comprises the universe we experience. Our universe is constructed from the up and down quarks, and the electron and electron neutrino leptons. Combining these particles in various combinations enables the creation of other particles. For example, a proton consists of two up and one down quarks. A neutron consists of two down quarks and one up quark. Mass-carrying neutrons and protons combined with force-carrying electrons give rise to the further aggregated forms of matter that are the elements that comprise the periodic table. These elements, when aggregated further, provide the substances of our world, including both regular and organic matter.

Sensing Matter

For human beings, there are five senses that are activated by external energy: vision, audition, smell, taste, and touch. In each case, the body has a set of receptors that receives and responds to the select energy that impinges upon it. The visual sensory system responds to light, hearing sound, smell and taste chemical molecules, and touch pressure.

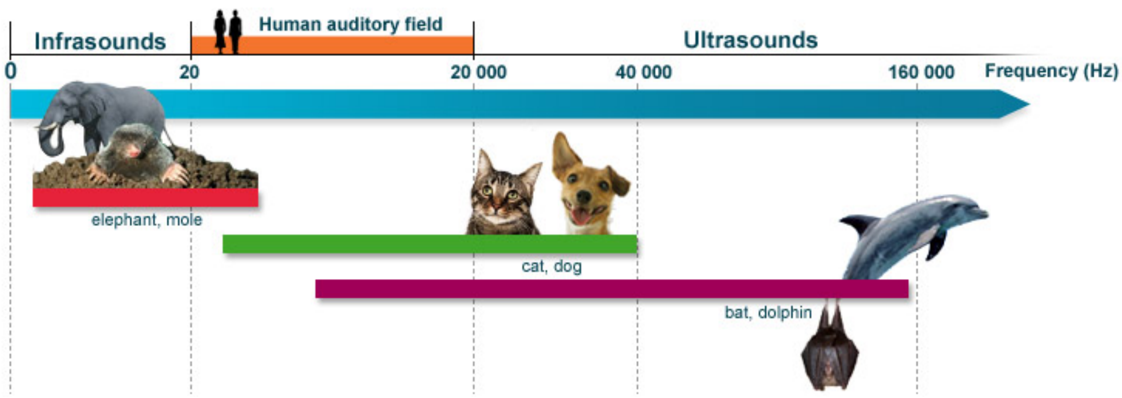

Figure 1. Sound Frequencies and Who Hears Them[3]

It is important to realize that our senses provide small slits that process a minute subset of the stimuli (electromagnetic energy, sound waves, chemical molecules, etc.) that exist in the world; they are not full-blown windows, or even windows at all. Sound for example, is a mechanical form of energy that propagates as a wave through a medium such as air or water. Sound is perceived when the mechanical energy bends the hair (cilia) in your ear (cochlea); this starts a cascade of chemical and electrical changes. The two most important properties or parameters of sound from a human perspective are frequency and amplitude. The human auditory system encodes these properties as pitch and loudness. Different animal species encode different frequencies and amplitudes (see Figure 1). A healthy human auditory system can encode frequencies between 500 and 20,000 Hz. However, humans only use a subset of these frequencies (between 500 -2000 Hz) to communicate (i.e., human speech normally occurs with this range). Dogs and bats, in contrast, can also hear sounds of higher frequencies than humans can hear, and use those frequencies to communicate, while elephants and whales hear lower frequencies than humans can hear and communicate in those ranges. Given these differences in auditory ranges of sound sensors, one could ask a rhetorical question: which species is it that hears the sounds of the world?

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[3] Picture from: http://kayjayr-akshay.blogspot.com/2016/01/science-of-hearing-i.html?view=flipcard

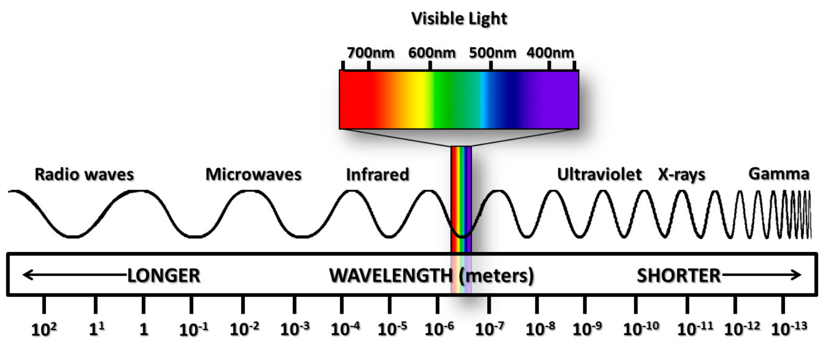

Figure 2 Electromagnetic Spectrum[4]

Light is a form of electromagnetic radiation that propagates through the world as a wave (or particles) with electric and magnetic components. The spectrum of electromagnetic radiation is quite broad, and is divided into regions based upon the frequency of the wave (see Figure 2). The standard taxonomy includes radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. The human visual system can only perceive visible light, which is about two percent of the electromagnetic spectrum. Other species can perceive other parts of the spectrum. Hummingbirds, for example, can perceive ultraviolet radiation and snakes can see infrared radiation.

The human visual system uses the differences in intensity perceived at the three different wavelengths captured by the visual receptors to construct the world we perceive. The actual process through which objects are perceived is very complicated and not completely understood. At a minimum, it involves motion cues (the binocular eyes are always moving, sampling the environment) and information about the disparity of visual images. This disparity arises from the fact that you have two eyes which perceive images slightly offset from one another, varying systematically as a function of the depth of the visual image. Other visually important information may include luminance of the object and its color as measured by the receptivity of cones (i.e., cells that transduce specific frequencies of electromagnetic radiation).

4 Picture from: http://www.ces.fau.edu/nasa/module-2/radiation-sun.php

Light arriving at the visual receptors can either come from a light source that emits photons at appropriate wavelengths, or more commonly, light reflected from an object. In general, if you are not looking directly at a light source (something actively giving off photonic radiation), you are perceiving light reflected off an object.

Figure 3 Visible Light versus Ultraviolet Light Perception[5]

Different objects reflect the range of wavelengths of light dissimilarly (i.e., more or less light is reflected at different frequencies). One animal species whose visual system has been extensively studied is the honeybee (Manning & Dawkins, 1992). The bee's eye has three classes of photoreceptors, just like the human eye does. But whereas a typical human eye encodes red, blue, and green wavelengths of light, the bee's eye encodes yellow, blue, and ultraviolet wavelengths of light. These encodings of different wavelengths are thought to produce quite different visual worlds for the two species. Figure 3 shows a flower in normal light (which a human sees) on the left and ultraviolet light (which a bee sees) on the right.

Another example is that a pure red object to us is either black or ultraviolet to a bee, depending upon whether the object reflects ultraviolet radiation or not. Dahlias and (red) roses appear black to a bee, while corn poppy (which reflects a lot of UV) looks ultraviolet. Note that we cannot know what the color ultraviolet looks like: we cannot perceive it. Figure 3 is a picture created by measuring and mapping the reflectance properties of the flower in ultraviolet into colors we can perceive.

The most spectacular views of the universe come from astronomers who have imaged the universe at different wavelengths. In contrast to recording reflected light,

5 Picture from: https://morebees.com/blog/

they take "photographs" of the universe's light sources in varying wavelengths (see Figure 4). What appears a dull patch of the sky in visible light might be a radiant area full of stars when viewed in ultraviolet or infrared.

It is important to note that just as we cannot see ultraviolet light we cannot see infrared, radio waves, or x-rays, either. What astronomers do is create sensors that capture the different frequencies of light. They then map the output from a specific sensor to an image, usually called a false color image, which maps the intensity of the captured electromagnetic energy as brightness in a color that we can see. In Figure 4 the visible light image (center) captures how a galaxy looks to us, through our three cone (receptor) visual systems. The other images capture how that galaxy looks in different wavelengths. These images have been mapped as false color images to colors we can see. Such images are particularly useful in seeing where the certain amounts of specific frequencies of energy are found in the system under study. In Figure 4, energy in the x-rays frequency band appears in the galaxy's core, while infrared energy is associated with the core and spiral arms. These results obviously have theoretical significance. Infrared energy is probably associated with burning stars while x-ray energy is usually associated with black holes.

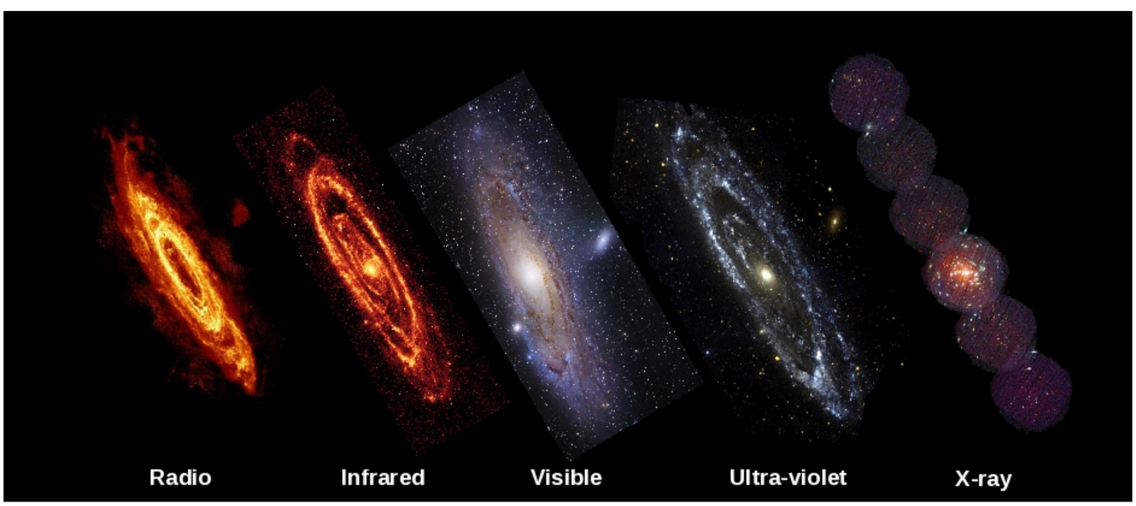

Figure 4 The Universe in Different Wavelengths[6]

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6 Picture from: https://www.pinterest.com/pin/19140367143554985/

Now as a thought experiment, consider a visual system that perceives neutrinos. Neutrinos are a type of sub-atomic particle that are generated in burning suns, and that rarely interact with what we call solid matter. However, detectors to record neutrinos have been built, and in principle, neutrinos can be perceived if they reflect off other matter (although this is very rare). Now if you had a visual system that encoded neutrinos, the sun would still be bright because it generates neutrinos, but most of what we call matter (the tables, chairs, bookcases, people and planets) would be perceived as empty space. A neutrino-based entity would not perceive the objects of our world and it could probably pass through them unobstructed. Further, if you could take a picture of a galaxy with a neutrino-based camera, the suns would show up (because their burning of hydrogen is a major source of neutrinos), but very little beyond that.

We mentioned above that our senses are not windows, not even really narrow ones. We expand upon that here. Our sensory systems provide very narrow "slits" through which we perceive the energy of the universe; in the case of vision our system, once again, perceives less than two percent of the energy out there. But our senses are not windows that we look out of. Rather they are systems that are continually sampling the environment and recording data in regular periodic intervals. These sensory sampling regularities also influence the aspects of the universe that are perceived. One example of this type of phenomena is called apparent motion. If two lights are displayed in a temporal sequence with less than a 100ms interstimulus interval between them, then the two lights appear to a viewer to be occurring simultaneously. They occur in the same temporal moment. There are a variety of parameters that can be manipulated here (e.g., distance between lights, interstimulus interval), but the basic phenomena demonstrates that the brain samples the environment using distinct temporal moments. Any two (or more) stimuli that occur within one of these moments appear simultaneous, even if in reality they are temporally distinct. The senses are not like windows through which we see continuously, they are more like camera film that captures light for a specific exposure duration.

While we have used the visual sense as our primary example here, similar differences exist for the other senses as well, although these differences are not as well understood. We only perceive by smell a sub-set of the range of chemical molecules that exist in the world, for example. Similarly, there is only a range of touches (range of pressure on the skin) that we can feel. This range varies based upon where it is felt on your body. The lips are very sensitive, and have high-resolution coverage. In contrast, our backs are less sensitive, and have much lower spatial resolution. And again, these qualities differ from species to species.

In sum, the world we perceive, including what we call matter and empty space, is heavily dependent upon how our being is embodied. Other animals (e.g., dogs, other primates, amoebas) do not perceive the same world we see. Our central nervous system and mind continually construct the world based upon the limited range in which they can induce energy and the sampling rates built into our nervous systems. Phenomenological aspects of the world that are constructed include space and its counterpart solid matter, color, temperature, sounds, smells and touch. Given these differences in the wavelengths perceived and other factors affecting the senses, one again can ask a rhetorical question: which species is it that actually perceives the universe?

Worlds 1, 2 & 3

In the following sections we further explore the question what can sentient beings be conscious of? We will consider this question both from the physical perspective of what sensors are available to an entity, and what do they enable an entity to see; and the ontological/phenomenological perspective of how do the perceived objects combine to create a world of meaning. In this discussion, we will use the framework developed by Karl Popper (1979, 1982) to help clarify select points. Popper's framework is quite useful because it provides a means to integrate these distinct perspectives.

Popper (1982) argues that to understand humans, or human activity, you must analyze them from three perspectives that he calls Worlds 1, 2, & 3. World 1 is the domain of the hard sciences such as physics, chemistry, and biology. A World 1 analysis describes humans from a physical perspective using the language and methods of the physical sciences. In contrast, World 2 is the domain of the so-called soft sciences such as psychology and ethology. A World 2 analysis focuses on subjective experience, to include feelings, beliefs, hopes, and fears. It includes both conscious and unconscious processes. The methods to characterize humans from a World 2 perspective are still under development (just as the sciences are too). Finally, World 3 consists of the products of human minds. It consists of all the artifacts that humans have created that embody or invoke meaning. It is the world of culture and intellectual accomplishment. It explores how meaning is transmitted to and invoked by individuals and societies. The three worlds are different frameworks to be used in discussing the same object of study. Analyzing from three perspectives leads to a greater understanding of the object of study.

Popper's framework is particularly appropriate because we take a property dualism stance (Nagel 2002, Searle, 1997). Property dualism argues that the mental and physical represent different ways to characterize the same thing (e.g., a person or animal). A physical description corresponds to a World 1 description in Popper's framework, while a mental or subjective rendering corresponds to a World 2 depiction. These two descriptions are both useful and independent of one another. They roughly correspond to employing what ethologists call physiological methods (World 1) and whole animal methods (World 2) (Manning and Dawkins, 1997). The most significant difference between the two frameworks is that most whole animal approaches take a functional view which looks at the significance of the behavior to the animal. For example, how do the behaviors support mating or foraging? In contrast, while we consider that type of analysis important, the main focus of a World 2 analysis is on subjective experience: What is the animal feeling and thinking? What types of concepts are activated by sensory data? To foreshadow the discussion below, we believe that this varies significantly based upon the complexity of the information-processing hardware (or neuronal architecture) of the subject under study.

Further, as discussed above, we believe that plants and animals both posses consciousness. Correspondingly, we generalize Popper's framework to both plants and animals, although in this essay we will primarily discuss animals. That is, a World 1 scientific analysis works equally well with either plants or animals, and we argue that the World 2 analysis should apply equally to both as well.

Also (once again), the best way to characterize the subjective World 2 is still very much under development. Elsewhere we have argued that the best approach might be a blend of techniques such as cognitive task analysis combined with methods from ethology and neuroethology (Young, 2016).

The World of Physics: What can we be Conscious of?

In this section we discuss how physical embodiment determines what aspects of the universe you can experience. We begin this World 1 description discussion by introducing terminology. All of the energy/matter of the universe, makes up or defines the *Universe*. The subset of the universe we can interact directly is our *realm*. As described above, those aspects of the universe we can interact with directly consist of matter composed out of only 4 of the 12 mass carrying particles. We are made up of, and can consequently perceive and interact with, matter consisting of up and down quarks, electrons, and electron neutrino leptons. We do not directly perceive top, bottom, charm, and strange quarks, nor tau, tau neutrino, muon, or muon neutrinos; nor do we perceive any aggregate matter that combinations of such particles might create. We only know of their existence through observing physical effects (e.g., gravity and the weak force) and seeing decay of some particles in accelerators. From a mass or energy perspective (as opposed to observation of particles), we can experience directly only 4% of the universe. That is the subset of the universe that comprises our realm.

Animal species inhabit *worlds* carved out by their sensory systems (see examples in Figures 1-3). Each species inhabits it own world, which is a subset of our shared realm (i.e., shared among all the species we know of). For example, the world of bats is likely quite different from the world of humans because bats use sonar to "see" whereas humans use visible light. And again, bees and many birds see ultraviolet light, where humans (and other species) do not.

The animal species that make up a world basically perceive the same external environment, although the meaning of a specific percept may vary depending on the *reality* of the individual animal. The term reality is meant to capture individual differences among conspecifics that might be due to internal states (e.g., hunger), learning, or external contextual variables (e.g., being in a specific habitat).

Animals in different worlds (but the same realm) may perceive the same objects, as when a bee and a human perceive a flower, but the object is literally perceived differently; for example a bee sees nectar guides (plant markings that guide a bee to the nectar) via ultraviolet light that the human cannot see. These physical differences in perception invoke different meanings in the perceiving creatures.

So what can we be conscious of? This depends both on the type of matter that we are comprised of and its degree of aggregation. Again, a change of consciousness is a change in the physical configuration of matter. Since we are only composed of a sub-set of all the matter in the universe, we can only experience a sub-set of all the possible states of consciousness that can be generated in the universe. We can never know (directly) what states of consciousness comprised of strange and charm quarks are like, for example. We can know other realms indirectly when we see the effects of the matter that comprises that realm, but only when that data is mapped into a state of consciousness we can experience. This is done through techniques such as false color mapping where the color (or matter) we cannot see is assigned a color (or form) we can see. The best we can ever do is to know our own world, and imagine what other worlds and realms might look (or feel, or taste, or smell, or sound) like.

Further, matter differs within a realm in the degree of aggregation that it partakes of. One of our central theses is that the richness of the conscious experience varies with degree of aggregation. The reason for this is that more aggregated matter can undergo more complex changes. An atom can capture and lose electrons. In more complex matter, however, the transduction of energy (whether it is chemical, electrical, or mechanical) can set off a cascade of changes in the states of matter which of course corresponds to changes in consciousness.

Using the complexity of the nervous system as a rough marker of aggregation, creatures with more complex nervous systems experience richer states of consciousness. In addition, creatures with roughly the same level of complexity of the nervous systems experience (roughly) the same richness of experience, although the experiences can be quite different. For example, bats and dogs have roughly the same complexity of nervous systems (as measured by number of neural connections and brain mass) though bats primarily experience the world through sonar while dogs experience it through smell. In general, evolution has produced species whose sensors are well adapted to an animal's evolutionary niche, which has lead to the creation of many distinct worlds of sensation and perception.

Characterizing an organism from a physical (World 1) perspective is the first step in understanding its world. It provides insight into what aspects of the realm the animal interacts with; which it turn enables one to look for stimuli that may activate behavior. Knowing what stimuli activate behavior enables scientists to identify specific areas in the brain involved in the perception and action. These can be studied using neurophysiological methods to gain deeper insight into the role of the brain and nervous system in behavior.

The World of Meaning: What is knowing and What can be known?

In this section we are going to consider World 2, the domain of subjective experience that is created by a "walling off" of an organism from the external world. Once again, the walling off enables the creation of an environment inside the organism that is different from the world outside. Importantly, the processes inside the organism seem to follow different physical laws than those outside. In particular, organisms (plants and animals) appear to violate the second law of thermodynamics that says that all matter tends toward a simpler state. Organisms execute programs that create greater complexity, and then they maintain this complexity for as long as they are alive. Critical to an organism's functioning is the extraction, storage, and use of energy (Maynard Smith & Szathmary 2009). It is the extraction and management of energy that seems to enable an organism to go its own way, generating complex systems.

The walling off, which is normally thought of in chemical terms (e.g., differences in chemical gradients across cell boundaries), also enables the creation of an internal world that represents and utilizes information. Some of the extracted energy from the environment is used to create complex molecules and proteins that enable the organism to sense the environment and respond to it in different ways depending upon what is sensed (Ferris, 2010). From an information processing perspective, the organism's representations are affordances that enable an organism to express actions based on the opportunities provided by the environment (Gibson, 1979; Norman, 1999; Dennett, 2017; c.f. Hoffman, 2016). The development of methods to extract, store, and subsequently use energy were simultaneously the beginning of life and the start of a world of meaning that uses information to enhance fitness.

World 2 is supposed to be a characterization of the world of subjective experience, to include your beliefs and feelings (Popper, 1979, 1982). While we agree with this goal, we also realize you can only experience your own consciousness, you cannot subjectively experience another's consciousness. The reason for this is that each individual consists of separate matter organized in a unique fashion. To experience another's consciousness would require having the same matter, configured in the exact same way. Given that quantum effects probably prevent matter from being in exactly the same state, it is extremely unlikely that you could ever experience another's consciousness. The best that one can do is get to an approximate understanding of another's state, to include what you think they mean when they engage in a specific behavior or use a certain word. Consequently, our focus will be on developing methods that enable us to understand as best as possible what motivations lie behind behaviors and what situational cues bring forth specific behaviors.

Let us begin this discussion with an obvious question: Why not just use a physiological approach to studying behavior? The issue is complexity. A snail has 10^6 neurons, a cat has 10^9 (Manning and Dawkins, 1997). Current neurophysiological methods are not capable of handling this complexity of mapping the relationship of neurons to behavior for all but the simplest behaviors. Further, it is unlikely that individual cells control behavior. For example, if a single neuron controlled a specific behavior then if the neuron died, the organism would lose that behavior. That clearly is not the case in almost all behaviors. Instead it appears the assemblies of neurons are the main processing unit, rather than individual cells (Edelman, 1989; Damasio, 1989). This significantly increases the complexity of the problem because you have to compare different neuron combinations to see which sets control or influence a behavior.

What many scientists do instead is invoke intervening variables that can be grouped under a "motivational rubric" (Manning and Dawkins, 1997). Example casual factors that are usually included in this rubric include thirst, hunger, reproductive behavior, etc. The scientific goal then becomes mapping these constructs onto neuronal activity in specific brain/ nervous system structures (i.e., assemblies of neurons). There is always the danger of anthropomorphizing the variables (e.g., do animals really get thirsty or hungry?), but as long as one does not get too specific in naming behaviors, it is normally a useful approach.

As an example, Manning and Dawkins (1997; referencing Maynard Smith & Riechert, 1984) describe how two unspecified variables, fear and aggression, are very useful when incorporated into a model that predicts the outcome of fights between desert spiders. The variables provide significant explanatory power, in spite of the fact that the physiological basis of these variables is unknown. Consequently, we believe the use of such motivational variables is the appropriate approach to classifying and studying behavior from an information processing perspective.

Now we consider some additional examples that will help us better understand the range of mechanisms involved in the control and execution of animal behavior. We start with relatively simple behaviors and then consider more complex behaviors.

As discussed by Manning and Dawkins (1997), animals are normally well adapted to their environments, as evidenced by their behavior. The sight of a predator elicits different behavior from that of a potential mate or food. Further, an animal does not react to all objects or activities in the environment. Some events are noticed and reacted to, others are noticed and ignored, while others are not detected at all. Events that are noticed and reacted to are called stimuli because they produce either behavior or changes to internal states that increase (or decrease) the likelihood of a behavior. Identifying stimuli and connecting them to behavioral responses is a primary scientific goal.

This task, however, is complicated by the fact that some stimuli might have to be repeated many times over a certain time period to be effective and even then the response to the stimuli may not be immediate. For instance, Manning and Dawkins (1997) cite studies of male doves that demonstrate a male’s courting behavior must be repeated many times before it triggers hormonal changes in the female which then manifest in changes in behavior; the hormonal changes have to have time to take effect by modifying cellular responsiveness to select stimuli.

Animal senses are not continuous windows to the world. Rather they are points at which an animal is coupled to the world in a way that affords the animal knowledge and behavioral opportunities. This is demonstrated by research by Narins and Capranica

(1976) who showed that male green tree frogs generate sound at two frequencies, a low call at 900Hz and a high call at 3000Hz. Female green tree frogs have receptors tuned to hear just these two frequencies. Further, the sounds the male generates is a double “co-qui” sound. Interesting, other males only hear the “co” component of the sound (i.e., they only have neuronal processing to hear that specific sound), which unleashes attack behavior in them, while females only hear the “qui” component which draws them to the male. The ”co” and “qui” sounds act as sex-specific sign stimuli which trigger very specific responses. A similar example is provided by Roth (1948) who showed that female and male mosquitoes are drawn to the sound stimuli produced by each other’s wings beating. This is demonstrated by the fact that male mosquitoes will be drawn to a tuning fork vibrating at the appropriate frequency (i.e., generating the same sound).

Two additional examples come from toads and frogs. Ewert and Traud (1979) studied stimuli that would elicit a defensive posture in toads. In response to the presence of a snake, toads inhale air sufficient to fill their lymphatic sacs, making them look much bigger. Ewert and Traud discovered that toads would perform this behavior in response to crude dummy snakes, as long as the fake snakes were presented horizontally. If, however, they were presented vertically there was no response. Clearly toads are wired to expect snakes to be long in the vertical dimension and not the horizontal one (Manning and Dawkins, 1992).

Classic research conducted by Lettvin, et al. (1959) mapped how receptor fields in a frog’s retina and brain worked together to create bug and danger detectors. These detectors are highly specific in the type of stimuli that activates them. The bug detector is triggered by small objects flying in a specific manner, as demonstrated through activation moving sequentially through a series of adjacent cells with small receptor fields. In contrast, the danger detector is triggered by several large receptive fields becoming active simultaneously, suggesting a large animal is looming over them. The frog does not see high-resolution objects (like flies or large creatures), but instead responds to very low-resolution objects moving in specific ways. These sign stimuli cause the frog to shoot out its tongue at the target or to jump away.

Context also plays an important role in determining the expression of behavior. For example, drakes use different courtship displays depending upon whether they are in front of the duck, or lateral to it (Manning and Dawkins, 1992). The sign stimulus is definitely the presence of a duck during the mating season, but which behavior is activated depends on the relative positions of the duck and drake. Finally, male birds show heightened aggressive behavior if another male is present when they are in their territory, as compared to when they are not. The territory must therefore have features that act as sign stimuli to modify the bird's behavior.

Many behaviors consist of sign stimuli and behaviors occurring as chained behavior. For example, red deer stags determine the ownership of groups of females through a multi-stage contest (Manning and Dawkins, 1992). The contest begins with a roaring match that communicates the fitness of a stag by the number of roars per minute it can produce. Roaring requires a lot of energy and the number of roars per unit time is an indicator of how fit a stag is and how it might fare in a fight. If there is a significant difference between the two contestants, the weaker one, as determined by the roaring contest, withdraws. If the two stags are about equal, they then proceeded to the next stage which is a parallel walk in which the contestants walk up and down parallel to each other, apparently sizing each other up. If one does not decide to withdraw after this stage, they proceed to the final stage which is an actual fight.

Historically, ethologists refer to short sequences of behavior as fixed action patterns. However, this term does not capture the variations in behavior as performed in the real world. The behavioral pattern is real, but there is some variation in the performance of the behavior from one display to another in the same animal and also from one member of the species to another. Hence, many ethologists are not happy with the term.

In recent years some individuals have proposed using the term *meme* to describe transmittable behavior. The term meme originated with Dawkins (1976), who described it as a unit of cultural behavior that can be transmitted to others much as a gene transmits information about physical properties. Some, such as Richerson and Boyd (2004), do not like the term meme due to its genetic connotations as a discrete and faithfully transmitted entity. They believe that what is transmitted can vary from one occurrence to another.

Maynard Smith and Szathmary (2009) note that the meme concept actually behaves quite differently from a gene in the way it is transmitted. Genes encode structures or behaviors that are transmitted to the next generation via a genome, the collection of genes that phenotypes (i.e., the specific individuals) pass to their offspring. Memes, in contrast, are more similar to phenotypes, which are manifest structures: pieces of knowledge or behavior to be copied. Further, many fixed action patterns seem to be innate, and do not require transmission from a conspecific to add them to the animal's behavioral repertoire. That is, the meme concept seems to deal solely with cultural transmission and not innate behavior. Finally, the meme concept does not seem to adequately address that variability or adaptability seen in animal behavior that triggered a search for a better term to describe sequences of behavior in the first place.

An alternative approach would be to import a representational scheme from computational cognitive science into ethological studies and use it to represent behavior. In cognitive science, sequences of actions are often bound together via the script concept (Bower, Black, & Turner, 1979). A script is similar to a decision tree where each node branches and one must choose a path to follow through the branching structure. The script concept is slightly different in that there are usually clear signs that trigger the appropriate behavioral response. The classic example of a script is the restaurant script which guides one's behavior through the process of entering a restaurant, ordering food, getting food, etc. The script encodes relevant options in a coherent structure that guides behavior based on specific contextual stimuli. Examples sign stimuli are whether there is a menu hanging over cash registers or whether a sign "please wait to be seated" is present when you enter the facility. Other observable signs include whether you pay when you order your food, or whether the waiter brings a tray with your bill on it. The script concept could be helpful in building better ethograms, which characterize an animal's complete behavioral repertoire (i.e., the ethogram would be a collection of scripts).

Each animal species inhabits its own world of meaning. Their senses are not general-purpose windows on the world as shown by the above examples. Instead, their sensory systems are tuned to their specific behavioral niche and provide species relevant information (Manning and Dawkins, 1992). Animals that live in prairies or savannahs, like elephants, have sensory (and communication) systems that use low frequency sounds (approximately 20 Hz) that travel far in that environment enabling communication at a distance. Animals, such as dolphins, that live in water have sensory systems that use high frequency sounds (120,000 Hz) that travel far in that environment. Animals that live and travel in dense vegetation use sounds to communicate instead of visual signals (Konishi, 1977). Humans have a narrowly tuned visual system that appears tailored to seeing emotions and moods in other conspecifics. This is an important requirement for species that live in social groups (Changizi, 2017).

From a phylogenetic perspective, early animals (in an evolutionary sense) started out with fairly primitive sensory systems. For example, insects have compound eyes that have poor image qualities (i.e., poor resolution), but are great for detecting movement over a wide field of view. These systems do not perceive objects, per se, but still afford the animal the opportunities to mate, eat, or flee a predator by triggering fixed action patterns based upon motion in the visual field. Each species, over time, evolved sensory systems adapted to the specific environment they live in and the survival challenges they face. Eyes alone (or visual systems) have evolved separately 50 – 100 times to support different animal species (Land & Nilsson, 2002). That is, there is not a common ancestor for all creatures that have eyes; they have evolved separately to meet specific challenges many times. This appears to be true for all sensory systems.

So what does all this mean for consciousness studies? The main conclusion is that consciousness is structured, or determined, by the neuronal architecture of each individual species. The neuronal architecture, to include sensory systems and information processing, determines what you can perceive and how you will respond to it.

When I look out the window and see a green bush, does that mean that there is a green bush there? Let's consider this from the perspectives of a human, a dog, and an insect. For the human, there is a bush, and it is seen as green because of the way the human visual system works. Further, for humans the visual system normally dominates sensory processing (i.e., when figuring out an environment or scene, humans normally rely on the visuals systems more than other sensory systems). In contrast, the dog would probably see a bush, but it would only be seen in black and white. Further, smell is the dominant sensation in dogs and there is evidence that they organize spatial information by smell (and not by visual objects). Finally, the insect would probably not see a bush, but might feel some attraction (or repulsion) to a specific sound or smell coming from the bush. This is the sensory system view.

Next from a percept point of view—the mental impression or concept that is activated by the information-processing that occurs when a sensation is present—the meaning of the sensation would be very different for the three species. Depending upon the human's background (e.g., how much they know about bushes), and what they are currently thinking about the sensation could activate a wide variety of thoughts and associations. There would be a lot of variation among humans, and even significant variation with the same human at different times (Atran & Medin, 2008). Humans are the least "hard wired" among the three species and this enables the role of context and learned associations to play a significant role in shaping what is perceived.

I think there would be considerably less variation in the percept among dogs. I not sure what their percept would be, but I suspect it would deal with what does the bush afford them in opportunities to find prey, or shelter from the environment, for instance. For the insect I do not think there would even be a percept unless there was a specific stimuli coming from the bush that activated a specific fixed action pattern. Insects are probably completely hard wired in that their behavior is more like a collection of electrical circuits than a general-purpose computer. If a stimuli is present they react, if not they do not.

In sum, when looking at an object, what is perceived and what it means varies from one species to the next. Further, the subjective experience depends heavily upon the neuronal architecture of the species (i.e., the way the sensory and cognitive systems are implemented in the species). The take away is that as a species becomes more phylogenetically sophisticated, its neuronal architecture becomes more complex and considers more factors before acting when a sign stimulus is present. This manifests behaviorally as a larger repertoire of behavioral responses.

This position that the species-specific neuronal architecture plays a major role in perception and behavior is also supported by animal biases in associative learning. There is an extensive literature in the associative learning community that demonstrates specificity in animal learning (Manning and Dawkins 1992). Early researchers thought that any animal could learn any behavior, and it would roughly take the same number of trials to do so. Studies quickly demonstrate that different animals learned best with experimental set-ups that played to, or required responses, that were part of their natural behavior. Cats, for instance, quickly learn to bite or lick a lever to get food, but have a great deal of difficulty if the required response is running on a treadmill (Manning and Dawkins 1992). Conversely, it is easy for a cat to learn an escape response if the required response is running on a treadmill, but very difficult if the required response if licking or biting a bar. A second example is electrical shock avoidance (Manning and Dawkins 1992). Rats can learn to run from one part of a cage to another to escape an electrical shock. In contrast, the response of many animals exposed to an alarming stimulus is to freeze, and researchers have not been able to find a way to train them otherwise. In both cases, ease of learning depends on how congruent the task is with the animals' natural behavioral tendencies, and this (in turn) depends on the neuronal architecture of the animal.

Koehler (1977) argues that the higher the evolutionary development of a species, the more adaptability they display in learning to refine and modify their fixed action patterns (FAP). Koehler relates adaptability to the progressive development of concepts in a species. Simple species have simple concepts due to their simple neuronal information processing. Insects hear and respond to specific frequencies of sound. They do not have the neuronal hardware that would enable them to perform frequency analysis of complex sounds (e.g., changing frequencies) and thus utilize this information in communication (Konishi, 1977). Hence their communication concepts are quite limited.

In his research, Koehler prefers the term innate releasing mechanisms (IRM) instead of FAP because the use of IRM puts the focus on the role of the stimulus in releasing behavior, whereas the use of FAP puts the focus on the behavior released by the stimulus. The IRMs are the concepts that control the activation and expression of FAPs (or scripts). Many ethologists prefer the use of the term IRM because of the variability in behavior execution mentioned previously.

More complex species, from an evolutionary perspective, have more complex IRMs. For a bird defending a territory, IRM concepts might include knowledge of how to recognize its mate and its territory. These concepts are, of course, non-verbal, but they are subjective states, and the presence of an intruder in a bird's territory triggers both behavior and a change of consciousness.

Much of ontogeny is devoted to developing or programming the IRMs. Further, the longer ontological development goes on, the greater the range of information that is acquired (and probably the longer period of time the young stay with the parents to acquire it). As a simple example, both birds and human children learn "languages". In most cases the language is learned during a critical period where feedback from an adult is required to refine the "dialect" of the child. Human children begin babbling the complete repertoire of phonemes in the human languages around the age of 4-6 months. Based on feedback from adults, they quickly refine their sound generation to only those phonemes used in the language spoken by those around them.

The situation is very similar in birds, although there are variations in this model that seem to take into account the environment the species of birds live in. For example, if there are similar species nearby, then it is important for the young bird to hear the parent's song, and incorporate aspects of it into its own (Konishi, 1977). The parent provides feedback that enables the fledgling to acquire the dialect specific to its species. Conversely, in an area where there is only one species, the bird song language might be completely innate because there is no chance of confusing dialects.

Many species with advanced phylogenetic architectures appear to be able to reason using internal knowledge. These include non-human primates, advanced birds (e.g., crows, parrots), and various other species, including non-vertebrates such as octopi (Godfrey-Smith, 2017), That is, they appear able to think in a non-verbal fashion. The standard way to explore non-verbal thinking with the goal of identifying the conceptual categories a species possesses is to use discrimination studies. In a discrimination study an animal has to identify which two things are alike based on a criterion. Example criteria include numbers (e.g. which two things have the same number of objects), melodies, weight, crooked versus straight, and many other dimensions. Hundreds, if not thousands, of such studies have been performed that indicate that many species have sophisticated non-verbal conceptual reasoning capabilities. These results are similar to the associative learning results discussed above in that animals have stronger discriminatory capabilities when the required behavior is congruent with their natural behavior (and underlying neuronal architecture).

In summary, in this section we have been exploring how worlds of meaning that link information in the external environment to inner states of an organism are created. The creation of a walled off area enables organisms to differentiate themselves from the environment and develop complex internal structures. Some of these structures become nervous systems (i.e., neuronal architectures) that process information enabling organisms to enhance their fitness. These neuronal architectures embody categorical knowledge that affords organisms opportunities, such as locating and moving towards food or mates. For all animals except humans the categorical information appears to be not linked to speech, although in many animals categorical knowledge is linked to alarms (which can be instantiated vocally, chemically or tactilely). In general, it seems that states of consciousness become richer with increasing phylogenetic complexity. That is, over time evolution has brought about more sophisticated neuronal architectures which are essentially synonymous with richer experience of consciousness. We discuss this further below.

General Discussion

In this section we are going to reiterate and then expand upon select points we made earlier with the intent of clearly summarizing our position. We propose a new way of thinking about consciousness, discuss states of consciousness and how they arise from specific configurations of matter, examine how the concept of intelligence relates to the concept of consciousness, consider whether machines can be conscious, and discuss the validity of the world of meaning.

Our proposal is that all matter has an attribute that is awareness (summarized above, & Young 2016). As part of this argument, we have argued that basic matter (i.e., an element of the periodic table) is not intelligent, nor it is strictly conscious. The traditional definition of consciousness is that it is subjective experience (Pierce 1989, 1935; Nagel 1974). For instance, Nagel defines it this way: "an organism has conscious mental states if and only if there is something that it is like to be that organism-something it is like for the organism". With respect to basic matter, there is only a simple continuum of "mental states" and no subject who experiences anything. Consequently, we strongly prefer to use the term awareness when talking about basic matter and reserve the term consciousness for living organisms that have internal representations of select aspects of the external world.

Living organisms—flora and fauna—have a wall (or walls) that enables the creation of an inner world that embodies intelligence and meaning. The wall (combined with energy and a genetic code) enables the state of matter within the walled off area to differentiate itself from the matter outside the wall and become more complex. This complexity provides a way to represent select aspects of the world and the state of the organism, and provides means to determine a course of action. Because this inner world embodies meaning and knowledge, we prefer to describe it as consciousness, as opposed to awareness. This brings us to the first vital point: consciousness is the subjective experience of matter structured to represent knowledge relevant to an organism. Plants and animals are both organisms, so both possess consciousness.

In the theory we have put forth (Young, 2016) we have argued that only animals have a sense of "I" because this construct developed to support mobility in organisms. Further, there is probably specialized neuronal hardware in the brain (probably in the frontal cortex and other areas) that instantiates this "I-ness". Not all organisms have this hardware, or a sense of I-ness. This brings us to a second vital point: there can be "subjective experience" (i.e., consciousness or awareness), without a subject (or sense of I). Consciousness is configurational in nature. It comes into existence when matter-cum-awareness achieves a certain configuration, relating aspects of the external world to inner states of the organism. It does not require the sense of I-ness, or the subjective sense of experience frequently called "mind" to exist (Young, 2016).

Many people become confused about what can be conscious when they compare their consciousness to other things (machines, plants, or animals). Clearly, no other thing we have encountered has anywhere near the richness of our conscious experience. We have a multitude of sensations, we can think and simulate alternatives, we can communicate with conspecifics via generative languages that are unbounded in what they can communicate, we have a sense of who we are, and a memory that enables us to establish ourselves as historical beings that exist through time and a multitude of experiences. As far as we know, no other species even comes close to this level of complexity. Our consciousness defines the maximum amount a species currently has; the real question, however, is what defines the minimum set of experiences needed for an organism to be considered conscious?

A few years ago, a group of leading researchers who study consciousness from varying perspectives issued a declaration that consciousness was found, as far as they could tell, in most if not all living creatures (Low, 2012). The problem that arises with such an assertion, is how do you determine if a creature actually possesses consciousness? The test that is often used is: Does the entity's behavior appear intelligent to an external observer? If it does, then the entity is considered to be conscious. Further, the criteria of what is for intelligence are usually adjusted based upon the complexity of the system being studied. Less complex systems may display less complex behavior and still be considered conscious, as long as the behavior appears appropriate to an external reviewer. Using this flexible criteria animals, plants, and even machines all can appear intelligent and by inference, conscious. However, we argue that animals and plants are conscious while machines are not (they only embody awareness). To achieve clarity on this issue we need to consider the role of architectures in supporting consciousness and intelligence. We will discuss plants and animals first, and then machines.

Our hypothesis is that neuronal architectures play a crucial role in the expression of consciousness and intelligent behavior. By neuronal architecture we mean the cellular-based systems that enable the representation and employment of knowledge. On a conceptual level, the neuronal architecture consists of sensory systems that originate information about the state inside and outside the organism, computational systems that can store information and combine it with incoming information to derive an optimal course of action, and effector systems (legs, fins, wings, etc.) that can execute the selected action. Importantly, neuronal architectures vary in phylogenetic or evolutionary development. They become more sophisticated as a result of evolutionary pressure.

If we consider the examples we discussed above, frogs and toads can only exhibit simple behavior because they have simple architectures. A frog doesn't see a bug, it sees movement of a specific type which causes it to strike out with its tongue. Mosquitoes hear a sound of a specific frequency and they respond by flying towards it (whether the sound comes from a conspecific or a tuning fork). The richness of their conscious experience is most likely minimal due to the minimal neuronal architecture they possess. However, their behavior is also considered intelligent because it leads to a meaningful outcome. The frog gets a meal and the mosquito gets a mate.

At a more sophisticated level of phylogenetic development, context begins to play a role as when the drake's behavior is modified depending upon the location of the duck it is displaying to, or when a bird's behavior varies depending upon whether it is in its territory or not. Further, as seen in the red deer example, behavioral components can be linked together to provide context sensitive scripts that involve seeking and evaluating information from the environment before moving to the next stage of the behavior.

In the plant world, the Venus flytrap rapidly closes its leaf when a bug flies in, and the Australian Telegraph plant constantly turns its tiny satellite leaves to monitor light in the environment in real time (Ferris, 2010). The behaviors of both plants are more sophisticated and happen much quicker that normal plant behavior. In both cases this is probably due to these plants' more sophisticated neuronal architecture compared to other plants.

These are only a few examples, but they begin to demonstrate the third vital point: more complicated and aggregated collections of matter, as found in more complicated and sophisticated neuronal architectures, are probably synonymous with more sophisticated experiences of consciousness; and they produce more complex (i.e., intelligent) behavior. Further, as the complexity of the neuronal architecture increases, it appears that specialized hardware (i.e., configurations of matter) develops, enabling states of consciousness to change more quickly; probably because this enhances the fitness of the organism that posses it.

Turning to intelligence, many people seem to confuse intelligence with consciousness: If someone or something appears intelligent, many people ascribe consciousness to it as well. In principle, we can build machines that can meet or exceed human intelligence on any task, although to date this has only been done in limited areas of expertise. But the fact that a machine may perform at the skill level of a human expert does not mean that the machine is conscious. Intelligence and consciousness are two different things. The presence of intelligence does not imply the presence of consciousness; nor does the lack of intelligence imply there isn't consciousness present.

There are many definitions of intelligence in the literature. Intelligence is a term for which there is not broad agreement as to what it means, probably because it is used in many diverse situations (Boden, 2001). As mentioned above, most definitions seem to focus on the appropriateness of the actor's actions in a given situation, as judged by an independent observer (e.g., Rogers, et al., 2015). On this basis, we accept that machines can be intelligent, even though they are artifacts of human activity (i.e., intelligent machines are created by humans). We further acknowledge that there are probably degrees of intelligence (in machines and organisms) from barely intelligent to very intelligent.

We have explained our position on machine consciousness in Young (2016). We repeat those arguments here. We have proposed a continuum of consciousness: (1) The basic awareness of matter leading to (2) the origination of consciousness in plants due to the separation from the environment along with the advent of representing and storing of information internally, which reaches a pinnacle in (3) the fuller development of consciousness in animals to include a sense of self or I-ness and the development of sophisticated information-processing systems. So where do machines fit into this characterization scheme? Can a machine be conscious?

Machines are made of matter, so there is definitely awareness associated with them. But do the separately created parts of a machine integrate together like the components of plants or animals? We say no. Machines built to date do not integrate in the same way that plants do. They do not become one organism. They remain separate pieces bolted together. The key issue is the sharing or not sharing of matter. In our proposed model the sharing of matter, for example the sharing of electrons, cause different pieces of matter to become one, to integrate their respective consciousnesses. This does not happen with contemporary machines. Each separate piece of a machine consists of matter, so there is a state, or states, of awareness that it can be in. The states a component can be in do not change, however, when the component is combined with another, unless there is sharing of matter.

As an example, consider the case of a machine, such as a calculator or a computer, where component pieces exchange information. Would that produce integration? No, because they are not sharing matter. One component is sending energy to another, and this produces a state change in the receiving component (i.e., a change of awareness), but the two components (sending and receiving) remain separate. They are designed to remain that way. For it to be otherwise, when the two components were bolted together their physical states would have to be such that they would immediately start sharing electrons, or something similar. They would have to become "one". So from our perspective machines are not conscious in the way an organism is, but one can say that machine parts are matter/awareness.

The last thing to discuss in this section is World 2, the world of subjective experience and meaning. It is perhaps easiest to understand World 2 and establish its validity, by first considering World 3, the world of artifacts created by human activity. World 3 artifacts embody meaning, and subsets of World 3 artifacts express the culture of specific groups of people.

As discussed by Popper (1979, 1982), if someone were to analyze a World 3 artifact (such as a scientific theory, an opera, a ballet, or a novel) from a World 1 physical perspective, they would not be able to extract its meaning. A physical analysis might tell you something about the matter that comprises the artifact, such as its durability or ability to reflect light, but it would not capture the meaningfulness of the artifact to you. Physical analysis, even using the scientific method, is the "wrong language". Scientific words invoke a distinct subjective experience.

To understand a World 3 artifact you must experience it appropriately. You must read it, sing it, dance it, or listen to it, and then contemplate and absorb its meaning. World 3 artifacts are meant to produce a change in the subjective state of consciousness of the one experiencing them. Reading (dancing, listening, etc.) an artifact allows one to simulate and partially experience the knowledge and experience of another (i.e., the artifact creator). World 3 artifacts thus enable one to learn about another's experience. It is this ability of World 3 artifacts to invoke changes in the subjective states of humans that establishes the validity of World 2, the world of subjective meanings.

World 3 artifacts play a key role in the transmission of culture and knowledge. World 3 artifacts invoke both images and associations, and individuals differ in the images and associations invoked. Consequently, the meaning of an artifact, or degree of understanding, varies from one individual to another based upon the number of shared associations between the creator and receiver.

Popper argues that World 3 only began with the evolution of an explicitly human language. Human language seems to be the only language that enables abstract reasoning and thought, which over time led to the creation of written artifacts. Instantiating the artifact physically is critical to the long-term transmission of the knowledge that it comprises. Bees, for example, can convey through the waggle dance knowledge about the direction, distance, and quality of a food source. This enables them to convey valuable information to those in their immediate vicinity valuable information. They do not, however, have a way to instantiate this information physically in an artifact so that bees arriving after the original messenger has left can find the food source.

That does not mean however, that only humans experience a world of meaning and thought. Humans are almost certainly the only species that thinks using words, but as mentioned above, there is plenty of evidence that animals engage in non-verbal thought and can transmit cultural behavior through observational learning. The use of sticks as tool by both chimpanzees and birds dropping clams from great heights to break them open are both examples such behavior (Maynard Smith and Szathmary (2009).

In fact, we agree with Koehler (1977) assessment that “it is fruitless to quarrel about exact beginnings of mental qualities (inner life) within the evolutionary scale”. Koehler argues that non verbal thinking includes “all inner life—pleasure, pain, memories, wishes, plans, likes and dislikes, hopes, and disappointments—all unnamed qualities still directly experienced in a non-verbal manner not only by higher animals and infants, but also by human adults”. He further suggests that: “We have a long way to go before we will understand the physiological processes that lie at the base of subjective experience”.

Conclusion

Consciousness is a configuration of matter that embodies knowledge important to the organism. Consciousness changes when a stimuli (i.e., energy that can come from outside or inside the organism) triggers a change in the internal configuration of matter (World 1), this is experienced as a change in our inner state of consciousness (World 2).

Further, while there may be a real universe out there, it should be clear that no sentient being actually perceives the universe. Rather all organisms that we know of create an internal representation of "their world"; or more accurately, a representation of things that afford them opportunities. From a World 1 physical perspective, these "worlds" are structured by neuronal configurations in the organism. That is, they depend upon the types of sensory systems an organism has, and the phylogenetic sophistication of its neuronal processing. From a World 2 subjective perspective, each neuronal configuration is experienced as a state of meaning. These perspectives are independent of, but relate to, each other.

Organisms differ across these two dimensions (Worlds 1 & 2). The physical dimension is fixed by the subset of matter that comprises our realm. Once again, our realm is composed of, and as a result we have the potential to experience, only a small subset of matter that comprises the universe. Further, different organisms, due to the specific material configurations of their sensory systems, can only experience a subset of the possible states of consciousness that could be experienced within a realm. If the matter comprising you doesn't interact with neutrinos, for example, you remain unaware of them (unless you perceive their effects some other way). In general, the sensory systems of different species of organisms show great variation in the types of energy they interact with.

The subjective experience dimension appears to be determined by the phylogenetic complexity of the neuronal architecture of the organism. As an organism's neuronal architecture becomes more complex, it may acquire more sophisticated information processing abilities such as planning, tool use, simulating alternatives, remembering prior episodes, and (in humans) generative language. Species differ considerably in their information processing abilities.

Finally, the human species has become adept at using language to create artifacts that embody meaning (Popper, 1979, 1982). This meaning is not stored in a purely physical configuration of matter, but as a code that when perceived invokes a configuration of matter in the recipient that is subjectively experienced as knowledge. How much of the code is understood depends upon the knowledge stored in the neuronal architecture of the receiver. The creation and use of these artifacts has enabled cultural transmission of knowledge to become an important driver of change in the environment.

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