Neurobiology of Pain

By Neil Pearson

What is Pain?

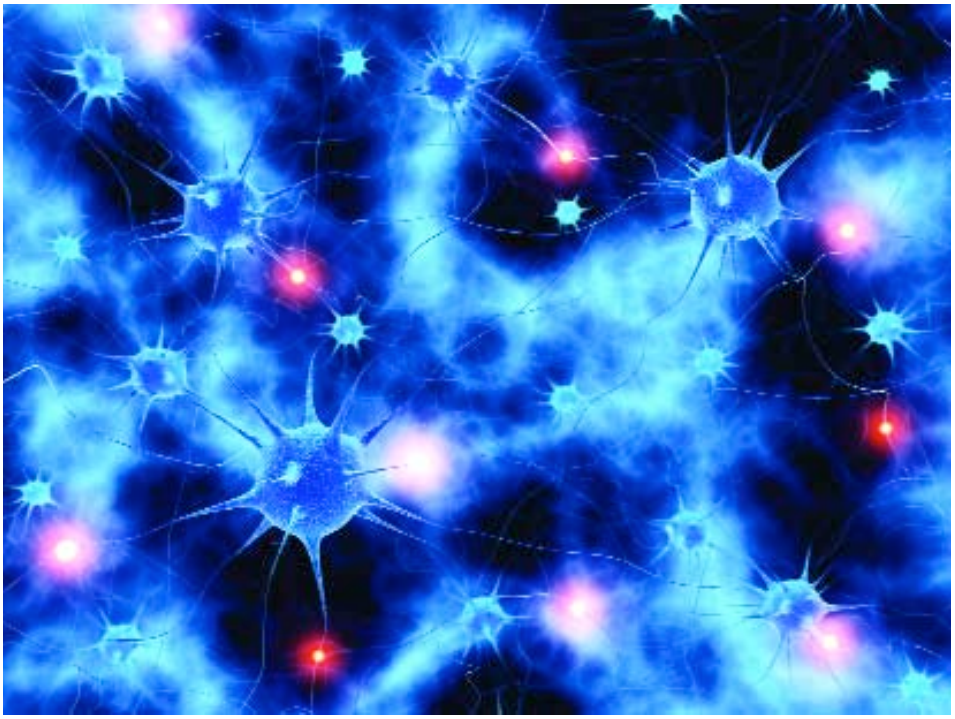
Pain is complex. It can arise for no apparent reason; it can be attributed to a specific event, an object or body part, or a physiological process or pathology. Ask a group of people how to complete the sentence "Pain is …*[blank]*" or to answer the question "What is the opposite of pain?" and its complexity becomes even more obvious. Pain is described as a symptom, a perception, the enemy, a teacher, a friend, and an experience; it is labeled as invisible, horrible, necessary, inevitable, and disabling. The opposite of pain can be stated as comfort, the absence of pain as bliss, calm, and sometimes, peace.

Pain is both a complex experience and a complex biological process. Yet its complexities are rarely explored, especially when we are in the midst of it. Only recently has science provided a new understanding of the physiological processes related to pain beyond the long-held views that pain and tissue damage are directly related. Understanding the intricacies of pain will help us respond to it in more helpful ways, both as yoga therapists and when we experience pain ourselves.

Neuroception Sometimes Starts with Nociception

Pain exists when neural circuits conclude that danger exists *and* that action is required.[1] As such, it is so much more than a symptom or a message telling us that there is something damaged or diseased in the body. Pain is an experience. It *motivates us to stop or change our behavior*.[2] Known as the *neuroception of danger*,[3] the experience begins subsequent to activity of special nerve cells (neurons) in the physical tissues of the body in response to potentially dangerous mechanical, chemical, or hot/cold stimuli. These neurons are called *nociceptors* because they are *receptors* (sensory neurons) that respond to potentially noxious stimuli, from the Latin word *noci*, meaning "to injure or hurt." Nociceptors are fascinating and multifunctional cells.

Nociceptors are classified as A-delta fibers or C fibers. Although both respond to similar stimuli, they are quite different in other ways. Because they are thicker and myelinated, A-delta fibers are able to send signals up to 20 meters per second. They primarily relay their information via the thalamus to the somatosensory cortex. C fibers are thinner and unmyelinated, so they send signals more slowly—up to 2 meters per second—and primarily relay their information via the thalamus to the insula. Recent research suggests that A-delta fiber inputs are the sensory apparatus of the central nervous system, whereas C fiber inputs are the sensory apparatus of the autonomic nervous systems.[4] The significance of these different types of fibers is that when something potentially dangerous occurs in the body, neurons can send signals to both the autonomic and central nervous systems and create a multitude of both automatic and volitional responses.



Nociceptors are found both internally—for example, in muscle, joints, and organs—and externally in the skin. Firing of nociceptive neurons is impacted by much more than what's occurring at the peripheral end of the neuron, where the sensors are. The signals they send are always influenced by activity in other peripheral nerves in the skin. For example, gentle stroking or applying soothing warmth over an area of pain can modify nociceptor signaling when it reaches the spinal cord.[5] Activity in the autonomic nervous systems, such as the increased sympathetic nervous system activity during a fight–flight response, can also enhance nociceptor reactivity. Even central nervous system activity such as expectations has been shown to either enhance or diminish how nociceptive signals are transmitted from the peripheral neurons to the spinal cord.[6] For example, believing that a posture will be painful or will aggravate an old injury can enhance nociceptive signaling, while a gentle comforting hand on our back or a calming breath can diminish the activity and signaling through nociceptive neurons.[3] In other words, each aspect of your nervous systems can influence nociceptors and nociceptive signaling. In fact, all systems of the body have an influence on these neurons, including respiratory, endocrine, cardiovascular systems, and especially the immune system. As such, it is important to view nociceptive neurons as dynamic. Their sensitivity, receptiveness, and sig-

(continued on page 14)

naling is always in flux, either adapting to (with less activity) or becoming hypervigilant (with more activity) to not only mechanical stresses or hot/cold and chemical stimuli, but to aspects of our internal and external environments.

Another fascinating aspect of nociceptors is that they are always ready and able to send danger signals toward the spinal cord and brain, even when there has not been any pain in a particular region or tissue of the body for weeks, months, or even years. Typically, cells that are not used will atrophy, so something different must be occurring with nociceptors. One possible explanation is that the cells are continuously active, always sending some signals to keep the nervous systems apprised of the physiological state of the body. This might lead one to wonder if we should actually be in pain all the time. However, these low-level signals can be inhibited by descending signals from the brain to the body, or they may be filtered out by brain mechanisms evaluating the importance or saliency of the signals. This is a similar situation to other physiological inputs that don't typically require your attention. For example, the brain is always getting information about skin temperature and bladder distention, but you don't know about this information until your attention is required and you need to act. This is important for two reasons: (1) it means that the experience of pain does not rely solely on nociceptive signaling from the body but also on neuronal cellular activity and processing in the central nervous system and (2) it means that when we experience increased pain, it may be the result of more nociceptive signals, the brain interpreting these signals as important for attention, or fewer descending inhibitory signals filtering the nociceptive inputs.

It is important to consider that nociception and pain are not only related to the activity of neurons. Neuronal activity is supported by cells referred to as glia, which were originally believed to be the cells "gluing" the nervous system together (the term *glia* means "glue"). Neurons make up only 10% of the brain's cells, while the majority of its cells are glia. These are considered to be neuroimmune cells.[7] The sophisticated interplay between both immune and neural cells and systems is beyond the scope of this article. However, given the potential links between yoga techniques and the immune system, this is an exciting area for us to observe as it develops.

Neuroception and the Brain

When we feel acute pain, many parts of the brain become more active. The amount of activity and the period of increased activity is as much dependent on the intensity of pain as it is on our thoughts, emotions, past experience, predictions of what this pain means for the future, our current internal physiological milieu, and all aspects of our external environment. In other words, just like tissue damage and pain intensity are not directly related, overall increases in brain activity are not directly related to pain intensity. The nervous systems—and even more so, the entire organism—are far too intricately interconnected for such a simplistic relationship.

The experience or perception of pain is believed to occur when neural circuits conclude that danger exists *and* action is required.

Beyond complexity, what we know about pain and the brain is that the brain does not have a pain center. When we experience pain, a network of brain areas is engaged. Interestingly, researchers have clearly demonstrated that this same network of brain areas is engaged during a number of experiences that can be theorized as important for defensive responses.[8] When we experience acute pain, the thalamus, insula, anterior cingulate cortex, dorsolateral prefrontal cortex, and primary and secondary somatosensory cortices typically become more active. Some researchers have unfortunately referred to this pattern of activity as the "pain neuromatrix," "pain network," or "pain signature." However, it is not specific to pain. This same network becomes more active when individuals experience potentially dangerous tactile vibration, noises, flashes of light, and experimentally induced social rejection.[8] In other words, this network is the *saliency* network—the network of brain activity that occurs when some form of defensive response is required. Ianetti goes so far as to state that this network allows us to bypass the details of an experience in favour of a defensive response, regardless of stimulus details.[9]

One key clarification is required here. Although we observe similar brain activity with acute nociception as with social rejection, this is not evidence that acute nociception is experienced in the person in exactly the same way as social rejection is or that social rejection should be treated with the same medications as acute tissue injury. There are similarities and differences in these experiences, and scientists have not yet found how to observe differences in how the brain encodes for the multitude of events we experience as potentially dangerous.

Brain scans of individuals with persisting pain* often differ from those with acute pain.[10-12] Differences are also observed related to differing pain conditions and how the experience of persisting pain has changed many aspects of the individual's life. However, since each part of the brain has many functions and each works in concert with many other areas, it is unwise to directly attribute specific changes seen on brain scans to the subjective experience of persisting pain. Possibly the most important thing to know about the changes that occur in the brain related to persisting pain is that they can be reversed—they are not permanent changes. Even those with disabling low-back pain who improve either via surgical intervention or with active rehabilitation show brain activity returning to normal when pain and function normalize.[13]

These changes in the nervous systems are referred to as *neuroplasticity*, which is defined as relatively enduring changes in the physiology (functioning) and structure (physical connections) of the nervous system. Learning something new, adapting to temperature variations, increasing tolerance to a noxious smell, and becoming more skilled in body awareness or a breathing technique are all associated with neuroplastic changes.

Research has shown neuroplastic changes in many brain areas in persisting pain, including important ones in the sensory and insular cortices, the amygdala and hippocampus, and the dorsolateral

*Persisting pain is often used as the preferred language for patients and clinicians. Although it is synonymous with chronic pain, it is a hopeful word, rather than suggestive of even worse pain to come.

(continued on page 16)

prefrontal cortex.[14] Changes in the sensory cortices have been related to the experience of pain spreading away from the original body area over time and to distortions of body awareness.[1] The insular changes, like sensory cortex changes, are often considered as both related to decreased sensory acuity and to body schema distortions experienced by many with persisting pain. Thankfully, there is evidence that the practice of body awareness leads to measureable neuroplastic changes in insula cell density and cellular interconnections[15] and may be associated with the benefits of decreased pain.

Learning something new, adapting to temperature variations, increasing tolerance to a noxious smell, and becoming more skilled in body awareness or a breathing technique are all associated with neuroplastic changes.

Increased activity reported in the amygdala is usually described as related to the increased hypervigilance and emotion turmoil (anxiety, grief, anger) of persisting pain. Unfortunately, when the amygdala is more reactive, it inhibits the hippocampus, one of the areas of the brain involved in spatial awareness (that we know is distorted in some individuals with persisting pain),[16] in turning short-term memory into long-term memory, and the ability to be present (temporal awareness).

The dorsolateral prefrontal cortex is associated with perceived control and with the brain's diffuse processes for inhibiting nociceptive inputs (diffuse noxious inhibitory control). The neuroplastic changes of decreased activity in this area on both the right and left hemispheres have been associated with learned helplessness and with increased pain from a diminished ability to inhibit nociceptive signaling via descending signals to the spinal cord.[17]

Nociception and the Autonomic Nervous Systems

According to Porges,[3] the neuroception of danger, and therefore our experience of pain, is impacted by activity of the vagus nerves. In his polyvagal theory, he describes three functions of the vagus nerves that serve to mediate our fight–flight response (sympathetic nervous system, SNS) and our freeze and social engagement responses (parasympathetic nervous system, PNS). Engaging the PNS inhibits the SNS and increases the neuroception of safety; this is related to greater inhibition of ascending nociceptive signaling.

When we breathe calmly and when we soften tension in the muscles of the face, vocal apparatus, and hearing, we increase the neuroception of safety. Complex alterations in the neural circuitry of the vagus nerve, the phrenic nerve,* the autonomic nervous system, insular cortex, anterior cingulate cortex, and the dorsolateral prefrontal cortices have all been implicated in the experiential changes, along with measurable changes in neurochemistry, cardiorespiratory, and cognitive and emotional factors.

Each of the factors listed below impact whether our neural circuits interpret movement as safe or dangerous. They are all highly interactive with the regions of the brain implicated in pain and the neural circuitry related to the neuroception of danger and safety. The experience and intensity of pain may well be intimately related to the current balance or imbalance between factors that increase and decreased the neuroception of danger:

- the mechanical pressure and/or stretch on the tissues
- how we are breathing
- the tension in face, jaw, and tongue muscles
- how we are listening and aware
- what we are thinking
- our emotional state

Many other factors are also implicated in the neuroception of safety. It is plausible that each of these may play a role in therapies and techniques used to create the neuroplastic changes related to less pain, greater ease of movement, and improved quality of life: social acceptance, compassionate listening, touch, music, smells, colors, fear, body awareness, body image, self-efficacy, and knowledge.

*The phrenic nerve provides motor and sympathetic supply to the diaphragm as well as sensory innervation to the fibrous aspects of the diaphragm, pericardium, and pleura, whereas the vagus nerve supplies parasympathetic innervation to the heart and organs.

The Role of Education in Changing the Experience of Pain

Moseley and others have studied the dramatic impact of knowledge on pain and recovery.[18-20] Findings from these randomized controlled trials (RCTs) showed that when individuals understood the role of the nervous systems in pain, their pain decreased, their ease of movement increased, and these immediate changes could persist for many months after just one session of education.

To date, few studies have measured brain changes related to the effects of explaining pain, although preliminary findings are promising. A case study report[21] showed that immediately following a single education session about pain neurobiology, brain scans of a woman with chronic low-back pain showed dramatic decreases in activity in the areas of the brain implicated in stress responses. Other findings reported in studies looking at the effects of education on pain neurobiology include diminished fear,[22] catastrophic thinking,[23] and peripheral sensitization.[24] In my opinion, when people understand how their pain is influenced by their thoughts and beliefs, their patterns of activity, and their social support systems, it increases their neuroception of safety and, by extension, it reduces their perception of pain. Adding support to the power of appropriate education are the research studies that demonstrate how education that focuses on pathology and fear-based language can lead to increased disability and pain.[25-26] These research findings on the power of education to change the experience of pain have direct implications for your clients. You might consider developing ways of incorporating pain education into your yoga therapy treatment plan. Many resources and workshops are available to assist with this.

Yoga is Education through Movement and Embodied Cognition

Multiple RCTs and four meta-analyses studying yoga[27-30] support the positive

(continued on page 52)

Case Report

continued from page 38

References

1. Garner, G. (Last sourced 2016). *Professional Yoga Therapy Institute.* Retrieved from http://proyogatherapy.org/about-pyts/

2. Rollnick, S., & Miller, W. R. (1995). What is motivational interviewing? *Behavioural and Cognitive Psychotherapy, 23*(4), 325–334.

3. Zimmerman, G. L., Olsen, C. G., & Bosworth, M. F. (2000). A 'stages of change' approach to helping patients change behavior. *American Family Physician, 61*(5), 1409–1416.

4. Ware, J. E., Snow, K. K., Kosinkski, M., & Grandek, B. (1993). *SF-36 Health Survey. Manual and Interpretation Guide.* Boston, MA: The Health Institute, New England Medical Center.

5. Garner, G. (2016). *Medical Therapeutic Yoga: Biopsychosocial Rehabilitation and Wellness Care.* East Lothian, Scotland: Handspring Publishing Ltd.

6. Garner, G. (2005). *Professional Yoga Therapy Institute Course Manual: Professional Yoga Therapy* Volumes I-II.

7. Pearson, N. (2016). Reconciling movement and exercise with pain neuroscience education: A case for consistent education. *Journal of Physiotherapy: Theory and Practice*, In Press.

8. Butler, D., & Moseley, G. L. (2003). *Explain Pain.* Adelaide, Australia: NOI Group Publishing.

9. Pearson, N. (Last sourced 2016). *Life is Now Pain Care.* Retrieved from www.lifeisnow.ca

10. Louw, A., Diener, I., Butler, D. S., Puentedura, E. J. (2011). The effect of neuroscience education on pain, disability, anxiety, and stress in chronic musculoskeletal pain. *Archives of Physical Medicine and Rehabilitation, 92*(12), 2041–2056.

11. Moseley, G. L., Nicholas, M. K., & Hodges, P. W. (2004). A randomized controlled trial of intensive neurophysiology education in chronic low back pain. *Clinical Journal of Pain, 20*(5), 324–330.

12. Pearson, N., & Prosko, S. (2014). *Overcome Pain with Gentle Yoga Levels 2 & 3 DVDs.* Life is Now Pain Care, Inc.

Shelly Prosko, PT, PYT, CPI, physical therapist and yoga therapist, is dedicated to promoting the integration of yoga therapy into our current healthcare system. She is a graduate of University of Saskatchewan, Professional Yoga Therapy Institute, and Life is Now Pain Care. She teaches at medical colleges, yoga therapy trainings, and conferences, and she offers workshops globally. www.physioyoga.ca

Yoga Therapy in Practice

continued from page 44

Yoga therapy has much to offer those in chronic pain. Almost 50 percent of Americans report having some type of chronic pain[10]—that's almost 160 million people whose lives could potentially be improved with your help! YTT

References

1. IASP Task Force on Taxonomy. (1994). Part III: Pain terms, A current list with definitions and notes on usage. In H. Merskey & N. Bogduk (Eds.) *Classification of Chronic Pain* (2nd Edition, 209–214). Seattle: IASP Press.

2. Finan, P. H., et al. (Feb. 2013). Discordance between pain and radiographic severity in knee osteoarthritis: Findings from quantitative sensory testing of central sensitization. *Arthritis and Rheumatism, 65*(2), 363–372.

3. Dunn, W. R., et al. (May 21, 2014). Symptoms of pain do not correlate with rotator cuff tear severity: A cross-sectional study of 393 patients with a symptomatic atraumatic full-thickness rotator cuff tear. *The Journal of Bone and Joint Surgery, American Volume, 96*(10), 793–800.

4. Barkhuizen, A., et al. (May, 1999). Musculoskeletal pain and fatigue are associated with chronic hepatitis C: a report of 239 hepatology clinic patients. *American Journal of Gastroenterology, 94*(5), 1355–1360.

5. Carragee, E. J., Alamin, T. F., & Miller, J. L. & Carragee, J. M. (2005). Discographic, MRI and psychosocial determinants of low back pain disability and remission: A prospective study in subjects with benign persistent back pain. *Spine, 5*(1), 24–35.

6. Westman, A. E., Boersma, K., Leppert, J. & Linton, S. J. (Sep. 2011). Fear-avoidance beliefs, catastrophizing, and distress: A longitudinal subgroup analysis on patients with musculoskeletal pain. *Clinical Journal of Pain, 27*(7), 567–577.

7. Feitosa, A. S., Lopes, J. B., Bonfa, E., & Halpern, A. S. (March 22, 2016). A prospective study predicting the outcome of chronic low back pain and physical therapy: The role of fear-avoidance beliefs and extraspinal pain. *Revista Brasiliera de Reumatologia (English Edition).* doi: 10.1016/j.rbr.2016.03.002.

8. Pedler, A., Kamper, S. J., & Sterling, M. (2016). Addition of posttraumatic stress and sensory hypersensitivity more accurately estimates disability and pain than fear avoidance measures alone following whiplash injury. *Pain.* doi: 10.1097/j.pain.0000000000000564.

9. Vallath, N. (2010). Perspectives on yoga inputs in the management of chronic pain. *Indian Journal of Palliative Care, 16*(1), 1–7.

10. Gallup. (2011). *Gallup-Healthways Well-Being Index.* Retrieved from http://www.gallup.com/poll/154169/Chronic-Pain-Rates-Shoot-Until-Americans-Reach-Late-50s.aspx?ref=image

Lori Rubenstein Fazzio, DPT, PT, MAppSc, YTRX, is on faculty in Loyola Marymount University's Master of Arts in Yoga Studies and Yoga Therapy Rx where she is director of the Level IV Yoga Therapy Internship at the Venice Family Clinic in Los Angeles. She is the founder of Mosaic Physical Therapy in Los Angeles, www.mosaicpt.com. She can be contacted at lori@mosaicpt.com.

Yoga Therapy in Practice

continued from page 50

When to Refer Clients

If the pain worsens or if clients have not experienced any relief in a couple of weeks, then I would recommend that they see a healthcare provider. There are some injuries to the knee that yoga cannot fix. For example, there are some meniscus tears that may be in the area where there is blood supply and healing can occur, but other meniscus tears may be more severe and/or not in the area that receives blood supply and may require surgical intervention.

When I worked for Dr. James Garrick at the Center for Sports Medicine, he would put all of his patients on a rehabilitation program to strengthen the VM at the very least, whether the patient was a candidate for surgery or not. Sometimes the rehabilitation would work well enough that no surgery was required. If the patient still needed surgery, they would recover faster because the extensor mechanism, in particular the VM, was already strong before surgery. With this in mind, yoga therapists can still play an important role when they work in tandem with other healthcare providers in helping to optimize their clients' health and outcomes even when surgery is necessary. YTT

References

1.DeAvilla Whiting, N. (2006). The role of yoga therapy in knee rehabilitation. *International Journal of Yoga Therapy,* 16, 79–94

2. Garrick, J. G., & Radetsky, P. (1989). *Peak condition: Winning strategies to prevent, treat, and rehabilitate sports injuries.* Random House Value Publishing

Nicole DeAvilla, E-RYT500, RPYT, RCYT, bestselling author, researcher, Two-Minute Yoga *host, pioneer in prenatal yoga and yoga therapy, has appeared on radio and TV. An Ananda-trained (1984) disciple of Paramhansa Yogananda, she serves through ministry, yoga therapist training, and yoga online.*