Chapter 2
Invertebrates and Humans: Science, Ethics, and Policy

Simone Pollo and Augusto Vitale

Abstract In this contribution we will first briefly describe different ways in which invertebrates are part of our lives and how we interact with them. A special focus is the use of invertebrates in scientific research. After a review of the major fields of investigation utilizing invertebrates, we will argue that their use in research constitutes an interesting and inspiring case study. As an example, the relatively recent European legislation on the protection of animals in scientific procedures now contemplates cephalopods. For this reason, it appears that animal experimentation is a kind of relationship in which the awareness of welfare problems of invertebrates is relatively more advanced. This opens a series of considerations on public attitude toward invertebrates, ethical issues arising on the use of these animals in research, compared both with other kinds of invertebrate/human relationship (e.g., pest control) and with the regulation of research on vertebrates, and the related legislative aspects. One question that is addressed is whether such attention for the ethical implications in the use of invertebrates in scientific research is and/or can be extended to other aspects of our relationships with these animals.

2.1 Introduction

The invertebrates are animals which do not possess a vertebral column, a distinction mainly of exclusion. This absence of a vertebral column groups together animals as different as insects, worms, and sponges. The term invertebrate covers 36 phyla, with 8 common ones: *Porifera* (sponges), *Cnidaria* (coelenterates), *Platyhelminthes* (flatworms), *Nematoda* (roundworms), *Annelida* (segmented worms), *Arthropoda* (the largest phylum in the animal kingdom, including insects, crustaceans, and spiders), *Mollusca* (the second largest phylum, including clams, snails, and octopuses), and *Echinodermata* (sea stars, sea urchins, and sea cucumbers). Invertebrates

S. Pollo
Department of Philosophy, Università "Sapienza", Rome, Italy

A. Vitale (✉)
Center for Behavioural Sciences and Mental Health, Istituto Superiore di Sanità, Rome, Italy
e-mail: vitale@iss.it

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do not share common structural or behavioral characteristics, which makes it difficult to think of them as a homogeneous group in terms of welfare. The largest group, the arthropods, possesses a hard and chitinous exoskeleton, but many have no skeleton and only vague neural organization. Like all animals, however, invertebrates are defined as heterotrophs, as they need other organisms to feed on in order to survive.

Invertebrates have colonized all kinds of climates and can be found in every ecosystem on the planet and are the only animal that can be found in the extreme regions of the Antarctica. The numbers are staggering: about 97% of living animals are invertebrates (IUCN 2014). The insect species are estimated to be around one million, whereas the total number of invertebrate species should be more than 1,300,000 (over one and a half million of living species have been described in total; see IUCN 2014). Despite these numbers, it has taken some time for invertebrate zoology to emerge as a significant field of research in biology. One of the first significant contributions was by Jean Baptiste Lamarck who authored, between 1815 and 1822, the "*Histoire naturelle des animaux sans vertebres*" (de Lamarck 1815) (Lamarck is thought to be the first to use the term "invertebrate"). His classification of molluscs was by far the most advanced for those times, and he was the first one to separate the arachnids from the insects. Charles Darwin also gave his contribution, including invertebrates in his theory of evolution, with the publication of his famous work on earthworms and the formation of vegetable mold (Darwin 1881). Having spent a great proportion of his younger years collecting insects, he made descriptions and notes on some beetle species appeared in Stephens' *Illustrations of British entomology* (1829–1932), giving the young scientist a great sense of satisfaction and fulfillment.

At the turn of and during the twentieth century, the study of invertebrates gave very significant contributions to medicine, genetics, ecology, and so on. Specialized scientific journals and dedicated scientific societies were born, with an increasing degree of specialization toward particular groups of invertebrates and to even more specific subdivisions within a particular group. Just to cite a few: the Entomological Society of America was born in 1889 (*American Entomologist* became its official journal) and the Malacological Society in London in 1893 (publishing the *Journal of Molluscs Studies*). Many scientific periodicals are published today, such as *Journal of Invertebrate Pathology*, *Invertebrate Biology*, *Invertebrate Neuroscience*, and many others.

2.2 Invertebrates Are Part of Our Lives

The presence of invertebrates extensively exists in the lives of humans. Here our intention is not normative, but purely descriptive: as in many other cases of our relationships with other animals, invertebrates are "used" by humans for many purposes; we are aware that this is a rather anthropocentric point of view. However, evolutionary and cultural history of humans is linked with different ways of exploiting other animals (see Pollo 2016), and invertebrates are no exception. To present these cases is, in our opinion, relevant also in the light of considering the use of animals, which are potentially able to experience pain. Later on, the ethical aspects of the relationships we have with invertebrates will be discussed from a philosophical point of view.

So, invertebrates, like all the other animals, are an essential part of our lives. We eat them, we study them, and some of us keep them as "pets," for example, tarantulas and other spiders (in Italy exists an association, called Aracnofilia, dedicated to the study, protection, and education on spiders (www.aracnofilia.org)). However, some species of invertebrates inspire fear and/or disgust in people. For example, the term arachnophobia indicates a specific terror of spiders and other arachnids, like scorpions (see Hardy 1988; Kellert 1993; Prokop and Tunnicliffe 2008 for some examples of how some invertebrates are perceived). The crawly movements of these animals make them particularly "alien" to us. Some of these animals indeed can harm people, and others are considered as pests: for example, in 2017 the EPA, the US Environmental Protection Agency, has listed cockroaches, crabs, mosquitoes, ticks, and bed bugs, among household pests, dangerous for public health (EPA 2017). The majority of invertebrates are in fact harmless and play a major beneficial role in different ecosystems. Many insects and other invertebrates are the primary food source for a large number of vertebrates, supporting and keeping alive entire ecosystems (Chap. 6).

Invertebrates also form part of our economy. The honey bees, for example, are farmed for agricultural reasons (Chap. 4). Honeybee farming origins are believed to be from 15,000 years ago. Egyptian art representing collection of honey has been estimated to be at least 4500 years old. Jars containing honey were found in Tutankhamun's tomb. Up to the eighteenth century, the hive was destroyed in order to collect honey, but from the nineteenth century onward, moveable hives have been used, improving the farming efficiency while protecting the bees' environment. The inventor of modern bee farming is Lorenzo Lorraine Langstroth, who published the book *The Hive and the Honey-bee*, pioneering the idea of moveable hives (Langstroth 1853). To illustrate the importance of honey production, just in the United States alone, more than four million bee colonies produce annually 80,000 tons of honey, and countries like Russia and India follow with more than 54,000 tons produced annually. Silk is another fundamental product we derive from invertebrates. The use of this natural fiber is known and documented from ancient times, especially in Asia. Silk fabric was first developed in ancient China (the earliest example of silk fabric is from about 3600 BC), and later the Roman Empire heavily traded in silk. The International Sericultural Commission publishes data on annual global silk production, and in 2016 about 192,692 of silk in metric tons were produced (www.inserco.org).

Pearls represent another commercial use of invertebrates with a long historic tradition. Pearls can be natural or cultivated. The natural ones are mainly due to pure chance, when the fragile edge of the shell of a bivalve mollusc or a gastropod is attacked by a fish or invaded by a parasite. Cultivated pearls are created by humans by inserting a tissue graft from another oyster. From Canada to the Gulf of Mexico, freshwater river mussels are also harvested for the purpose of creating artificial pearls. Currently China is the major producer of artificial pearls, and it is estimated at about 95% of the world production, with about 1600 tons of pearls put on the market every year (www.sustainablepearls.org/pearl-farming/pearl-farming-world-map/).

Invertebrates are part of our diet too, and in very general terms, we eat a great number of molluscs: marine snails, clams, cephalopods, land snails, and shrimps, lobster, or crab can all be eaten. The most important consumers of molluscs are the Japanese: it is thought that more than 100 different species are eaten daily in Japan. Squid is considered a basic and fundamental element of the diet of the Japanese people (Kurokura 2004, http://www.noaanews.noaa.gov/stories2008/20080717_seafood.html). Eating insects is part of the normal diet of many populations around the world. Insects are commonly eaten in the Americas, Africa, and Asia; about 1000 species of insects are known to be eaten in 80% of the countries in the world (that makes about 3000 ethnic groups practicing entomophagy) (Ramos-Elorduy and Menzel 1998). Arab populations commonly consume locusts as part of their diet, whereas ants, termites, grasshoppers, and beetle grubs are eaten by African people. Entomophagy has been suggested as a possible solution to environmental pollution: insects emit less greenhouse gases than conventional farm animals and can be fed grown on organic waste (Premalatha et al. 2011).

Invertebrates are ubiquitous in mythological tales and artistic expressions; their strange appearance, far away from the classical four-legged vertebrate, contributed to making these species perfect monsters in myths and legends. The folklore of nearly every country refers to invertebrates, who are protagonists in myths and legends since ancient times. For example, John Batchelor, describing the folklore of the Japanese people Ainu, mentions the sea monster Akkorokamui, a gigantic octopus with arms 120 m long (Batchelor 1901). To cite a few more examples, bees were linked to the cult of Artemis in ancient Greece (Elderkin 1939), and molluscs are represented beautifully in pottery art from the Minoan era (see, e.g., Gill 1985). In art and aesthetics, designs based on invertebrates are widespread in jewelry and fashion. Thousands of stamps illustrate insects and other invertebrates. Furthermore, we cannot forget the famous “Flight of the Bumblebee” by Rimsky-Korsakov or a musical quartet from Liverpool that named itself after a group of insects (although slightly changing the correct term to relate it to musical beat).

An important question is whether the general public acknowledges and appreciates the different ways these animals are important. Most people have a limited appreciation of the many benefits we derive from invertebrates and suffering from anxiety, and antipathy avoidance toward insects and arthropods in particular is still widespread (Prokop and Tunnicliffe 2008). Scientists and conservation group members were exceptions to this trend, but they really represent minor groups within society. Education on the importance of invertebrates will have positive effects on young generations, but cultural biases are sometimes difficult to change (see, e.g., Prokop et al. 2010). Scientists are very aware of the important progress made in science studying invertebrates.

2.3 Invertebrates in Scientific Research

Scientists have been and are studying invertebrates for different purposes: systematic models and molecular biology, cooperation and mutualism, mimicry, and genetics, just to name a few topics. Around 300,000 papers on invertebrates can be currently found in the PubMed website. It is impossible to enumerate all of the contributions the study of invertebrates have provided to general biology, but we can remember some remarkable examples, both in basic and more applied research (for an exhaustive review, see Wilson-Sanders 2011).

The first example comes from the fruit fly (*Drosophila melanogaster*). Thomas Hunt Morgan established the famous "fly room" at Columbia University at the beginning of the last century, to study heredity and mutation. The fruit fly was thought to be an excellent model, due to the speed of reproduction and inexpensive housing facilities. Morgan performed a series of very simple, elegant experiments, which are still considered classics in genetics and are part of any course in genetics at most universities. One of the important achievements, through hours and hours spent at the microscope and magnifying glass, was the confirmation of the chromosomal theory of inheritance, and that some genes are linked and always inherited together. Thanks to his work on the fruit fly, Morgan was awarded the Nobel Prize in Physiology or Medicine in 1933. However, the contribution of the fruit fly to the development of biological studies does not limit itself to classic genetics. As Kohler points out in his book *Lords of the Fly* (Kohler 1994), the fruit fly became one of the first "model organisms." In other words, this little insect showed a significant adaptability to laboratory conditions, and to standardization techniques, allowing it to be the subject of many studies in genetics and developmental biology. Entire infrastructure of laboratories and research groups were built around the possibilities offered by this animal. As Ankemy and Leonelli pointed out, a model organism is an organism that can be standardized to fit multiple purposes of research, and the fruit fly presented these characteristics (Ankeny and Leonelli 2011). The study of this little invertebrate has changed the history of the study of genetics. Seminal studies on *D. melanogaster* have led to the Nobel Prize for medicine in 2017 on the molecular basis of circadian rhythms (Hardin et al. 1990; Price et al. 1998).

Another biological milestone, in the field of behavioral biology, comes from the work of William Hamilton on social insects in the 1960s. Hamilton studied the society of social insects, to find a solution to the paradox of altruistic behavior. How is it possible, in Darwinian terms, for an individual to behave in a way that benefits another individual, at its own cost? Hamilton, in a famous paper published in 1964 in the *Journal of Theoretical Biology*, proposed that eusociality arose in social insects (Hymenoptera) by kin selection, through a particular sex determination. This intuition was crucial for the birth of sociobiology and opened an entirely new theoretical framework to explain the different forms of altruistic behaviors. Not only in social insects but termites, bees, and ants were absolutely instrumental in opening this new theoretical territory (Hamilton 1964).

The use of invertebrates in applied science relies on the crucial concept of the animal model. An animal model in biomedicine can be defined as a condition which permits us to study the fundamental biological and behavioral processes, or a pathological process can be induced that resembles, at least a certain aspect, the same pathological phenomenon observed in humans, or in other animal species (see, e.g., www.merriam-webster.com/dictionary/animal%20model). This is a concept which implies that certain characteristics (anatomical, physiological, behavioral) are shared by different animals, which have been conserved through evolution. It is feasible to think that the most basic and functional biological characters (e.g., basic cell structure and functions) have remained intact, from one species to another. The presence of analogous systems between invertebrates and vertebrates, though convergent evolution, makes the use of invertebrate models particularly promising. However, it must be pointed out that many factors can influence the choice of a particular species as a model, including the difficulty in changing consolidated experimental traditions (Vitale et al., unpublished data). Never forget that in many instances we are comparing very different animals indeed, and the transition of information acquired from a species to another must be always done with prudence and conceptual clarity.

In the context of applied science, invertebrates have been and are crucial in the field of neuroscience. Perhaps, the most famous example is the sea slug, or *Aplysia*, which is very distant from us in phylogenetical terms. The study of the nervous system of this little animal is straightforward as the animal has 20,000 very big brain cells (almost visible to human eyes), which makes it easier to study (humans have about 100 billion nervous cells). Neuroscientist Eric Kandel and colleagues have studied memory and learning using this mollusc as a model, and their discoveries resulted in the Nobel Prize in 2000. A focus of their research was the primary reflexes of *Aplysia*, which consists of the retraction of the gill and the siphon, in adverse conditions. Due to the characteristics of its nervous system, it was possible to study the behavior of the synapses during the withdraw reflex, which led to finding functional correlations between this mollusc and mammals. *Aplysia* has become a powerful model to study learning and conditioning (at a cellular level) in other organisms (including our own species). For example, the properties of the synapses displayed in the tests on conditioning involving dopamine neurons in the *Aplysia* are directly related to behavioral responses such as addiction in mammals (see, e.g., Baxter and Byrne 2006).

In recent years, basic and applied research have greatly benefited from the use of very simple invertebrates such as the flatworms or *Platyhelminthes*. Within the *Platyhelminthes*, the planarians are known for being able to regenerate any part of the body which has been damaged. This ability is due to the presence of pluripotent stem cells. Researchers have discovered a protein that is required to maintain stem cells active in planarians and could also be involved in pluripotent stem cells of mammals. Many questions are still to be answered. Are stem cells responsible for the regeneration of each organ, or what activates stem cells when regeneration is needed (Adler et al. 2014; Rossant 2014)? Another example from these invertebrates comes from the study of aging: the round worm (*Caenorhabditis elegans*) has been extensively used to study longevity. In particular the discovery of the gene age-1, able to increase lifespan of *C. elegans* when mutated, has provided important insights into the factors contributing to aging in vertebrates (Friedman and Johnson 1988; Lopez-Otin et al. 2013). However, also in this case, much remains to be learned about these mechanisms. Future use of other invertebrates will provide new models that will be very useful (see, e.g., Murthy and Ram 2015).

The use of invertebrates in experimental research opens a series of important ethical dilemmas.

2.4 The Moral Status of Invertebrates

As previously stated many invertebrate species are part of human life because they are used as food and research subjects (and to a very far lesser extent, kept as companion animals). And like many other nonhuman living beings, they are affected by environmental effects of human civilization. Many are deeply intertwined with human life and have rarely been regarded as deserving any kind of moral consideration. In popular culture metaphoric references to invertebrates mainly address something or someone without particular value (if not disgusting and depreciable), an example being when someone threatens to "crush him/her like a bug." Very rarely positive values have been attached to invertebrates in novels and fables (probably bees are the invertebrates with the best reputation). Bad fame is not limited to insects, "octopus" (*piovra* in Italian) is a nickname for mafia, and calling someone a mollusc means blaming him/her for a weak character. Separation of invertebrates from the human beings seems to be wider and deeper than the separation of vertebrates, and here we cannot address and analyze all of them. But we can just mention the role that phylogenetic distance could play in making human empathy with invertebrates more difficult than with many vertebrates (especially mammals).

Besides a commonsense attitude toward nonhuman animals, since the 1970s philosophical ethics has dedicated systematic analyses on the topic of nonhuman animals' moral status. Pioneering works of philosophers such as Peter Singer (1975, 1979) and Tom Regan (1983) have set the agenda of theoretical discussions about animals' moral value and human responsibilities and obligations toward them. Their work founded the research field of "Animal Ethics" that is articulated in many different theoretical views. Many are in favor of reforms of the many instances of human/animal relationships (farming and lab experimentation are the most important). Animal ethics combined with knowledge and reflection about nonhuman life (ethology, just to mention one of the most important) fostered societal changes in favor of the recognition of animals' moral status and legal protection. The process of systematic inclusion of animals into the domain of law began during the nineteenth century when the first laws aimed at protecting animals from cruel treatment and regulating animal experiments were issued by UK Parliament (Ryder 2000). It has only been during the twentieth century that animals have been systematically included into political agendas and processes of law making of Western countries. The Directive of the European Union regulating the use of animals in scientific procedures is an excellent example of the steady process of widening the circle of legal protection to nonhuman animals. In the previous version of the Directive, regulations were limited to vertebrates, but the current Directive now in force includes cephalopods among the animals whose welfare has to be taken into account if they are used for scientific purposes.

The EU Directive states invertebrates are currently on the threshold between disregard and consideration. Common sense attitudes are among the causes of the fact that moral consideration of invertebrates seems more difficult to be socially recognized, but they are not the only reason. Mainstream animal ethics seems to have devoted little attention to invertebrates. Normative theories like Singer's and Regan's link to moral status the possession of cognitive capacities that have been denied invertebrates for the most part. Singer's utilitarianism recognizes moral value to animals capable of feeling pain and pleasure. Regan's deontological right theory grants the status of a "subject of a life" to any organism endowed of the capacities, to be self-conscious and have beliefs, feelings, desires, and memories. The most influential animal ethics normative theories set the baseline for the admittance into the circle of moral consideration at a level that seems met by a good number of vertebrates species but not invertebrates for the most part. When those theories were developed, poor scientific evidence of invertebrates' sentience and cognition was available. The ethical approaches developed as alternatives to standard utilitarian and deontological ones, like those referring to the ethics of care (Donovan and Adams 2007), appear to fail in providing a convincing framework able to grant some moral consideration to invertebrates. Sympathetic attunement with invertebrates is more difficult than with vertebrates, and this makes it more unlikely to ground recognition of invertebrates' moral status in empathy.

The most recent scientific developments about sentience in invertebrates require philosophers interested in animal ethics to review their views. If subjective experience can be recognized in some invertebrates species (Klein and Barron 2016), then some kind of moral consideration ought to be afforded to them. The scientific understanding of invertebrates' mental capacities plays a key role in philosophical discussion. If the scientific evidence about invertebrates' sentience increased the eventual recognition of their moral status, this could be just part of a more articulated (and complex) theoretical discussion. What would invertebrates' moral status mean from a practical point of view? As Peter Singer recently stated, recognition of invertebrates' sentience would mean that the Earth is populated by a quantity of subjective experiences incredibly higher than that commonly believed (Singer 2016). Taking seriously such an enlargement of the domain of organisms deserving some kind of moral respect seems quite problematic. "From the practical point of view, what kind of consequences for human behavior and practices could entail the recognition of the invertebrates' moral status?"

It seems difficult to accept such a change of the moral scenario by human beings. Singer himself raises the question of what kind of success invertebrates' rights could have in a world where the recognition of the moral value of animals much closer to humans is so far from being a matter of universal consensus.

Skepticism about possible outcomes of recognition of invertebrates' moral status should not prevent scientific and philosophical discussion from proceeding and to call for the reform of human behaviors, practices, and institutions. As in the case of more consolidated fields of ethical, political, and legal reflection about human/animal relationships, it is reasonable to expect that reforms will be produced starting in selected fields of interaction. Given what it is happening in the practice of laboratory research, it is likely that invertebrates will start to gain consideration and respect.

2.5 Sentience

In the process of moral recognition of invertebrates, the discussion about sentience becomes crucial, especially when it comes to the legal protection of this particular group of animals. Sentient animals are protected by the Directive 2010/63/EU. Legislators have set a threshold for protection of certain animals above others, but in biological terms thresholds are difficult to identify for characteristics such as sentience or awareness: characteristics gradually vary between different organisms, following a evolutionary gradient.

Sentience can be simply defined as the capacity of feeling. However, sentience is one of the most slippery and difficult-to-grasp concepts in animal behavior. A certain consensus exists that sentience usually refers to the ability to feel and have subjective experiences. These experiences can be both aversive and attractive, so sentience can be associated with the possibility to feel "pain" and/or "pleasure." In particular, the feeling of pain can be intended as an unpleasant experience related to the damage of tissues or organs (Fiorito 1986; Duncan 2002). In a recent short article, Vallortigara affirms that sentience, intended as feeling an experience, has not necessarily got to do with advanced cognition (Vallortigara 2017). However, the search for sentience is frequently seen as the search for higher and higher cognitive abilities in animals. It is also argued that sentience can also be intended in a broader sense, that is, the whole experience of an animal in its own environment, as well as its own body. The obvious reference to this kind of sentience is the famous Nagel's article on "feeling as a bat" (Nagel 1974). There is a link between the two kinds of sentience, animals can have a sense of their own body and movements (it is hard to think differently for any kind of moving creature) but not necessarily associate this kind of sentience with pleasant or unpleasant feelings. Broom (2013) describes sentient beings as animals able to distinguish between their actions and others who can act on the basis of memory and experience. To emphasize excessively on the cognitive and intellectual side of consciousness may lead us to overlook other aspects that are equally important. It does not take much intellectual effort to experience pain, fear, or hunger. This is not of secondary importance, especially if we recall the words of Jeremy Bentham "The question is not Can they reason? Nor, Can they talk? But Can they suffer?" (Bentham 1789). Sentience is a very important controversial issue and so is the definition of "pain." Pain can be intended as an unpleasant experience, but because this characterizes pain as a personal experience, we can only infer indirectly which animals experience pain (apart from our species which can directly declare that it feels pain).

An interesting question in the present context is: "Do invertebrates have those characteristics which indicate that they are sentient and feel pain?". The Animal Health and Welfare Scientific Panel of the European Food Safety Authority (EFSA) was asked in 2005 to examine evidence of sentience in invertebrates. The literature survey indicated the presence of higher brain centers, a possibility of the presence of nociceptors, and a likely presence of nervous pathways connecting nociceptors to the brain centers, where "higher brain centers" have not to be intended sensu mammalian brain. Different invertebrates have nervous systems, which differ immensely, but, as the the nervous system becomes more complex, they can develop structured cephalic ganglia, which integrate inputs coming from sensory systems (Zullo and Hochner 2011). One very interesting example is the case of the octopus, in which much of the sensory processing take place in the peripheral parts of the arms and not in a centralized brain (Carls-Diamante 2017). This observation questions the idea of considering a "higher brain centre" as a requisite for sentience, even more so because the cephalopods are included in the list of sentient animals protected by law. It appears that biology sometimes is required to fit within a consensus of terminology and concepts among legislators and scientists.

Cephalopods are particularly interesting because they are the invertebrates normatively recognized as sentient. These animals respond to noxious stimuli (Andrews et al. 2013), but do they actually feel pain? Learned avoidance of electric shock, as well as sensitization and hyper-responsiveness after injury, were observed in cephalopods a long time ago (Boycott 1954). The discovery of nociceptors in cephalopods has occurred relatively recently, and in 2013 nociceptors responsive to mechanical and electrical stimuli were described in a squid species (*Doryteuthis pealeii*) (Crook et al. 2013). Cephalopods show behavioral and neuronal plasticity (Yasumuro and Ikeda 2011). All of these could be indications of the ability of these animals to experience pain, but it is still to be confirmed by more evidence. However, on the basis of the existing evidence, EFSA requested the inclusion of the cephalopods under the protective umbrella of the forthcoming new European Directive on the protection of animals utilized in scientific procedures (then published in 2010, Chap. 9).

What about the other invertebrates? Neuronal plasticity is not limited to cephalopods, and structural changes in synapses and neurons due to external stimuli have been also recorded *Orthoptera* (Pfister et al. 2013; Pfluger and Wolf 2013), as well as other invertebrate species (see, for a review, Pyza 2013). Neurons and neuronal circuits generating responses to noxious stimuli have been observed in nematodes (*C. elegans*) and fruit fly (*D. melanogaster*) (Tobin and Bargmann 2004).

Who has sentience then? If we are satisfied by a simple definition of this concept, in the terms of "feeling" a pleasant or aversive experience, then the reaction to pain could be a parameter we could use. We have evidence showing many invertebrate species could experience pain, and we have already mentioned the cephalopods, but then reactions to aversive stimuli have been recorded in other marine invertebrates, such as the sea slug and hermit anemone (see St. John Smith and Lewin 2009 for review). But again, do these animals feel pain?

It is clear that associating sentience to a particular species is not an easy task. Opinions are contrasting both in terms of the terminology used and scientific arguments in favor of sentience, awareness, and consciousness in animals (see, e.g., Duncan 2006). It appears to be a problem very difficult to understand. It is a matter of consensus among researchers, with the scenario still confused.

It is worth mentioning here a controversial point of view, expressed by Marian Dawkins, who does not think we really know whether animals are conscious. Dawkins argues against anthropomorphism and claims of animal consciousness, which lack firm empirical evidence. Instead, animal welfare arguments must focus on science, appreciating the critical role animals play in human welfare. In the end, she argues, it is human self-interest that will drive changes in our treatment of animals (Dawkins 2012). Her view can be considered rather cynical but interesting, because it opens the question of how we should proceed in discussing the topic of moral recognition of nonhuman animals and the reasons underlying such recognition.

However, in the face of persistent uncertainty in granting (in a rather anthropocentric and patronizing perspective) sentience to a particular species of invertebrate, the precautionary principle on animal sentience appears to be justified.

2.6 The Protection of Invertebrates

Among the invertebrates, cephalopods are now legally protected in the European Union across the Member States. The Directive 2010/63/EU, different from the previous Directive 86/609/EEC, brings under its protective umbrella "live cephalopods" (both adults and juveniles) (European Parliament 2010). In 2003 the EU Commission asked for a technical expert working group (TEWG) to give their opinion on the protection of invertebrates, in consideration of the revision of the EU Directive 1986/609. The TEWG proposed: "Inclusion of any invertebrate species should only occur on the basis of sound scientific evidence as to their sentience and ability to feel pain..." (TEWG 2003). It must be noted that the EU Commission has taken a very clear position to extend protection to cephalopods. One could argue, as already mentioned in a previous section of this chapter, that "the scientific evidence...ability to feel pain" is far from being scientifically proven, and still a matter of methodological and terminological consensus (see, e.g., Ponte and Fiorito 2013). A further opinion (EFSA-AHAW 2005) has recommended the inclusion of decapod crustaceans, referring to work on defensive behavior of crabs to aversive stimuli. However, this recommendation was not incorporated in the final version of the new Directive, due to strong objection expressed by the biomedical research community (Member of EC, pers. comm.). This decision to protect cephalopods adopted by the European Commission came with consideration of the literature on cognitive abilities of these animals, improved understanding and assessment of animal welfare. The British were pioneers in this respect. The welfare of *Octopus vulgaris* was included in 1993 under the scope of the Animals (Scientific Procedures) Act (Animal Act Order 1993). The Directive 2010/63/EU adopted for all of the 28 Member States a norm on the welfare of cephalopods, which was already present in the British national law. Other countries are now considering the welfare of cephalopods. Switzerland now regulates experiments on cephalopods and decapod crustaceans, and Norway does the same with squids, octopus, and crustaceans (and honey bees). Some states of Australia regulate the use of cephalopods through the National Health and Medical Research Council's Code, and New Zealand includes in its legislation consideration for octopus, squid, crab, lobster, and crayfish. It is interesting to note what has been declared by the Canadian Council on Animal Care: "cephalopods and some other higher invertebrates [that] have nervous systems as well developed as some vertebrates, insofar as they may experience from little to severe pain, stress, discomfort or other suffering" (see Tonkins 2016 for review).

Still, cephalopods are protected, and decapods not. Cephalopods are therefore considered sentient, and decapods not. It is our opinion that this distinction is not based exclusively on scientific ground. Perhaps it is based on the fact that the terms "pain" and "suffering" are still not well defined and understood. So, who are we going to protect? Based on what? Maybe the precautionary principle can help us. The original version of this principle argues that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (United Nations 1992). The principle has been formulated in relation to environmental policy, and we can translate the phrasing "threats of serious or irreversible damage" to, for example, pain and/or sufferance inflicted to animals (invertebrates in our case) in the practice of animal experimentation.

Birch (2017) poses the question about the resistance by the scientific community to put in practice this principle, when it comes to protection of animals used in research possibly creating significant bureaucratic problems to studies performed on nematodes or fruit flies (see, e.g., Bioscience Sector 2009). One possible danger would be to see scientists perform invertebrate experimental work outside the EU, to escape the bureaucratic burden associated with project applications. In this case welfare conditions would not always be guaranteed at a European level. However, in our opinion, invertebrates not protected by European law are in the hands of the good will of the scientists using them for research. This would not necessarily mean that their level of welfare is always at a very high standard. Realistically speaking, it is not feasible to apply the precautionary principle to any living organisms (do bacteria have sentience? And nematodes?): a bar has to be set somewhere. Birch asks every pertinent question about what indicators should we use to apply the precautionary principle to a particular set of animals (Birch 2017). The suggestion, which we find sharable, is that the possession of nociceptors are not enough, but the information acquired by nociceptors must be centrally integrated with information coming from other sources. And then what about the octopus with its "intelligent arms"? An animal, which shows a physiological or behavioral response due to this kind of process could be a good candidate for the precautionary principle. By the way, decapods fall into this category (Elwood and Appel 2009; Magee and Elwood 2013; see Chap. 7). This does not solve the question on "who has sentience and who has not," but it merely gives us an indication on the parameters on which humans draw a line. In terms of treatment of invertebrates, as in any other animals, the law can help us to set up minimal standards, but then it comes down to the sensibility of each researcher how to treat their experimental subjects in their daily laboratory practice, and the need to promptly publish scientific results must not be an excuse to overlook the welfare needs of the experimental subjects.

2.7 Conclusions

For many decades the whole scenario of human/animal relationships has been subjected to moral scrutiny by parts of public opinion, which is continuously increasing. Such scrutiny is the main reason for the process of transformation of such relationships with animals in different areas. Until now most attention has been devoted to vertebrates (and not all of them). The immensely diversified group of invertebrates is the new territory for this process of transformation. We have endeavored to show how diversified, deep, and large the presence of invertebrates in human life is. Given the nature and the extent of such a presence, reasoning about their moral status and human responsibilities toward them is strongly recommended. Use of invertebrates in scientific research is a good case study for this, because it seems to be the most advanced field of human/animal interaction with respect to the reasoning about animal status and human duties. This is also the case for invertebrates, with legislations regulating lab research starting to include some invertebrates among species worthy of some kind of protection. The key issue in reasoning about invertebrates' protection is the scientific assessment of their capacity for sentience. The capacity to empathize with nonhuman emotions has a key role in triggering human moral reflection about the status of animals and our responsibilities toward them (Aaltola 2013). The attunement with the emotions of vertebrates is easier because of their phylogenetic proximity with us (although sometimes phylogenetic proximity is not what counts the most). The lives of the most of invertebrates are somehow "alien" for human beings. Empathy and imagination are more likely to foster sympathetic concern for mammals than for crustaceans, because for humans to imagine what it is like to be a calf is much easier than trying to put themselves in the shoes of a lobster. For this reason, empathic concern alone seems not enough to systematically and consistently put invertebrates under the focus of moral consideration.

Reasoning about invertebrates' moral status and their legal protection springs out from a possibility to extend protection already in force for other animals. The case of the extensions to cephalopods of the EU Directive is exemplary. As we have demonstrated, such a reasoning can be usefully driven by a well-balanced use of the precautionary principle. Prudence should be balanced by a reasonable knowledge of the capacities for sentience and suffering of the nonhuman species used for scientific research and other human purposes. Moral reasoning alone can never be enough for determining moral responsibilities toward invertebrates (and in general all the nonhuman world). It must be always accompanied and inspired by scientific understanding and knowledge.

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