# 3 Fish are sentient beings

## Pain and fear in fish

*"Anatomical, pharmacological and behavioural data suggest that affective states of pain, fear and stress are likely to be experienced by fish in similar ways as in tetrapods [amphibians, reptiles, birds and mammals]" (Chandroo et al, 2004a)*

Credit: National Oceanic and Atmospheric Administration/Department of Commerce. Photographer: Mr. Mohammed Al Momany, Aqaba, Jordan

Professor John Webster, of the University of Bristol, defines sentience with (2009):

> *"A sentient animal is one for whom feelings matter".*

Sentience is about the inner life of an animal, and a sentient animal has capacity to suffer fear, pain or distress as well as a sense of well-being. Evidence that fish are sentient has been sufficient to achieve international recognition that their welfare matters. The policy statement of the World Organisation for Animal Health (OIE) states (OIE, 2008b):

> *"The use of fish carries with it an ethical responsibility to ensure the welfare of such animals to the greatest extent practicable."*

In the European Union, a scientific panel commissioned by the EU Commission adopted its "General approach to fish welfare and to the concept of sentience in fish" in 2009 (AHAW, 2009). Having examined the research carried out for some species of fish (a relatively small number of species have been studied), this panel concludes:

> *"The balance of the evidence indicates that some fish species have the capacity to experience pain"*

and that

> *"Responses of fish, of some species and under certain situations, suggest that they are able to experience fear".*

Fish sentience is central to the case for more humane treatment of fish in commercial fishing, and is therefore discussed in this chapter.

### The Medway Report

1980 saw the publication of the "Medway report" (Medway, 1980) commissioned by the RSPCA to enquire whether practices related to shooting and angling in the UK involved cruelty (defined as "unnecessary suffering"). As part of its investigation, the panel of inquiry considered the evidence that fish feel pain. They point out that ability to feel pain is generally useful to an animal, helping to prevent injury and unhelpful movement during recovery. They quote the report of the Committee on Cruelty to Wild Animals, 1951:

> *"Pain is of the utmost biological value to animals because, in general, what is painful is also harmful, and consequently animals tend to avoid anything which gives them the sensation of pain. Pain is the "conditioning" stimulus which teaches an animal to avoid anything which is physically harmful to it, and this end could hardly be achieved unless the pain felt*

> *by an animal were painful in the ordinary sense. Pain is therefore a sensation of clear-cut biological usefulness..."*

The Medway Report discusses the neurological and pharmacological evidence that fish can feel pain. The pain receptors present in the skin of man, called "**nociceptors**", have been found in other vertebrates including fish. So too has "substance P", a chemical "*apparently important in the transmission of pain*". The Medway report published data on levels of **substance P** and **enkephalin** found in the trout brain, which were "*of the same order as in a mammal*". Enkephalins are endogenous opiates, i.e. painkillers similar to morphine in their effect, produced in the body and "*it has been suggested to us that they may play a role in the process of learning through gratification*". The report also refers to benzodiazepines, which "*apparently play a role in the pharmacology of anxiety in man*" and which have also been found in a range of other vertebrates including 3 bony fish (cod, plaice and eel).

The Medway Report concluded that:

> *"In the light of evidence reviewed … it is recommended that, where considerations of welfare are involved, all vertebrate animals (i.e., mammals, birds, reptiles, amphibians and fish) should be regarded as equally capable of suffering to some degree or another, without distinction between 'warm-blooded' and 'cold blooded' members."*

## Researching fish sentience

In the last 20 years, animal welfare science has developed into a scientific field in its own right, and the evidence for fish sentience has grown.

Because animal consciousness cannot be measured directly, animal welfare scientists look for anatomical, physiological and behavioural evidence as indicators of sentience or suffering. Fish intelligence has also been studied and, for example, it is known (FSBI, 2002) that some

### Social intelligence in fish

*Fish are "steeped in social intelligence, pursuing Machiavellian strategies of manipulation, punishment and reconciliation, exhibiting stable cultural traditions, and co-operating to inspect predators and catch food" (Laland et al, 2003).*

Credit: National Oceanic and Atmospheric Administration/Department of Commerce. Photographer: Farb Monitor Expedition

fish species:

> *"form mental representations of their environment and use these for quite complex feats of navigation"*

and a collection of articles on fish learning was published in a special edition of "Fish and fisheries" (Laland et al, 2003) in which the introductory chapter states that fish are:

> *"steeped in social intelligence, pursuing Machiavellian strategies of manipulation, punishment and reconciliation, exhibiting stable cultural traditions, and co-operating to inspect predators and catch food".*

The BBC news website reported this (BBC News, 2003b) saying that, according to scientists, fish

> *"do not deserve their reputation as the dim-wits of the animal kingdom".*

Also reported in the news (Mail Online, 2008), have been the learning achievements of a goldfish called "Comet". Comet has been trained by his owner Dr Dean Pomerleau to perform a number of tricks for food rewards, and a video clip of this can be viewed on the internet at fishcount.org.uk/fish-sentience. The video shows, for example, Comet fetch hoops *"just like dogs do"*.

Of key importance in animal welfare is the capacity to experience pain, fear and distress. Professor Donald Broom, of the University of Cambridge, sums up the case for fish feeling pain (1999a):

> *"There are some differences in sensory functioning between fish and mammals because fish live in water but the pain system of fish is very similar to that of birds and mammals. Fish have pain receptor cells, nociceptive neuronal pathways, specialized transmitter substances, electrophysiological responses to cuts, bruises and electric shocks, behavioural avoidance, learned avoidance of places where they had unpleasant experiences and processing systems in the brain which parallel those in birds and mammals. Hence at least some aspects of pain as we know it must be felt by fish."*

Following a request from the European Commission, the AHAW Panel was asked to deliver a Scientific Opinion on the animal welfare aspects of fish farming. The AHAW panel reviewed the current evidence for pain and fear in fish, which it presented in the above-mentioned "General approach to fish welfare and to the concept of sentience in fish" (AHAW, 2009). This evidence is outlined below following a brief discussion of the arguments made against fish sentience.

## Critics of fish sentience

Some people argue that fish are not sentient and take a Cartesian view of fish. Descartes (1596-1650) dissected conscious dogs without anaesthetic, after nailing them to boards, in order to demonstrate the circulation of blood (Magnotti, 2006). This is perhaps not so dissimilar to the way fish are treated in commercial fishing (for example, when they are dissected while conscious or impaled on hooks as live bait). Descartes argued that dogs, and other animals, do not feel pain or have feelings and are just machines. The dog's screams were just a mechanical response devoid of any feeling.

### Fish feel pain

*"at least some aspects of pain as we know it must be felt by fish" (Broom, 1999a)*

### Herring caught in the crush

Credit (above left): Courtesy of United Nations Food and Agriculture Organization. Photographer: Danilo Cedrone. National Oceanic and Atmospheric Administration/Department of Commerce.

Credit (above): National Oceanic and Atmospheric Administration/ Department of Commerce. Photographer: J. M. Olson.

For some people, this Cartesian view is largely based on an emotional response to their own perceptions of fish. For others this view is more considered, and is presented as a scientific argument.

While many people respect the welfare of these animals, it is also true that many people empathise less with fish than they do with mammals or birds. Fish have a particular "public relations" problem in that their physiological and behavioural responses to painful or distressing events are not always obvious to human observers. Fish lack the ability to make facial expressions and their vocalizations are more limited (Yue, 2008).

People may be inclined to believe that fish have less ability to feel pain because they may consider them to be less intelligent than birds or mammals. Broom argues that there is no logical reason to assume that greater cognitive ability makes pain feel worse (Broom, 2001):

> *"Pain might be a greater problem in animals with less cognitive ability".*

Is it not the case in humans, that young children seem all the more sensitive to pain, fear and distress despite, or perhaps because, of the fact that they have less developed cognitive ability? As Professor John Webster of the University of Bristol said (2005a)

> *"you don't have to be clever to suffer".*

Some scientists have argued that fish cannot suffer. In 2002, Rose published a paper, conducted at the behest of the American Fisheries Society, arguing that fish do not feel pain because they do not have a neocortex and that their behaviours are reflexes without feeling (Yue, 2008).

The evidence that fish do in fact have brain structures capable of feeling pain and fear is discussed below. The evidence that fish have a pain system which is

- similar to that of other vertebrates (e.g. mammals and birds), and that
- involves these animals *feeling* pain,

is discussed subsequently.

## Fish have brain structures capable of feeling fear and pain

AHAW (2009) discusses the similarities in brain structure between fish and other vertebrates and begins by saying that:

> *"As vertebrates, fish, birds and mammals share a similar general brain structure".*

Like that of other vertebrates, the fish brain consists of the forebrain (i.e. telencephalon and diencephalon), midbrain and hindbrain. The fish brain is not identical to the mammalian brain. It is smaller and fish do not have the extensive cerebral cortex seen in the forebrain of mammals. This is a laminated structure which covers the telencephalon.

It has sometimes been argued that because fish do not possess this laminated structure (a "neocortex"), they must therefore be incapable of experiencing pain. However, there is good reason to believe that fish do experience pain and fear without this particular structure.

AHAW (2009) argues it is known that the same brain function can be served by different brain structures in different groups of animals, e.g. cognitive functions in birds and mammals (visual stimuli are processed by part of the cerebral cortex in mammals but by the midbrain optic tectum in birds (FSBI, 2002)). Another example, cited elsewhere, is that seen in dolphins, highly intelligent animals whose brain is organized in a fundamentally different way to that of primates (Marino 2002, cited in Chandroo et al, 2004b). It is also a matter of some debate whether human consciousness is a function of the neocortex

## Convergent evolution

*The brains of sentient animals can perform similar functions, without necessarily following the same design.*

*An example of convergent evolution is seen in the dolphin brain, which is organised in a "fundamentally different pattern" to those of primates. Yet these animals have great cognitive abilities, seen elsewhere only in humans and great apes (Marino 2002, cited in Chandroo et al, 2004b).*

Credit: OAR/National Undersea Research Program (NURP).
Photographer: M. Herko. National Oceanic and Atmospheric Administration/ Department of Commerce.

alone, or restricted to any single area of the brain (Chandroo et al, 2004b).

As AHAW (2009) states, there is evidence that the fish forebrain contains within it several brain structures that perform similar functions to those associated with pain and fear in higher vertebrates. These are known to be active after a noxious stimulus, such as pin-prick stimuli in trout or goldfish. For example, the dorsomedial (Dm) and dorsolateral (Dl) telencephalon are thought to perform the same functions as the amygdala and hippocampus respectively in mammals. The amygdala is important in arousal and emotions, particularly fear responses, while the hippocampus is involved in memory and learning of spatial relationships. Damage to the Dm area in fish has been observed to impair the fear response without affecting spatial learning, and vice versa for damage to the Dl area.

Critics of fish sentience focus on the structural differences between the brain of fish and that of humans. Through convergent evolution, different species can develop the same function through anatomical structures that may be quite different. For example, there is good evidence that some invertebrates, such as decapod crustaceans (e.g. crabs and lobsters), have the capacity for pain and fear, despite the lack of a vertebrate pain system (Elwood et al, 2009; Broom, 2007). The invertebrates with the most complex brains are the cephalopods (including octopus and squid), which can solve maze puzzles and remember the solutions (Håstein et al, 2005). These authors also state that cephalopods appear to show strong emotions that are signalled by profound changes in colour. In 1993, the UK legislation governing the use of animals in scientific research was amended to include the common octopus (Elwood et al, 2009).

AHAW (2009) concludes its discussion on brain structure by saying:

> *"There is scientific evidence to support the assumption that some fish species have brain structures potentially capable of experiencing pain and fear".*

As Professor John Webster argues, since all or nearly all the evidence points in the direction of fish feeling pain (Webster, 2005b):

> *"The claim that fish 'do not have the right sort of brain' to feel pain can no longer be called scientific. It is just obstinate"*

and that (John Webster, personal communication, 2009)

> *"to say that a fish cannot feel pain because it doesn't have a neocortex is like saying it cannot breathe because it doesn't have lungs".*

## Fish probably experience pain, fear and stress in a similar way to other vertebrates

Fish have a pain system similar to that of other vertebrates. As stated by Chandroo et al (2004a):

> *"Anatomical, pharmacological and behavioural data suggest that affective states of pain, fear and stress are likely to be experienced by fish in similar ways as in tetrapods [amphibians, reptiles, birds and mammals]".*

Fish have nociceptors (pain receptors) to detect harmful stimuli such as high temperatures or harmful chemicals. These pain receptors connect, via sensory pathways, to the brain. Activity in the brain has been measured when nociception (detection of harmful stimuli) occurs. The fact that the brain is involved during nociception "*demonstrates the potential for pain perception in lower vertebrates [fish]*" (Dunlop and Laming, 2005).

Painkillers, such as morphine work on fish. Fish, like other vertebrates, produce their own natural painkillers in the brain called "endogenous opioids". The presence and action of painkillers in fish is further evidence that fish feel pain, or why would they need them?

Fish can learn to avoid noxious or threatening stimuli. For example paradise fish learned to operate an escape hatch to avoid electric shocks. Avoidance learning further suggests the behaviour is more than just a reflex. While reflexes occur quickly, the detection of noxious stimuli in fish can cause profound and prolonged changes to the animal's behaviour, lasting several hours. Fish can also learn to avoid threatening, but not painful, stimuli suggesting they also feel fear.

The evidence that fish can feel pain and fear is given in more detail in 3.1 and 3.2 below. Animal suffering is wider than pain and fear. AHAW (2009) reports that the stress physiology in fish is *"directly comparable to that of higher vertebrates"* and manifested as primary, secondary and tertiary stress responses. The primary response includes the release of hormones e.g. cortisol.

In a number of studies referred to in this report, the measurement of physiological variables (such as cortisol) and adverse behaviour have shown that fish suffer stress when caught (for example in gill nets (see 8.1 of chapter 8) and purse seine nets (see 7.1 of chapter 7), in fish traps and by hooks (see 13.1 of chapter 13)) and when subjected to live chilling (see chapter 17) and removal from water (see chapter 17).

## Implications of the evidence for fish sentience

**Fish are sentient beings**

*The sentience of fish has huge ethical implications for the way they are caught and killed in fisheries*

Credit: OAR/National Undersea Research Program (NURP); University of North Carolina at Wilmington. Photographer: A. Hulbert. National Oceanic and Atmospheric Administration/Department of Commerce

Most of what is known about human pain is from self-reporting (Broom, 2001) and because a fish cannot report to us what it is feeling, it may be that scientific method cannot prove, in an absolute sense, that fish feel pain. Just as it cannot be totally proven that babies, or even you and I, can feel pain. The balance of evidence, together with what is understood about evolution and the biological purpose of pain, indicate that fish do feel pain and, for humane reasons, the benefit of any doubt should be given to avoiding suffering.

As this report goes to press, Dr. Victoria Braithwaite's book "Do fish feel pain?" (Braithwaite, 2010) brings the science behind the debate around pain in fish into the open. She describes the many different pieces of evidence that together build up a picture of fish as animals that, she concludes, *"have the mental capacity to feel pain"*. She argues, on the basis of the evidence, that *"I see no logical reason why we should not extend to fish the same welfare considerations that we currently extend to birds and mammals"*.

The sentience of fish has huge implications for the way they are treated in fisheries and elsewhere. Dr. Braithwaite (2010) identifies the welfare of fish caught in commercial fishing as a major fish welfare concern:

> *"In terms of sheer numbers of fish, the real business is ocean-going trawlers scooping fish from the sea. Fish, netted by the tens of thousands, are pulled to the surface through such rapid changes in pressure that their swim bladders overinflate, causing the body to become severely distended. On reaching the surface fish are dropped onto open decks where they then flap around as they suffocate. We tend not to think too hard about the way we capture fish at sea – it isn't very pretty. We wouldn't accept killing chickens by throwing them into a tank of water and waiting for them to drown, so why don't we object to fish suffocating on trawler decks?"*

Fish are also likely to suffer considerably when chased to exhaustion and buried in the crush of trawl nets; when snared in gill nets; when thrown to tuna, or impaled on hooks, for use as live bait; and when gutted or frozen while still conscious.

Taking into account the great numbers of animals involved, this is a huge animal welfare problem. Action to address this problem is now required in the EU since the EU Treaty recognises animals as sentient beings and states that full regard should be given to their welfare needs in fisheries[2]:

> *"In formulating and implementing the Union's agriculture, fisheries, transport, internal market, research and technological development and space policies, the Union and the Member States shall, since animals are sentient beings, pay full regard to the welfare requirements of animals, while respecting the legislative or administrative provisions and customs of the Member States relating in particular to religious rites, cultural traditions and regional heritage."*

## 3.1 The evidence that fish feel pain in more detail

The AHAW (2009) report lists some of the criteria used to indicate whether an animal, including fish, might be capable of experiencing pain as follows. It goes on to give some examples of evidence supporting each of these in fish species:

(i) the existence of functional nociceptors
(ii) the presence and action of endogenous opioids and opioid receptors,
(iii) the activation of brain structures involved in pain processing,
(iv) the existence of pathways leading to higher brain structures,
(v) the action of analgesics in reducing nociceptive responses,
(vi) the occurrence of avoidance learning,
(vii) the suspension of normal behaviour associated with a noxious stimulus.

All of the above show a pain system in fish that is similar to that of mammals.

### (i) the existence of functional nociceptors (pain receptors)

Fish have pain receptors. Pain receptors are called "nociceptors" because they detect noxious, i.e. harmful, things such as high temperatures or

[2] The EU Treaty as amended by the Lisbon Treaty, Title II: Article 13 (CONSILIUM, 2008)

harmful chemicals. AHAW (2009) defines "nociception" as follows:

> *"Nociception is the detection of a noxious stimulus and is usually accompanied by a reflex withdrawal response away from that stimulus immediately upon detection. Noxious stimuli are those that can or potentially could cause tissue damage so stimuli such as high mechanical pressure, extremes of temperature and chemicals, such as acids, venoms, prostaglandins and so on, excite nociceptive nerve fibres".*

As AHAW (2009) states, Sneddon and her team found nociceptors on the face of rainbow trout. Elsewhere, Broom makes a more general point (Broom, 2001) that:

> *"most vertebrate animals which have been investigated seem to have very similar pain receptors and associated central nervous pathways".*

As Broom explains, lampreys are one of the most primitive vertebrates and modern teleosts (most species of fish alive today) have more in common with humans than they do with lampreys. Primitive as they are, lampreys too possess nociceptors. Recordings were made from sensory neurones in the skin and mouth of lamprey during heavy pressure, puncture, pinching and burning and the output was "*like that which would be recorded in a mammalian pain receptor*".

### (ii) the presence and action of endogenous opioids and opioid receptors

Endogenous opioids are substances produced in the brain in order to reduce pain. In mammals, these natural painkillers work through three distinct types of opioid receptor, and these have also been identified in zebrafish. Other evidence that fish produce these substances is given by the fact that (AHAW, 2009):

> *"When goldfish are subjected to stressful conditions, there is an elevation of pro-opiomelanocortin, the precursor of the enkephalins and endorphins, just as there would be in humans"*

**Fish have endogenous opioids**

Endogenous opioids are substances produced in the brain in order to reduce pain. "*One has to ask why they are needed in fish if these animals do not experience pain*" (FSBI, 2002).

Credit: FreePixels.com

and that (Ibid.):

> *"The distribution of enkephalins in the fish brain shows a similar pattern to that seen in higher vertebrates".*

FSBI (2002) reports the response of goldfish to analgesics (painkillers) is *"similar to that of a rat"* and says of these endogenous painkillers:

> "*one has to ask why they are needed in fish if these animals do not experience pain*".

### (iii) the activation of brain structures involved in pain processing

The processing of pain in fish involves the brain. AHAW (2009) cites research by Dunlop and Laming which measured electrical activity in the forebrain of trout and goldfish. Measurements in goldfish subjected to something noxious (e.g. heated prods) differed from those for harmless stimulation (e.g. being stoked with a paint brush) (Dunlop and Laming, 2005). Dunlop and Laming argue that this research "*demonstrates the* *potential for pain perception in lower vertebrates [fish]*'.

### (iv) the existence of pathways leading to higher brain structures

The pain receptors of fish connect, via sensory pathways, to the brain.

AHAW (2009) reports that in fish, as in other vertebrates, information received by nociceptors in the skin is relayed to the brain via two major routes. Information from the head is sent via the trigeminal tract, while information from the rest of the body is sent via the spinothalamic tract. In fish, the trigeminal tract has been shown to project to the thalamus (part of the diencephalon in the forebrain (FSBI, 2002)) as it does in other vertebrates.

### (v) the action of analgesics in reducing nociceptive responses

Analgesics (i.e. painkillers) work on fish, which gives further evidence of a fish pain system similar to that of other vertebrates such as mammals. Analgesics reduce the adverse behaviour seen in response to noxious stimuli, and this indicates that a feeling of pain is involved.

Some of the research by Sneddon et al into pain perception in rainbow trout is discussed in (vii) below. Rainbow trout that had been injected in the lips with acetic acid (a noxious substance) showed adverse behaviour. They were observed rubbing their lips on the substrate of the tank and displayed a rocking behaviour, as well as a faster breathing rate. In a separate study, Sneddon et al showed that when morphine was administered to the fish, these effects were reduced.

AHAW (2009) goes on to cite research in which goldfish subjected to electric shocks show agitated swimming, but if injected with morphine, the threshold for this response increased.

### (vi) the occurrence of avoidance learning

There is evidence that fish can learn to avoid noxious stimuli, such as common carp and pike avoiding hooks in angling trials and goldfish that have learnt to avoid electric shocks.

Broom (2001) describes experiments in which paradise fish were given an electric shock when they entered a black compartment. They subsequently avoided the black compartment and learned to activate an escape hatch to avoid further shocks. Avoidance learning has also been documented for rainbow trout, as discussed in 3.2.

### (vii) the suspension of normal behaviour associated with a noxious stimulus

It is sometimes argued by critics of fish sentience that, although fish can detect noxious (harmful) stimuli through nociceptors (pain receptors), that their response is a reflex behaviour without feeling. AHAW (2009) argues that where a noxious stimulus has adverse effects on an animal's normal behaviour beyond a simple reflex, then this may indicate that the animal is perceiving pain, stating that:

> *"Reflex responses occur instantaneously and within a few seconds but some of the responses of fish may be prolonged to 3 to 6 hours (Sneddon, 2006)".*

AHAW (2009) goes on to describe research by Sneddon et al to investigate the behavioural response of rainbow trout to noxious substances (acetic acid and bee venom) injected into their lips. Changes in behaviour over a prolonged period of time appeared to result from experiencing pain:

> *"These fish showed an enhanced respiration rate for approximately 3 hours, did not feed within this period, and showed anomalous behaviours such as rubbing of the affected area on the aquarium substratum and glass and rocking from side to side on either pectoral fin (Sneddon et al., 2003a; Sneddon et al., 2003b)".*

In this research, fish injected with acid also failed to show their normal fear response to a novel challenge. As Yue (2008) explains, rainbow trout are fearful of novel objects and try to keep a distance from them, at least for a period of time. The failure of these fish to avoid new objects indicates that the painful stimulus dominated their attention.

A later study published after the AHAW panel's report, found that goldfish subjected to an aversive, but non-harmful, heat were displaying signs of fear 2 hours later (Nordgreen et al, 2009). For the experiment, each fish was fitted with a miniature jacket containing a tiny heater with an upper limit of 50°C to prevent harm. The fish showed an escape response when the temperature was raised to a certain level, at which point the heat was turned off to prevent suffering. Half the fish were given morphine prior to the heat tests. The Telegraph online (Dobson, 2009) reported this, quoting one of the researchers Dr. James Garner of Purdue University, Indiana:

> *"Morphine had some effect on their behaviour in the test, but the major effect was this response two hours later. That was really key…Those fish not given morphine showed hovering behaviour and were less active. These are defence and fear behaviours.*
>
> *"We believe this hovering and inactivity are indicators of a general increase in fearfulness, wariness, and a generalisation of a bad experience. It is extremely difficult to explain this two hours later as a reflex".*

## 3.2 The evidence that fish feel fear

As discussed by AHAW (2009), fear, like pain, serves a function that is fundamental to survival in protecting animals against dangerous environmental threats.

Behavioural responses to potentially threatening stimuli that have been described for fish include escape responses, such as fast starts or erratic movement, freezing and sinking in the water. In a number of studies these behaviours were shown in response to conditioning, i.e. learnt. Learned avoidance studies, as discussed in 3.1 above, provide evidence that the displayed behaviour is not merely a reflex response.

AHAW (2009) refers to a study of avoidance learning in rainbow trout. This study (Yue et al, 2004) showed that these fish can learn to avoid threatening stimuli, indicating that they experience fear. Rainbow trout were placed individually into a tank comprising two chambers connected by a doorway. When subjected to the frightening stimulus of a plunging dip net in the chamber containing the fish, the fish escaped through the doorway to the other chamber. Each fish was then presented with a neutral stimulus of a light that went on 10s before the net plunged into the water. Over a 5-day period, all fish learned to avoid the plunging net by swimming through the doorway when the light was illuminated. All fish showed evidence of longer-term memory by performing this response on the first occasion they were tested after 7 days of no testing.

Learning is thought to involve receptors in the brain that are activated by a substance called NMDA. Chemicals that block these NMDA receptors (antagonists of NMDA receptors) have been shown to impair learning and fear conditioning in mammals. Experiments have shown that administering an NMDA receptor antagonist into the brain of a goldfish likewise impairs the fishes' fear conditioning.