Written evidence submitted by Dr Jonathan Birch (LSE), Professor Nicola Clayton FRS (University of Cambridge), Dr Alexandra Schnell (University of Cambridge), Dr Heather Browning (LSE) and Dr Andrew Crump (LSE) (AWB0026)

July 2021

This evidence pertains specifically to the question: "5. Is the Government correct to limit the scope of the Bill to vertebrate animals?"

Executive summary:

- Sentience is the capacity to have feelings, such as feelings of pain, pleasure, hunger, thirst, warmth, joy, comfort and excitement. It is not simply the capacity to feel pain, although feelings of pain and suffering have a special significance for animal welfare law because they are sources of widespread ethical concern.
- There is no single test for sentience. Evidence about brain mechanisms, physiology, cognitive abilities and behavioural responses can all be relevant to the overall case, even though no single piece of evidence is conclusive.
- For octopods (order Octopoda), there is a diverse and strong body of evidence that supports regarding these animals as sentient. For other coleoid cephalopods (cuttlefish, squid), the evidence is not as strong, but there is nonetheless a substantial amount of evidence gleaned from various different species.
- For true crabs (infraorder Brachyura), there is again a strong body of evidence, albeit not as strong as that regarding octopods. For other infraorders of decapod crustacean, the evidence is not as strong, but there is nonetheless a substantial amount of evidence gleaned from various different species.
- In our opinion, the evidence vindicates the 2012 extension of the Animals (Scientific Procedures) Act 1986 to cover all cephalopod molluscs. We now have a very strange situation in the UK: all cephalopod molluscs are protected *in science* but they are not protected by robust animal welfare laws *outside* scientific settings.
- Regarding decapod crustaceans: although it would be possible for animal welfare law to protect some infraorders while excluding others, this has the potential to generate significant confusion. A better approach would be to protect all decapod crustaceans in very general legislation such as the Animal Welfare (Sentience) Bill, while also developing enforceable best-practice guidance and regulations that are specific to the welfare needs of commercially important species. This is consistent with the approach that has long been taken with vertebrates.
- This would involve giving the benefit of the doubt to infraorders for which there is very little evidence (in particular, the commercially important penaeid shrimp, sold as "king prawns"). We do not consider there to be any significant drawbacks to doing this.

About the authors:

- ***Dr Jonathan Birch*** *is an Associate Professor at the LSE's Centre for Philosophy of Natural and Social Science and Principal Investigator on the Foundations of Animal Sentience project, a five-year Horizon 2020 project investigating the foundations of the science of animal sentience.*
- ***Professor Nicola Clayton FRS*** *is Professor of Comparative Cognition at the University of Cambridge, where she leads the Comparative Cognition Lab.*
- ***Dr Alexandra Schnell*** *is a Research Associate at the University of Cambridge and a member of the Comparative Cognition Lab, where she specializes in investigating the cognitive abilities of cephalopods and corvids.*
- ***Dr Andrew Crump*** *and* ***Dr Heather Browning*** *are Postdoctoral Research Officers on the Foundations of Animal Sentience project.*

Context

1. A single invertebrate species, *Octopus vulgaris*, was brought within the scope of the Animals (Scientific Procedures) Act 1986 (ASPA) by an amendment in 1993. The rationale was explicitly precautionary. The Animal Procedures Committee wrote at the time that:

> a clear majority of the Committee believe that there is sufficient doubt about the sentient status of cephalopods, to give the benefit of that doubt to one species, *Octopus vulgaris*, about which most is known and which is of particular concern (APC 1992, p. 7).

2. In the 2000s, EFSA asked its Animal Health and Welfare Panel to review the evidence of sentience in invertebrates as part of the process leading to the EU's 2010 directive on the use of animals for scientific purposes. The Panel's conclusion regarding cephalopod molluscs (e.g. octopuses, squid, cuttlefish) was that:

> There is evidence that cephalopods have a nervous system and relatively complex brain similar to many vertebrates, and sufficient in structure and functioning for them to experience pain. (AHAW 2005, p. 34)

3. Regarding decapod crustaceans (e.g. crabs, lobsters, shrimp), the Panel concluded:

> The largest of these animals are complex in behaviour and appear to have some degree of awareness. They have a pain system and considerable learning ability. Little evidence is available for many decapods, especially small species. However, where sub-groups of the decapods, such as the prawns, have large species which have been studied in detail they seem to have a similar level of complexity to those described for crabs and lobsters. (AHAW 2005, p. 35)

4. These conclusions led them to recommend that "all Cephalopoda and decapod crustaceans fall into the same category of animals as those that are at present protected." However, only the recommendation regarding cephalopod molluscs was implemented in the final directive.

5. We now have a very strange situation in the UK: all cephalopod molluscs are protected *in science* (and *O. vulgaris* has been protected for nearly 30 years) but they are not protected by robust animal welfare laws outside scientific settings.

What constitutes evidence of sentience?

6. Sentience is the capacity to have feelings, such as feelings of pain, pleasure, hunger, thirst, warmth, joy, comfort and excitement. The terms "experience with a positive or negative quality", "experience that matters to the animal", "valenced experience" and "affective experience" are alternative ways of describing this capacity. Sentience is not simply the capacity to feel pain, although feelings of pain and suffering have a special significance for animal welfare law because they are sources of widespread ethical concern.

7. There is no single test for sentience, no "smoking gun". Inferences about the likelihood of sentience have to be made from a wide range of relevant pieces of evidence. Evidence about brain mechanisms, physiology, cognitive abilities and behavioural responses can all be relevant to the overall case, even though no single piece of evidence is conclusive.

8. Some particularly relevant types of evidence include:

(1) evidence of nociceptors (that is, receptors specialized for detecting noxious stimuli such as high acidity, breaks to the skin or high temperature);

(2) evidence of integrative brain regions where information from different sensory sources is brought together;
(3) evidence of pathways connecting the nociceptors to the integrative brain regions;
(4) evidence that the animal's responses to stimuli are altered by potential local anaesthetics or analgesics in a way consistent with the hypothesis that these substances attenuate pain;
(5) evidence of motivational trade-offs, in which the disvalue of a noxious or threatening stimulus is weighed (traded-off) against the value of an opportunity for reward, leading to flexible decision-making.
(6) evidence of flexible, directed, self-protective behaviours in response to injury and threat (e.g. wound-tending, guarding, grooming, rubbing);
(7) evidence of associative learning in which noxious stimuli become associated with neutral stimuli, and/or in which novel ways of avoiding noxious stimuli are learned through reinforcement.
(8) evidence that the animal values potential local anaesthetics or analgesics when it is injured. For example, the animal might learn to prefer, when injured, a location at which analgesics or anaesthetics can be accessed.

Lists of this general type can be found in past reviews of the evidence (e.g. Andrews et al. 2013). These lines of evidence are admittedly "pain-centred", with less direct relevance to positive states like pleasure and joy, but it is appropriate for animal welfare law to take these pain-centred criteria especially seriously.

The question of generalization

9. A fundamental issue in this area is how reasonable it is to generalize across biological taxa. For example, "vertebrates" is a vast category including everything from a lamprey to a chimpanzee. Extending protection to all vertebrates is an ethically appropriate move, but the approach taken towards invertebrates should be consistent with this. What, then, would be consistent? The category "invertebrate" is astoundingly broad, and extending protection indiscriminately to all invertebrates would bring microscopic animals such as tardigrades and dust mites within the scope of animal welfare law. Even a category such as "crustacean" is extremely broad, encompassing microscopic copepods in addition to more familiar animals.

10. Yet to protect one or more specific species, as in the 1993 amendment to ASPA, is in tension with the approach taken to vertebrates. With vertebrates, we do not demand species-specific evidence before granting protection. For example, we do not protect red deer on the basis of evidence specific to red deer, or swans on the basis of evidence specific to swans. Most of the evidence relevant to mammals in fact comes from studies of a single species, the lab rat (*Rattus norvegicus*). Legislators have always been willing to allow sensible inferences from a laboratory species to other relevant species.

11. Given this, there is a need to use categories that are narrower than "crustacean" but broader than a single species. This is why "mid-level" taxonomic categories such as the order and the class have been the focus of past discussions, such as the discussions around the 2010 EU directive. The cephalopod molluscs are a class of around 750 species, including an important subclass: the famously large-brained coleoid cephalopods (octopods, squid, cuttlefish). The decapod crustaceans are an order of around 15,000 species, with two suborders (the Pleocyemata and Dendrobranchiata) and, within the Pleocyemata, ten different infraorders.

12. The Swiss Tierseuchenverordnung, or Animal Protection Order, is an example of an animal welfare law that protects some invertebrates. This legislation uses the category of "Reptantia", a category encompassing all those decapod crustaceans that move primarily by walking rather than swimming. This aligns reasonably well—but not perfectly—with the largest-brained decapod crustaceans.

Brief summary of the evidence: cephalopod molluscs

13. This is not the place for a detailed review of the evidence. In short, for octopods (order Octopoda), there is a diverse and strong body of evidence of the types described above. To briefly highlight some important evidence:

- *It has long been recognized that octopods, like all coleoid cephalopods, have a well-developed vertical lobe that performs complex integrative processing in support of learning and memory (Andrews et al. 2013; Fiorito et al. 2015).*
- *Recent studies by Alupay et al. (2014) and Perez et al. (2017) provide evidence that octopods possess receptors that fire selectively in response to crush injuries and that are sensitized by such injuries.*
- *A study by Crook (2021, see Figure 1) provides evidence that a noxious stimulus (acetic acid in the arm) triggers activity in the brachial connectives (which connect the arms to the brain)—activity which is silenced by injecting a local anaesthetic (lidocaine) into the affected arm.*
- *The aforementioned studies by Alupay et al. and Crook also showed directed self-protective behaviours. In the Alupay et al. study, injured octopods were found to wrap another arm around the injured arm. In Crook's study, octopods used their beak to scrape at the affected region of skin.*
- *The ability of octopods to learn associatively in sophisticated ways has been demonstrated in many different studies (Schnell et al. 2021).*
- *In the Crook (2021) study, there was also evidence that the animals valued the local anaesthetic. Given a choice between three chambers, the octopods learned to avoid the chamber in which they were placed after the noxious stimulus was applied, and learned to prefer the chamber in which they were placed after receiving the local anaesthetic.*

14. For other coleoid cephalopods (cuttlefish, squid), the evidence is not as strong, but there is nonetheless a substantial amount of evidence of the types listed above, gleaned from various different species. To briefly highlight some important evidence:

- *As noted above, all coleoid cephalopods have a well-developed vertical lobe that performs complex integrative processing in support of learning and memory (Andrews et al. 2013; Fiorito et al. 2015).*
- *Crook et al. (2013) demonstrated the presence of nociceptors in loligo squid that activated only in response to (and were sensitized by) crush injuries. Injection of a local anaesthetic numbed these receptors. Studies of bobtail squid revealed similar receptors (Howard et al. 2019) and found that the detection of a noxious stimulus activates a pathway that leads to the brain (Bazarini & Crook 2020).*
- *Cuttlefish learn associatively about aversive stimuli: when pinched by a crab, they learn to attack the crab from behind (Boal et al. 2002).*
- *Personal observations by A. K. Schnell and C. Jozet-Alves (not peer reviewed) indicate that, following surgery, common cuttlefish will exhibit directed wound attention and grooming, brushing their arms across the surgery site for several days to weeks.*

16. In our opinion, the evidence vindicates the 2012 extension of the Animals (Scientific Procedures) Act 1986 to cover all cephalopod molluscs. To protect all *coleoid* cephalopods would also have been reasonable. But to extend protection to just some coleoid cephalopods, namely those specific types that have been intensively studied up to now, would have been inconsistent with the approach taken to vertebrates—and would have created a perverse incentive to experiment on different cephalopod species in order to evade the law.

Brief summary of the evidence: decapod crustaceans

17. In short, for true crabs (infraorder Brachyura), there is a strong body of evidence of the types listed above, albeit not as strong as the body of evidence for octopods. To briefly highlight some important evidence:

- *The hemiellipsoid bodies are an integrative brain region associated with learning and memory in crustaceans. A recent study (Strausfeld et al. 2020, Figure 2) showed these integrative brain regions to be particularly well developed in true crabs, compared to other decapod crustaceans.*
- *Various studies persuasively demonstrate the associative learning abilities of Brachyuran crabs (e.g. Dimant & Maldonado 1992).*
- *Elwood et al. (2017) showed that applying acetic acid to the mouths of crabs caused the crabs to move their mouth parts, scratch at their mouth with their claws, and attempt escape significantly more than a control group.*
- *Dyuizen et al. (2012) found that injecting a claw with formalin leads to active rubbing of the claw. The crabs disfavoured the injured claw when walking and "seemed to press their injured cheliped closer to the carapace compared with the intact cheliped until the end of the experiment". A different study reported that crabs injected with formalin "made many movements of bending, unbending, and shaking the injured cheliped" (Kotsyuba et al., 2010).*
- *McCambridge et al. (2016) showed that manually "declawed" crabs tend to touch the wound with the remaining claw or front legs. They also observed "a 'shudder' response when touching the wound" and noted that "some manually declawed crabs shielded their wound by positioning the remaining claw in front of the wounded area".*

18. For other infraorders of decapod crustacean, the evidence is not as strong, but there is nonetheless a substantial amount of evidence of the types listed above, gleaned from various different species. To briefly highlight some important evidence:

- *In lobsters and crayfish, the hemiellipsoid bodies are smaller than in the Brachyura, but there is some evidence that integrative functions are performed by a different integrative brain region, the accessory lobes (Sandeman et al. 2014).*
- *Fossat et al. (2014) studied "anxiety-like" behaviour in crayfish. Crayfish were placed in a maze in which they were free to explore both light and dark arms. When electrical fields were used to induce physiological stress in the animals, they became substantially less willing to enter the light arms. There was evidence that the effect was mediated by endogenous serotonin.*
- *There is some evidence that responses to electric shock in hermit crabs are modulated by shell quality: hermit crabs are less likely to abandon a shell of better quality when shocked, suggesting (without conclusively establishing) a motivational trade-off (Appel & Elwood 2009a). N.B. Hermit crabs are classified in a different order (Anomura) to the true crabs.*
- *Appel & Elwood (2009b) reported 31 instances of hermit crabs grooming their abdomen after receiving an electric shock in that location.*

19. In our opinion, to include true crabs of the infraorder Brachyura while excluding infraorders with comparable (if slightly smaller) integrative brain regions would involve an element of excessively arbitrary line-drawing. The main comparable infraorders in question are Anomura (including hermit crabs), Astacidea (astacid lobsters and crayfish), Achelata (spiny lobsters) and Caridea (caridean shrimp), which all have substantial brain regions associated with learning and memory (see Figure 1). Since shrimp move primarily by swimming, the evidence of integrative brain regions in caridean shrimp calls into question the usefulness of the "Reptantia" category used in Swiss law. As noted above, this category lines up reasonably well, but not perfectly, with the evidence.

20. Setting the scope of any legislation at such a fine-grained level (including some infraorders, excluding others) has the potential to generate significant confusion. A better approach would be to protect all decapod crustaceans in very general legislation such as the Animal Welfare (Sentience) Bill, while also developing enforceable best-practice guidance and regulations that are specific to the welfare needs of commercially important species. This is consistent with the approach taken towards vertebrates. It would imply giving the benefit of the doubt to infraorders for which there is very little evidence (in particular, the commercially important penaeid shrimp, sold as "king prawns"), just as

octopuses were given the benefit of the doubt in 1993. We do not consider there to be any significant drawbacks to doing this.

A comment on other invertebrates

21. Because the science in this area is developing at pace, it is a good idea to build in flexibility, as the Animal Welfare (Sentience) Bill does, by enabling ministers to adjust the scope of animal welfare law through statutory instruments. This sort of flexibility is needed in all animal welfare law, not just the present Bill.

22. That said, the Animal Welfare Act 2006 incorporates a similar power—but it has never been used, despite the well-known inconsistency regarding cephalopod molluscs that has existed since 1993. This suggests it is very easy for ministers to deprioritize the question of scope when parliament does not have its eye on that question.

23. The general direction of travel in science, in relation to cephalopod molluscs and decapod crustaceans, suggests we should take seriously the possibility of sentience in other invertebrates, especially other molluscs and arthropods. Insects in particular look like serious candidates. Some insects, such as honey bees, are known to have well-developed integrative brain regions (the mushroom bodies) that are capable of impressive feats of learning and memory. They have not been studied in relation to sentience, but new evidence is likely to appear over the next few years.

24. It is generally recognized that animal welfare protections should always be enforceable, practical and proportionate to identified risks. So, there is no reason to fear that, if we were to recognise insects as sentient, we would end up with absurd laws banning us from stepping on them or mowing lawns. There is no "slippery slope" here. At the same time, it is sensible to reflect on the issue of whether insect farming should be completely unregulated, or whether it might be a good idea to develop some animal welfare regulations in this area to limit the potential for suffering.

References

Alupay, J. S., Hadjisolomou, S. P., and Crook, R. J. (2014). Arm injury produces long-term behavioral and neural hypersensitivity in octopus. *Neuroscience Letters*, 558, 137–142.

Andrews, P. L., Darmaillacq, A. S., Dennison, N., Gleadall, I. G., Hawkins, P., Messenger, J. B., Osorio, D., Smith, V. J. and Smith, J. A. (2013). The identification and management of pain, suffering and distress in cephalopods, including anaesthesia, analgesia and human killing. *Journal of Experimental Marine Biology & Ecology*, 447, 46–64. https://doi.org/10.1016/j.jembe.2013.02.010

Animal Health and Animal Welfare Panel of the European Food Standards Agency [AHAW]. (2005). Aspects of the biology and welfare of animals used for experimental and other scientific purposes (EFSA-Q-2004-105). *Annex to the EFSA Journal*, 292, 1-136.

Animal Procedures Committee [APC]. (1992). Report of the Animal Procedures Committee for 1992. Retrieved from: https://www.gov.uk/government/publications/report-of-the-animal-procedures-committee-for-1992

Appel, M., & Elwood, R. W. (2009a). Motivational trade-offs and potential pain experience in hermit crabs. *Applied Animal Behaviour Science*, 119, 120–124.

Appel, M., & Elwood, R. W. (2009b). Gender differences, responsiveness and memory of a potentially painful event in hermit crabs. *Animal Behaviour 78*(6), 1373-1379.

Bazarini, S. N. and Crook, R. J. (2020). Environmental estrogen exposure disrupts sensory processing and nociceptive plasticity in the cephalopod *Euprymna scolopes*. *Journal of Experimental Biology*, *223*, jeb218008.

Boal, J. G., Wittenberg, K. M., & Hanlon, R. T. (2002). Observational learning does not explain improvement in predation tactics by cuttlefish (Mollusca: Cephalopoda). *Behavioral Processes*, 52, 141–153.

Crook, R. J. (2021). Behavioural and neurophysiological evidence suggests affective pain experience in octopus. iScience, 24, 102229. https://doi.org/10.1016/j.isci.2021.102229

Dimant, B., & Maldonado, H. (1992). Habituation and associative learning during exploratory behavior of the crab Chasmagnathus. *Journal of Comparative Physiology A*, *170*, 749-775.

Dyuizen, I. V., Kotsyuba, E. P., & Lamash, N. E. (2012). Changes in the nitric oxide system in the shore crab Hemigrapsus sanguineus (Crustacea, Decapoda) CNS induced by a nociceptive stimulus. *Journal of Experimental Biology, 215*(15), 2668-2676.

Elwood, R. W., Dalton, N., & Riddell, G. (2017). Aversive responses by shore crabs to acetic acid but not to capsaicin. *Behavioural Processes, 140*, 1-5.

Fiorito, G., Affuso, A., Basil, J., Cole, A., De Girolamo, P., D'Angelo, L., Dickel, L., Gestal, C., Grasso, F., Kuba, M., Mark, F., Melillo, D., Osorio, D., Perkins, K., Ponte, G., Shashar, N., Smith, D., Smith, J., & Mark, F. (2015). Guidelines for the Care and Welfare of Cephalopods in Research–A consensus based on an initiative by CephRes, FELASA and the Boyd Group. *Laboratory Animals*, 49(S2), 1-90. https://doi.org/10.1177/0023677215580006

Fossat, P., Bacqué-Cazenave, J., De Deurwaerdère, P., Delbecque, J. P., & Cattaert, D. (2014). Anxiety-like behavior in crayfish is controlled by serotonin. *Science*, *344(6189)*, 1293-1297.

Howard, R. B., Lopes L. N., Lardie C. R., Perez P. P., & Crook R. J. (2019). Early-life injury produces lifelong neural hyperexcitability, cognitive deficit and altered defensive behaviour in the squid Euprymna scolopes. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *374*, 20190281. https://doi.org/10.1098/rstb.2019.0281

Kotsyuba, E. P., Dyuizen, I. V., & Lamash, N. E. (2010). Stress-induced changes in the nitric oxide system of shore crabs living under different ecological conditions. *Russian Journal of Marine Biology, 36*(3), 201-208.

McCambridge, C., Dick, J. T., & Elwood, R. W. (2016). Effects of autotomy compared to manual declawing on contests between males for females in the edible crab cancer pagurus: implications for fishery practice and animal welfare. *Journal of Shellfish Research, 35*(4), 1037-1044.

Perez, P. V., Butler-Struben, H. M., Crook, R. J. (2017). The selective serotonin reuptake inhibitor fluoxetine increases spontaneous afferent firing, but not mechannociceptive sensitization, in octopus. *Invertebrate Neuroscience*, 17, 10.

Sandeman, D. C., Kenning, M., & Harzsch, S. (2014). Adaptive trends in malacostracan brain form and function related to behavior. In C. Derby & M. Thiel (Eds.) Crustacean nervous system and their control of behaviour (pp. 11-48). New York: Oxford University Press.

Schnell, A. K., Amodio, P., Boeckle, M., & Clayton, N. S. (2021). How intelligent is a cephalopod? Lessons from comparative cognition. *Biological Reviews*, 96, 162–178. https://doi.org/10.1111/brv.12651

Strausfeld, N. J., Wolff, G. H., & Sayre, M. E. (2020). Mushroom body evolution demonstrates homology and divergence across Pancrustacea. *eLife*, *9*, e52411.

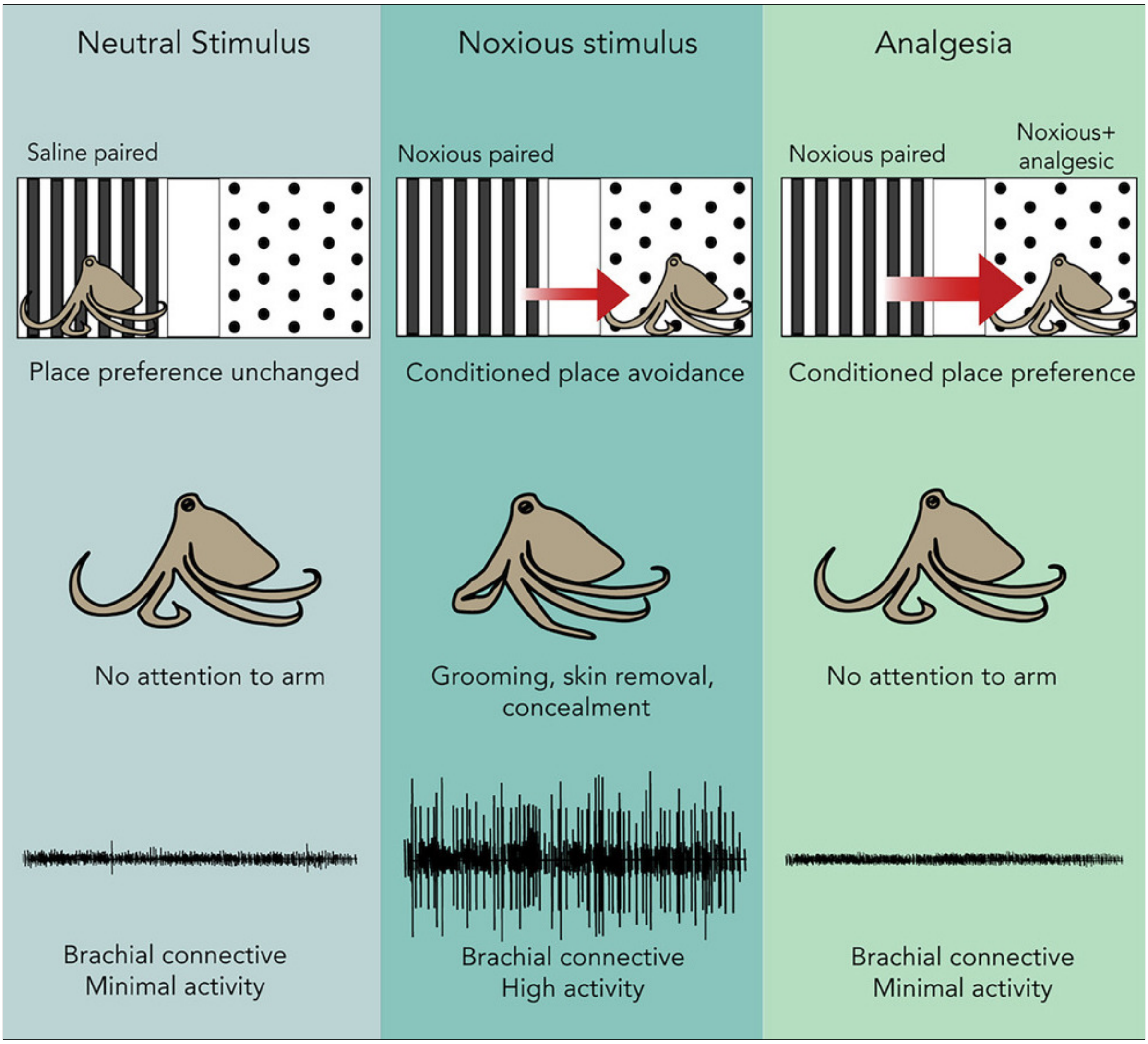

Figure 1: *A key figure from Crook (2021). The experiment involved four groups of animals: a group injected with only saline solution; a second group injected with acetic acid; a third group injected with acetic acid and, later, lidocaine; and a fourth group (not shown) injected with saline and then lidocaine. After receiving acetic acid, the affected animals showed directed self-protective behaviour, increased neural activity, and avoidance of the chamber where they had received it. Lidocaine silenced the heightened neural activity, stopped the self-protective behaviour, and led to a conditioned preference for the chamber where the effects of the lidocaine were experienced. The figure is © Robyn Crook 2021, CC-BY-NC-ND 4.0 licensed. See the original source for further methodological details.*

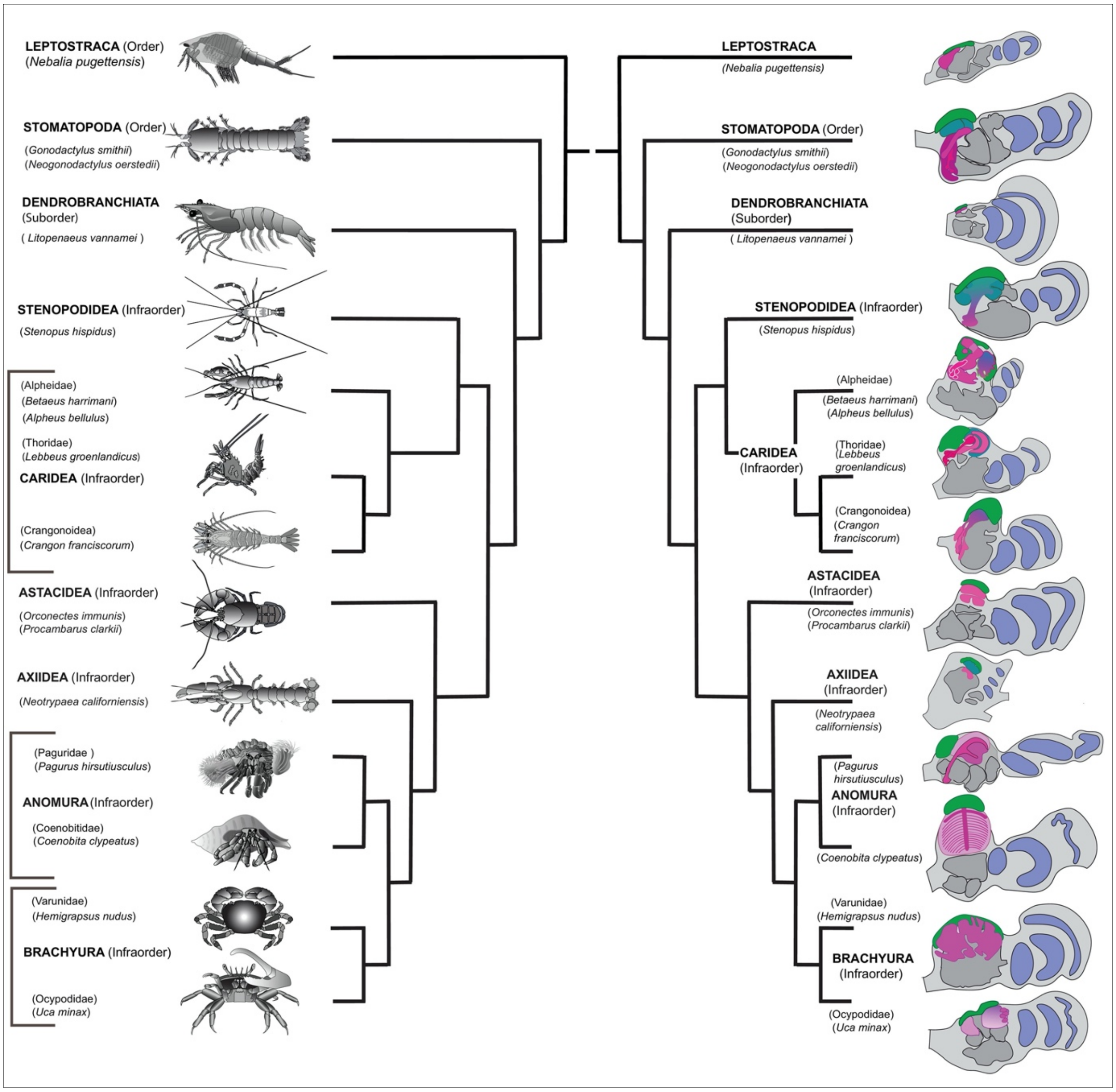

Figure 2: *The pink regions indicate an integrative brain region (the hemiellipsoid bodies) associated with learning and memory in various species of crustacean, as identified using an immunostaining technique (N.B. Leptostraca and Stomatopoda are not decapods). This figure is reproduced from Strausfeld et al. 2020 / CC-BY-4.0. See the original source for full details.*