"Ouch!" The Biological and Psychological Mechanisms of Pain

What differentiates the universal symptoms of pain between, and within individuals?

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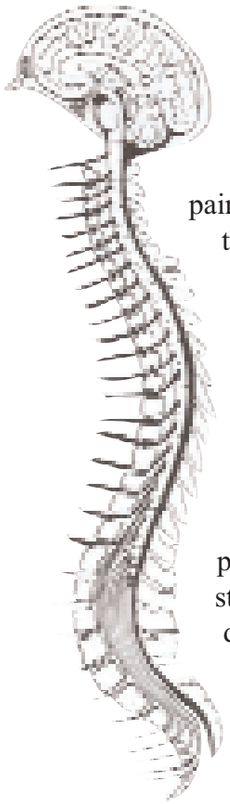
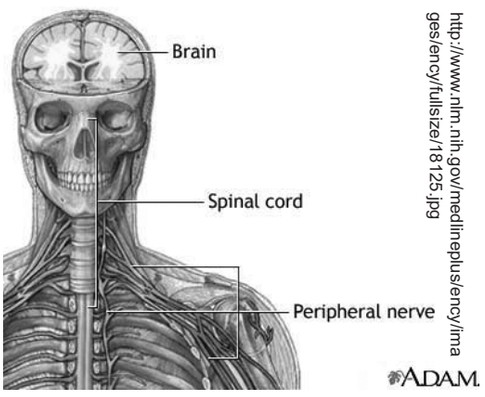


Pain can be ambiguously defined as an "unpleasant sensation" caused by signals from the central nervous system. Despite its unpleasantness, pain actually has an advantageous biological function in that pain indicates when something is wrong with the body. For instance, individuals who cannot sense pain, as with those suffering from congenital insensitivity to pain with anhidrosis (CIPA), will injure themselves frequently without so much as a grimace (Bonkowsky 2008). And, people who refuse to see a doctor for a yearly check-up may be more willing to schedule a visit if they are experiencing pain. However, chronic pain due to the constant firing of neurons can cause permanent damage and may disrupt one's quality of life through disturbed sleep, depression, anxiety, and impaired ability to make decisions (MedlinePlus 2008). Pain is a basic physical sensation with scientifically proven biological and psychological causes, and studying these causes allows for a clearer understanding of an otherwise vague term that encompasses a wide variety of symptoms.

The Biology of Pain

Medically, pain may be described as any sensation from sharp to dull, intermittent to constant, throbbing to steady, or mild to intolerable. However, it is difficult to precisely define pain due to its variation between and even within individuals. Pain may affect a single, specific site or a large area of the body. Its nature depends mostly on the location in the body, often depicted by popular 'Homunculus' diagrams (University of Minnesota 2007). For example, the skin is resident to a plethora of pain receptors, and thus a very precise response is emitted upon injury. These receptors can transmit information regarding the location of the injury as well as the nature of the wound by identifying the source of pain as sharp (such as a knife wound) or dull (from pressure, heat, or cold). In contrast, pain receptors in internal organs are highly limited. Intestinal pain, for example, can be felt if the intestine is being stretched or is experiencing pressure. However, injuries such as cuts or burns to the intestines are not sensed as acutely. In these cases, discomfort is felt over a larger area because the brain is unable to pinpoint the actual source of the pain (Merck 2007). Interestingly enough, pain felt in one area of the body may actually indicate injury in another area, a phenomenon known as "referred pain," due to the nature of the human body's electrical wiring. For example, nerves from organs such as the heart or the skin sometimes meet up with a single spinal nerve, which is why pain from a heart attack may feel as if it is coming from the arm. If the brain receives a pain signal from this spinal nerve, the brain will have difficulty determining if the pain is occurring in the heart or on the area of skin. Indeed, most pain signals arise from cutaneous nerves (Virtual Medical Center 2008).

The general mechanism for pain due to injury involves the stimulation of pain receptors at the site of injury (which, as discussed above, often depends on the location in the body). Electrical impulses generated by these receptors travel along peripheral nerves that extend from the spinal cord to the skin, muscles, and internal organs. Peripheral nerves may have nerve fiber endings sensitive to touch, vibration, and temperature, Or nerves may have endings called nociceptors, which can detect tissue damage. These



Pain receptors generate electrical impulses that travel along peripheral nerves, transmitting pain messages from the spine to the brain.

nociceptors are highly concentrated in areas that are more injury-prone, such as the fingers and toes. Pain messages from such nerve endings enter the spinal cord in a region called the dorsal horn. There, they release neurotransmitters to activate other nerve cells that transmit information to the thalamus in the brain. Then, the information is sent to the somatosensory cortex, the limbic system, and the frontal cortex. In response, the brain sends messages back to the spinal cord that signal nerve cells to release painkillers such as endorphins or enkephalins to alleviate the pain (MayoClincic 2007).

> Though 'mind over matter' may be an exaggeration . . . the sensation of pain is caused by the marriage of biological and psychological symptoms.

The way in which the human body is electrically wired can help to explain the reason behind the pain when one's foot "falls asleep," or becomes numb. Sometimes, arteries become compressed, hindering the provision of nutrients to local tissues and nerve cells. Other times, nerve pathways are blocked, preventing normal transmission of pain messages to the brain. The starved or pinched nerves cease firing, while others fire excessively. These mixed signals are interpreted by the brain as burning, prickling, or tickling, a sensation scientifically known as paresthesia. The discomfort alerts the individual to change positions. If we did not experience this pain, certain body parts could be permanently damaged if blood flow were to be restricted or nerves compressed for long periods of time (MSNBC 2008).

The gate-control theory, an addition to the previous discussion on the human body's electrical wiring, states that pain messages may take alternate routes to the brain, depending on their intensity (MayoClinic 2007). In the spinal cord, pain messages must interact with specialized nerve cells. The surface of these cells, like all other cells in the human body, are equipped with ion channels that open and close like gates, thus allowing pain signals to be conveyed or blocked (Garber 2003). The nerve cells filter severe pain messages through 'express routes' in order to minimize bodily damage. This explains why an individual automatically removes his hand after touching an extremely hot object. In contrast, weak pain messages may be blocked by the ion channels. The gate-control theory also applies to nerve fibers responsible for conveying touch. For example, rubbing the site of injury alleviates the pain since it decreases the conveyance of pain messages (MayoClinic 2007).

There are two general types of pain - nociceptive and neuropathic. Most pain can be described as nociceptive pain, which denotes injury to body tissues in the form of cuts, bruises, fractures, burns, and the like (Merck Manual 2007). It is under this category that pain receptors in the skin and internal organs are categorized. Such pain is time-limited, meaning that the pain dissolves as damaged tissues heal. (Note that arthritis is an exception since it is a chronic condition). Treatment of nociceptive pain can include the use of opioids (Richeimer Pain Institute 2000). The strongest known pain relievers, opioids are derivatives of opium, the main ingredient of which is alkaloid morphine (Meehan 2006). In contrast, neuropathic pain does not respond well to opioids, though it may be alleviated by anti-seizure and anti-depressant drugs (Richeimer Pain Institute 2000). Neuropathic pain involves the damage to, or dysfunction of the nerves, spinal cord, or brain. Felt as a tingling or burning sensation, neuropathic pain may be caused by injury, tumors, scar tissue, infection, or the abnormal processing of pain signals by the brain and spinal cord (Merck Manual 2007). This type of pain is more persistent than nociceptive pain (Richeimer Pain Institute 2000).

http://www.mouthulcers.org/images/homunculus.gif

The above Homunculus illustrates that the location of the pain in the body significantly determines the nature of the discomfort. For example, the enlarged lips and hands indicate that these regions are highly sensitive to pain.

Phantom Limb Pain

One important example of neuropathic pain is phantom limb pain. Different from the more common phantom limb sensation, phantom limb pain refers to pain in the toes, ankle, or foot of an amputated leg or the fingers of an amputated arm (Merck Manual 2007). At first diagnosed as a psychological problem, it is now known that amputation actually disrupts normal peripheral nerve activity (King 2006). Nerve endings at the amputation site send pain signals to the brain and these messages confuse the brain into sensing that the missing limb is still there. Another cause of this disorder involves retention in the central nervous system of a memory of the pain and subsequent incorrect interpretation of signals from injured nerves (WebMD 2008).

The treatment of phantom limb pain includes: heat application, massage, surgery to remove scar tissue, tampering with relevant nerves, medication, neurostimulation techniques, and the latest technique - 'virtual massage' (WebMD 2008). Virtual massage was devel-

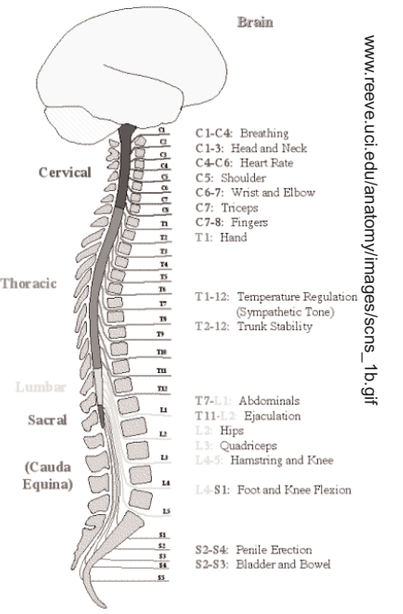
oped from the concept of 'mirror neutrons,' which fire when an individual both performs an action and watches another performing that same action. Amputees are thus able to physically empathize while observing another individual because the missing limb cannot inhibit the mirror neurons. For instance, pain can be alleviated in a hand-amputee by watching another individual rub his hand. This action typically causes blood flow restoration and activation of sensory fibers, responsible for preventing pain messages from reaching the brain (NewScientist 2008). Another similar treatment is geared towards pain arising from a 'clenched' phantom fist, in which an individual perceives that his nonexistent fingers are cutting into his nonexistent palm (Ramachandran 1998). A mirror is positioned in front of the one good hand so that the brain visually believes that the hand has been 'resurrected.' The amputee unclenches his real fist, and in effect, feels as if the phantom fist has also been unclenched (Answers.com 2008).

The Psychology of Pain

The remarkable phenomenon of phantom limb pain bridges the gap between biological and psychological mechanisms of pain. That is, pain is not simply biological. An individual may experience pain due to certain emotional states, memories of past pain experiences, upbringing and attitude, expectations, gender, and age. For instance, athletes playing in the heat of the moment may not feel serious pain, whereas a child who is fearful of receiving an injection may feel an exaggerated sense of pain. Furthermore, upbringing greatly influences individuals' attitudes towards pain, as some children are taught to bear pain quietly and thus have higher 'pain thresholds' (MayoClinic 2008).

Some individuals only need a little stimulation for their nerves to deliver pain messages. For example, elderly people complain less frequently of pain because of the body's general desensitization toward pain (Merck Manual 2007). There have also been studies that show that women with irritable bowel syndrome (IBS) who have suffered some form of abuse in the past are more sensitive to IBS-induced pain (MedlinePlus 2008). Expectations of pain can also alter an individual's response. Brain imaging supports the claim that an optimistic attitude serves to increase the effectiveness of treatments by enhancing the efficacy of prescription drugs. It has been found that, when an individual is expecting pain, he forms a mental image of the projected event by integrating past experiences and current circumstances. The areas of the brain responsible for this image interact with other areas of the brain responsible for pain processing, thus indicating that expectations play a role in the brain's interpretation of pain (Jones-London 2007).

Psychogenic pain is a disorder associated with psychological factors - there are no 'organic' causes of pain in this case because the symptoms simply do not match the complaints. But, the individual is actually experiencing pain, which is different from the patients who pretend that they are in pain, referred to as malingerers (University of Iowa Health Care 1998). This psychogenic pain can be caused by life stressors, drug abuse, alcoholism, hysteria, and even premenstrual tension in women (Wrong Diagnosis 2007). Headaches and muscle, back, and stomach pains are the most common types of psychogenic pain. Psychiatrists can diagnose which psychological processes are responsible for the pain. Current treatments include: psychotherapy, antidepressants, and non-narcotic painkillers (University of Iowa Health Care 1998). One specific case study of psychogenic pain involves an eight-year-old girl with abdominal pain and vomiting, s no obvious physical causes. An evaluation with a psychiatrist indicated that the pains had started after an accident that took her mother's life. The morning before the accident, the mother had bought her a coke and cupcake and so, the girl felt that her hunger was the reason for her mother's death. After subsequent psychotherapy, she was somewhat relieved of her guilt and the accompanying physical discomfort (Pederson 1975).



The spinal cord is divided into 'dermatomes' that receive information from throughout the body.

Conclusion

Though "mind over matter" may be an exaggeration, through the above examples, it can be seen that the sensation of pain is caused by the marriage of biological and psychological symptoms. Often, these symptoms complement each other, giving rise to a variety of techniques to alleviate pain. By understanding how both biological and psychological phenomenon affect the inherent nature of pain in human beings, researchers and medical professionals are able to optimize treatment depending on a specific individual's needs.

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