The legacy of phantom limbs
Phantoms once lurked at the extremities of the human body—now they are invading the brain! Sensations in amputated limbs have been described for centuries and they have been associated with activity in the brain, but a wider range of phantoms has now been related to brain function (see Ramachandran and Blakeslee 1998). Evidence of loss of limbs, through disease, accident, warfare, or ritual has been commented upon since records began. With this legacy, it is remarkable that reports of phantom limbs entered so late into medical records. Perhaps this was because few of those who had limbs amputated survived to describe their experiences. Ambroise Pare (1510–1590) made great strides in the surgical treatment for amputation; he applied ligatures to the large vessels in the limbs to staunch the bleeding following amputation, and he applied tourniquets above the site of severance. Figure 1 shows a portrait of Pare, together with illustrations of instruments and procedures that were employed in his time.

As a consequence of his improved surgical techniques, more of Pare’s amputees survived. Indeed, Pare (1649) described and illustrated a wide range of prostheses that could be used after amputation. These included mechanical hands, arms, and legs, all with moveable parts. To Pare’s great surprise, some of his patients reported sensations in the lost limb. The first phase of understanding any phenomenon is an adequate description of it. In this sense, Pare initiated medical interest in this intriguing phenomenon:

“Verily it is a thing wondrous strange and prodigious, and which will scarce be credited, unlesse by such as have seen with their eyes, and heard with their ears the Patients who have many months after the cutting away of the Leg grievously complained that they yet felt exceeding great pain of that leg so cut off.” (Pare 1649, page 338)

Once attention has been drawn to a phenomenon then its phenomenology can be examined in more detail, and it can be integrated into prevailing theories. This second phase is found in the speculations of René Descartes (1596–1650, figure 2). In his book on optics, Descartes (1637/1965) argued that all sensation is located in the brain.
Objections to this view were expressed by some of Descartes's correspondents, and he responded by commenting on reports of sensations in amputated limbs; they were used as evidence that all sensations take place in the brain. In subsequent letters concerning such sensations, Descartes attributed them to activity in the brain normally associated with the missing limb. He stated that this was a condition familiar to doctors and surgeons of the day:

“for they know that those whose limbs have recently been amputated often think they still feel pain in the parts they no longer possess. I once knew a girl who had a serious wound in her hands and had her whole arm amputated because of creeping gangrene. Whenever the surgeon approached her they blindfolded her eyes so that she would be more tractable, and the place where her arm had been was so covered with bandages that for some weeks she did not know that she had lost it. Meanwhile she complained of feeling various pains in her fingers, wrist and forearm; and this was obviously due to the condition of the nerves in her arm which had formerly led from her brain to those parts of her body. This would certainly not have happened if the feeling or, as he says, sensation of pain occurred outside the brain.” (Descartes 1991, page 64)

In addition, Descartes considered that the phenomenon indicated the unreliability of the senses. In his sixth meditation on The existence of material things, and the real distinction between mind and body he wished to “see whether the things which are perceived by that mode of thinking which I call ‘sensory perception’ provide me with any sure argument for the existence of corporeal things” (1984, page 51). The first aspect he considered was the perception of his own body parts, but doubt was cast upon this from examples of sensations in amputated limbs: “And yet I had heard that those who had a leg or an arm amputated sometimes still seemed to feel pain intermittently in the missing part of the body” (page 53). Finally, Descartes also used the phenomenon to support the unity of the mind in comparison to the fragmented nature of the body: “Although the whole mind seems to be united to the whole body, I recognize that if a foot or arm or any other part of the body is cut off, nothing has thereby been taken away from the mind” (1984, page 59).

There were many such reports in the eighteenth and nineteenth centuries, and Finger and Hustwit (2003) have described a number of them in detail, including the accounts by Silas Weir Mitchell (1829–1914). Mitchell (1871) treated injuries received by soldiers during the American Civil War, and he gave the sensations the name “phantom limb”. The purpose of this editorial is to highlight some of the benefits to the study of perception that have derived from examining the phantom phenomena, particularly in the eighteenth and early nineteenth centuries.

Almost all the early reports of phantom sensations were second-hand, so to speak. They relied on the amputees relating their experiences to physicians or surgeons. Most of the amputees had little prior medical experience, and the accuracy of their account was often dependent upon the literary skill of the surgeon. This was not the case for William Porterfield (c.1696–1771), who was able to give a first-hand account of his own phantom leg. Porterfield was a Scottish physician of some prominence and an authority on the senses (see Wade 2000; Wade and Finger 2003). He is best known for his two volume Treatise on the Eye, the Manner and Phenomena of Vision, the title page of which is shown in figure 2. The Treatise is based in part on two long essays he had written twenty years earlier on motions of the eyes (Porterfield 1737, 1738). The Treatise addressed the known anatomy and physiology of vision, but its principal aim was philosophical. Porterfield inveighed against Berkeley’s (1709) empiricist theory of vision by proposing that visual location is innate. He was also critical of the starting point for Berkeley’s theory, namely the two-dimensional retinal image. Phantom limb experiences were used to support his arguments. In addition to Porterfield’s nativist attack on empiricist theory, he was critical of Berkeley’s proposal regarding perceptual
learning. Porterfield argued that touch is as arbitrary in its representation of space as is vision, and therefore cannot teach vision external dimensions. He stated his position succinctly in the Treatise:

“But if, by the Touch alone, we can judge thus of the Situation and Distance of external Things, I see not why the same Power should be denied to the Sight.... for the tangible Ideas are as much present with the Mind as the visible Ideas, and, on that Account, must be equally incapable of introducing the Idea of any Thing external.” (1759b, pages 301 and 307)

In the period between writing his essays and his Treatise he had a leg amputated; in the Treatise Porterfield used his experiences of a phantom limb to support the projective features of perception generally. He was specifically attacking Berkeley’s theory that a pictorial image existed on the retina, and that this was perceived by the mind. He described his own experiences of a phantom limb in this same general context:

“Tho’ there was a Picture in the Retina in that vulgar gross Sense that so many imagine, yet it is impossible that the Mind could perceive it there; because all the Sensations or Perceptions of the Mind are present within it and in the Sensorium: I appeal to every one’s Experience, if he ever sees or observes any Pictures or any Thing else in the Retina. And to say we see, observe or perceive Pictures there, without being sensible or conscious of it is absurd and ridiculous. The Mind or sentient Principle does not at all perceive in the Retina, but in the Sensorium where it is present; for when, thro’ any Defect or Paralysis of the Nerve, the Motions or Vibrations impressed on the Retina by the Rays forming the Picture are not propogated to the Sensorium, or that the place in the Brain in which the Mind resides, the Mind perceives nothing; nor is it indeed possible it can perceive any thing; for whether the Mind be thought active or passive in its Perceptions, it is certain, that it can perceive nothing but what is present with it; for it can no more perceive where it is not, than when it is not; and it may as well be or exist where it is not, as act, suffer, or perceive where it is not. All Things perceived must therefore be present with the Mind and in the Sensorium, where the Mind resides; and that not only virtually, but substantially... It is therefore evident, that, did the Mind perceive Pictures in the Retina, it behoved to be there present: And for the same Reason, did it perceive in the other Organs of Sense, it behaved also to be present to all the Parts of the Body; because the Sense of Feeling is diffused thro’ all the Body: Nay, in some Cases it behaved

Figure 2. Left, René Descartes (1596–1650), after a portrait in Lavater (1799); right, the title page of volume 1 of Porterfield’s Treatise.
to be extended beyond the Body itself, as in the Case of Amputations, where the Person, after Loss of his Limb, has the same Perception of Pain, Itching, &c. as before, and feels them as if they were in some Part of his Limb, tho’ it has long been amputated, and removed from the Place where the Mind places the Sensation. Having had this Misfortune myself, I can the better vouch the Truth of this Fact from my own Experience; for I sometimes still feel Pains and Itchings, as if in my Toes, Heel or Ancle, &c. tho’ it be several Years since my Leg was taken off. Nay, these Itchings have sometimes been so strong and lively, that, in spite of all my Reason and Philosophy, I could scarce forbear attempting to scratch the Part, tho’ I well knew there was nothing there in the Place where I felt the Itching. And however strange this may appear to some, it is nevertheless no way miraculous or extraordinary, but very agreeable to the usual Course and Tenor of Nature; for, tho’ all our Sensations are Passions or Perceptions produced in the Mind itself, yet the Mind never considers them as such, but, by an irresistible Law of our Nature, it is always made to refer them to something external, and at a Distance from the Mind; for it always considers them as belonging either to the Object, the Organs, or both, but never as belonging to the Mind itself, in which they truly are; and therefore, when the nervous Fibres in the Stump are affected in the same Manner as they used to be by Objects acting on their Extremities in the Toes, Heel or Ancle, the same Notice or Information must be carried to the Mind, and the Mind must have the same Sensation, and form the same Judgment concerning it, viz, that it is at a Distance from it, as if in the Toes, Heel or Ancle, tho’ these have long ago been taken off and removed from that Place where the Mind places the Sensation. If this should prove hard to be conceived, it may be illustrated by what happens in the Sensation of Colours; for tho’ the Colours we perceive are present with the Mind, and in the Sensorium, yet we judge them at a Distance from us, and in the Objects we look at; and it is not more difficult to conceive how Pain may be felt at a Distance from us, than how Colours are seen at a Distance from us.” (1759a, pages 362–365, original italics)

Porterfield displays considerable sophistication in the analysis of his phantom limb, by associating the projective features of the experience with other aspects of perception. He was well-versed in Newtonian colour theory, and cited Newton many times. Indeed, he gave a quotation from Newton’s *Opticks* on the title page of volume 1 of his *Treatise* (see figure 2). The reference to colour relates to Newton’s statement that the rays are not coloured, but that the experience of colour is subjective and projected externally to objects. Porterfield was extending this subjectivity of sensation to phantom limbs, and incorporating the sensations into the body of perceptual theory. A similar relationship is drawn for the visual perception of direction, an aspect of spatial vision that exercised Porterfield considerably (see Wade 2000). He wrote:

“Now, as Objects seen by Reflection or Refraction appear and are seen, not in their true Place, but in some other Place from which they are absent, and that because the Rays fall upon the Eyes, and make a Picture on their Bottom, in the very same Manner as if they had come from the Object really placed there, without the Interposition of the Glass; so, when the Impression made upon the nervous Fibres of the Stump is the same as if it had come from the Object acting on their Extremities, the Sensation must also be the same, and the Mind, by forming the same Judgment concerning it, must feel it as in the Toes, Heel or Ancle &c. in which those nervous Fibres terminated before the Leg was taken off.” (Porterfield 1759a, pages 366–367)

Both Descartes and Porterfield employed the phantom limb sensations to advance their ideas about the nature of vision. Unlike Descartes, Porterfield does not regard the experiences of the lost limb as illusions, but as a natural consequence of stimulating the brain in a manner similar to that which existed prior to amputation. He integrated the phantom limb experiences with a general theory of perception, in which the sensations of sight as well as touch are experienced as projected externally from the sensorium or brain.

The third phase in understanding natural phenomena is to use them as tools to address other issues in related areas. For phantom limbs this was achieved by John
Hunter (1728–1793, figure 3) who proposed a putative doctrine of specific nerve energies on the basis of experiences related to him by amputees. In his book *Observations on certain Parts of the Animal Economy* he described two cases of phantom sensations in the missing penis:

“I knew a gentleman who had the nerves which go to the glans penis completely destroyed by mortification, almost as high as the union of the penis with the pubes; and at the edge of the old skin, at the root of the penis, where the nerves terminated, was the peculiar sensation of the glans penis; and the sensation of the glans itself was now only common sensation; therefore the glans has, probably, different nerves, and those for common sensation may come through the body of the penis to the glans. A serjeant of marines who had lost the glans, and the greater body of the penis, upon being asked, if he ever felt those sensations which are peculiar to the glans, declared, that upon rubbing the end of the stump, it gave him exactly the sensation which friction upon the glans produced, and was followed by an emission of the semen.” (Hunter 1786, pages 216–217)

The quotation above was a footnote, added to support Hunter’s speculation about the function of the nerves:

“For it is more than probable, that what may be called organs of sense, have particular nerves, whose mode of action is different from that of nerves producing common sensation; and also different from one another; and that the nerves on which the particular functions of each of the organs of sense depend, are not supplied from different parts of the brain. The organ of sight has its peculiar nerve; so has that of hearing; and probably that of smelling likewise; and on the same principle, we may suppose the organ of taste to have a peculiar nerve. Although these organs of sense may likewise have nerves from different parts of the brain; yet it is most probable that such nerves are only for the common sensations of the part, and other purposes answered by nerves... it is more probable, that every nerve so affected as to communicate sensation, in whatever part of the nerve the impression is made, always gives the same sensation as if affected at the common seat of the sensation of that particular nerve.” (1786, pages 215–216)

Hunter considered that all senses responded to touch and pain (common sensation), in addition to their specific sensations. He restricted his discussions to the anatomical and physiological consequences of phantom sensations, unlike Porterfield whose nativist theory of space perception was in opposition to the prevailing empiricism. Erasmus Darwin (1731–1802, figure 3) interpreted phantom limbs within the context of empiricist philosophy, in which the emphasis was placed on the association of ideas from different senses. Such a sensorimotor account was given in his brief mention of...
the phenomenon in *Zoonomia*, which was described in the chapter on “Motions of the retina”:

“After the amputation of a foot or a finger, it has frequently happened, that an injury being offered to the stump of the amputated limb, whether from cold air, too great pressure, or other accidents, the patient has complained of a sensation of pain in the foot or finger, that has been cut off. Does this not evince that all our ideas are excited in the brain, and not in the organs of sense? This objection is answered, by observing that our ideas of shape, place, and solidity of our limbs, are acquired by our organs of touch and of sight, which are situated in our fingers and eyes, and not by any sensations in the limb itself. In this case the pain or sensation, which formerly has arisen in the foot or toes, and been propagated along the nerves to the central part of the sensorium, was at the same time accompanied with a visible idea of the shape and place, and with a tangible idea of solidity of the affected limb: now when these nerves are afterwards affected by injury done to the remaining stump with a similar degree or kind of pain, the ideas of the shape, place, or solidity of the lost limb, return by association; as these ideas belong to the organs of sight and touch, on which they were first excited.” (Darwin 1794, page 28)

Loss of the penis appears to have been a particular hazard for soldiers, as another instance was reported in the late eighteenth century by Marshal (1815), and Charles Bell (1774 – 1842, figure 4) referred to it obliquely in his *Idea of a New Anatomy of the Brain* (Bell 1811/2000). Bell made recourse to phantom limb sensation to support his view that the seat of sensation is in the brain; however, his sensibilities led him to express the report of sensations in the missing penis in Latin:

“It may be said, that there is here no proof of the sensation being in the brain more than in the external organ of sense. But when the nerve of a stump is touched, the pain is as if in the amputated extremity. If it be still said that this is no proper example of a peculiar sense existing without its external organ, I offer the following example: Quando penis glandem exedat ulcer, et nihil nisi granulatio maneat, ad extremam tamen nervi pudice partem ubi terminatur sensus supersunt, et exquisitissima sensus gratificatio.” (Bell 1811/2000, pages 11 – 12)

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**Figure 4.** Left, Charles Bell (1774 – 1842) after a frontispiece engraving in George Bell (1870); right, Johannes Müller (1801 – 1858) after an illustration in Hirsch (1929).
Bell provided a more fully formulated doctrine of specific nerve energies than Hunter’s (see Wade 2003); it was based upon this and other phenomena:

“In this inquiry it is most essential to observe, that while each organ of sense is provided with a capacity for receiving certain changes to be played upon it, as it were, yet each is utterly incapable of receiving the impression destined for another organ of sensation. It is also very remarkable that an impression made on two different nerves of sense, though with the same instrument, will produce two distinct sensations; and the ideas resulting will only have relation to the organ affected.” (Bell 1811/2000, pages 8 – 9)

The doctrine of specific nerve energies is, of course, associated with Johannes Müller (1801 – 1858, figure 4), and his initial formulation of it in 1826, followed by its full expression over a decade later in his Elements of Physiology, which has just been reprinted (Müller 2003). The first statement was brief:

“The eye does not radiate, the ear does not sound, the tongue is not salty, sour, etc Only external objects radiate, sound, and so forth. The sense organs experience the external light, sound, etc with difficulty; the different sense organs only have a so-called specific receptivity for particular stimuli.” (1826, pages XII – XIII)

It was restated in greater detail in Müller’s Elements (pp 1059 – 1086), where ten consequences of the doctrine are described. Müller also provided descriptions of thirteen cases of sensations following amputation. His summary of the effects of amputation is astute:

“When a limb has been removed by amputation, the remaining portion of the nerve which ramified in it may still be the seat of sensations, which are referred to the lost part.—This is a fact known to all surgeons, and is subject to no exception. It is usually said that the illusion continues for some time, namely, as long as the patient is under the care of the surgeon; but the truth is, that in most cases it persists throughout life: of this it is easy to convince oneself by questioning a person whose limb has been amputated, at any period after the operation. The sensations are most vivid while the surface of the stump and the divided nerves are the seat of inflammation, and the patient complains of severe pains felt, as if in the whole limb which has been removed. When the stump is healed, the sensations which we are accustomed to have in a sound limb are still felt; and frequently throughout life tingling, often pains, are felt, which are referred to the parts that are lost. These sensations are not of an undefined character; the pains and tingling are distinctly referred to single toes, to the sole of the foot, to the dorsum of the foot, to the skin, &c. These important phenomena have been absurdly attributed to the action of the imagination, &c. They have been treated merely as a curiosity; but I have convinced myself of their constancy, and of their continuance throughout life,—although patients become so accustomed to the sensations that they cease to remark them.” (Müller 2003, pages 745 – 746, original italics)

Müller’s claim that the experience of phantom limb sensations in amputees was universal needs to be modified slightly: Mitchell found that eighty-six of ninety cases he examined reported sensations in the missing limb (Finger and Hustwit 2003). These features make the absence of reports before Paré even more surprising. Limbs have been amputated because of damage or disease for millenia, and some must have survived the trauma of amputation to experience these enigmatic feelings. Moreover, the common feature of all reports is the existence of localised pain in the severed part; other sensations associated with the skin and muscles (like being touched, temperature sensitivity or movement) have not been so commonly reported.

The phenomena associated with phantom limbs continue to intrigue and excite us, as is evident from Ramachandran and Blakelk’s (1998) book. Despite the puzzles they still pose, these phantoms have provided perception with a tangible legacy.

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