The left recurrent laryngeal nerve design in mammals is not poor design

Jerry Bergman

A common claim by evolutionists is that the mammalian left recurrent laryngeal nerve was poorly designed because it travels downward past the larynx, then around the aorta and, last, back up to the larynx. They reason that a much shorter route directly to the larynx would be far more effective. This analysis concludes that the reasons for the longer route include both developmental and design constraints. Furthermore, the evidence for intelligent design of this arrangement is both obvious and compelling.

Evolutionists commonly claim that the human body is poorly designed, and that this proves it was not intelligently designed, but rather cobbled together by the unintelligent process of evolution. One of the most common examples of poor design cited by evolutionists today is that of the *recurrent laryngeal nerve* (RLN), which controls the larynx (voice box) muscles. The claim is often made by Darwinists that evolution is proved because examples of "poor or at least very puzzling design can be accumulated endlessly", and one of the best examples is

> "… the recurrent laryngeal nerve, which connects the brain to the larynx and allows us to speak. In mammals, this nerve avoids the direct route between brain and throat and instead descends into the chest, loops around the aorta near the heart, then returns to the larynx. That makes it seven times longer than it needs to be!"[1]

The main argument is that the laryngeal nerve is poorly designed because it does not take the shortest route to the larynx, a condition also true for many other nerves. Examples include the optic nerves, which do not take the shortest route to the occipital lobe of the brain, but rather cross over at the optic chiasm for what are now known to be very good reasons rooted in optimal design.[2]

Likewise, except for the right and left frontal branches of a facial nerve, which are supplied by both sides of the brain, the nerves *from the right side of the brain* innervate the *left* side of the body.

Professor Richard Dawkins claims that the RLN is also proof of human evolution from fish. He writes that during the putative evolution of mammals

> "… the neck stretched (fish don't have necks) and the gills disappeared, some of them turning into useful things such as the thyroid and parathyroid glands, and the various other bits and pieces that combine to form the larynx. Those other useful things, including the parts of the larynx, received their blood supply and their nerve connections from the evolutionary descendants of the blood vessels and nerves that, once upon a time, served the gills in orderly sequence."[3]

However, no scientific evidence exists to support gills "turning into useful things such as the thyroid and parathyroid glands". Gill cells are very different from endocrine cells. Dawkins concludes:

> "As the ancestors of mammals evolved further and further away from their fish ancestors, nerves and blood vessels found themselves pulled and stretched in puzzling directions, which distorted their spatial relations one to another. The vertebrate chest and neck became a mess, unlike the tidily symmetrical, serial repetitiveness of fish gills. And the recurrent laryngeal nerves became more than ordinarily exaggerated casualties of this distortion."[3]

Anyone who has studied human anatomy knows that the vertebrate chest and neck are not a "mess", but a well-designed, complex, functional system.

RLN anatomy

As we will show, the left RLN, which supplies the mammalian larynx and intrinsic epiglottis muscles, has an anatomical trajectory very different from what one would first expect and for very good reasons. In contrast to Prothero's claim, the RLN does not avoid "the direct route between brain and throat" but "instead descends into the chest, loops around the aorta near the heart, then returns to the larynx."[1] Rather, the *vagus* nerve travels from the neck down toward the heart, and *then* the recurrent laryngeal nerve *branches* off from the vagus just below the aorta (the large, main artery extending upward from the left ventricle of the heart and extending down the abdomen). Last, as will be detailed below, these branches travel upward to innervate several organs, some near where it branches off of the vagus nerve.[4]

Nerve signals that control various bodily operations travel from the brain, down the spine or the cranial nerves, and then branch off to connect to the organs that they serve. The larynx is located in the neck, and in an embryo the right laryngeal nerve branches off of the vagus nerve in the neck area.[5]

In adults, though, rather than taking the direct route from the vagus nerve to the larynx in the neck area, the

left vagus nerve travels down the neck into the chest near the heart on its way to provide cholinergic innervation to numerous internal organs. The laryngeal nerve branches off of the vagus nerve in the chest area, then loops *under* the posterior side of the aorta just above the heart and, last, travels *back up* to the larynx. For this reason it is called the *left recurrent laryngeal nerve*. In contrast, the right laryngeal nerve loops around the subclavian artery, and then travels up to the larynx. Of note is the fact that the longer left RLN works perfectly in harmony with the right RLN, precluding the claim that it is a poor or faulty design.

Reasons for the design

The most logical reason for this design is that it is due to developmental constraints. Embryologist Professor Erich Blechschmidt wrote that the recurrent laryngeal nerve's seemingly poor design in adults is due to the "necessary consequences of developmental dynamics and are not to be interpreted … as historical carryovers" from evolution.[6]

Human-designed devices, such as radios and computers, do not need to function until their assembly is complete. By contrast, living organisms must function to a high degree in order to thrive during every developmental stage from zygote to adult (figure 1). The embryo as a whole must also be a fully functioning system in its specific environment during every second of its entire development. For this reason adult anatomy can be understood *only* in the light of zygote-to-adult development:

> "The pathway for nerve fibers is normally prescribed by the organs-to-be-innervated and is therefore laid down from without. We must assume that submicroscopic material (i.e., molecular) movements are decisive for this process; namely, that ordered metabolic movements work in a manner that determines the form of the incipient innervation pattern."[7]

An analogy Blechschmidt uses to help elucidate his argument is the course of a river, which

> "… cannot be explained on the basis of a knowledge of its sources, its tributaries, or the specific locations of the harbors at its mouth. It is only the total topographical circumstances that determine the river's course."[7]

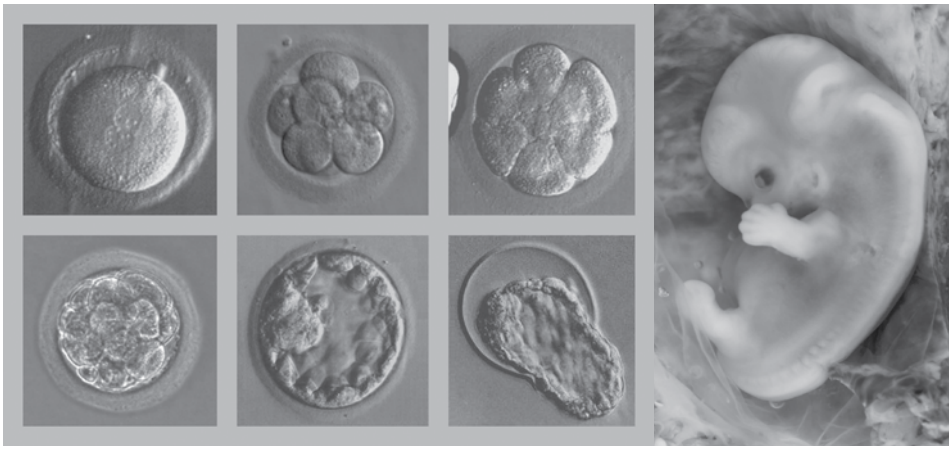
Due to variations in the topographical landscape of the mammalian body, the "course of the inferior laryngeal nerve is highly variant" and minor anatomic differences are common.[8] This fact has been documented by a series of neck dissections completed on 90 human cadavers 48 hours following death to study the anatomy of the right and left recurrent laryngeal nerves. The dissections found that the path of these nerves was sometimes different from that shown in the standard medical literature, illustrating Blechschmidt's analogy.[9] An interesting result of the RLN design is that it can be an indicator of vascular disease to a physician, i.e. an enlargement of the aorta or subclavian artery caused by an aneurysm may compress the left RLN, causing vocal dysfunction.[10] As a result. vocal dysfunction can be indicative of an aneurysm.

Developmental considerations

The human body begins as a sphere called a blastocyst and gradually becomes more elongated as it develops. Some structures, such as the carotid duct, are simply obliterated during development, while others are eliminated and later replaced as the foetus matures. Other structures, including the recurrent laryngeal nerve, are moved downward as development proceeds. The reason for this movement is that the neck formation and elongation of the body that occurs during foetal development forces the heart to descend from the cervical (neck) location down into the thoracic (chest) cavity.[11]

As a result, various arteries and other structures must be elongated as organs are moved in such a way so as to remain functional throughout this entire developmental phase. The right recurrent laryngeal nerve is carried radically downward because it is looped under the IV arch, which develops into the right subclavian artery, and thus is forced to move down with it.[12]

In cases where the right IV arch is absorbed, the right recurrent laryngeal nerve does not recur but connects directly into the larynx.[9] The left laryngeal nerve recurs around the ligamentum arteriosum (VI arch, a small ligament attached to the top surface of the pulmonary trunk and the bottom surface of the aortic arch) on the left side of the aortic arch, and thus must move down as the thoracic cavity lengthens. Blechschmidt notes that:



Zygote: Jrockley and Embryo: Ed Uthman, MD: wikimedia.org

Figure 1. In the very early stages of embryo development elongation is required to change a spherical structure eventually into the normal, tall, human body. At each stage of development the organism must be alive and also requires designed modifications as it develops.

> "No organ could exist that is functionless during its development. This axiom applies to the nervous system. The nervous system achieves its subsequent performances on account of its previous growth functions."[13]

As a result of the downward movement "of the heart and the disappearance of the various portions of the aortic arches, the course of the recurrent laryngeal nerves becomes different on the right and left sides".[11] Before this shift, these two nerves supply the sixth brachial arches, but as the heart descends the left nerve hooks around the sixth aortic arch, and then ascends again up to the larynx, thus accounting for their recurrent course. These nerves cannot either be obliterated or replaced because the nerve must function during every foetal development stage. Sadler explains that on the right side

> "… the distal part of the sixth aortic arch and the fifth aortic arch disappear, the recurrent laryngeal nerve moves up and hooks around the right subclavian artery. On the left, the nerve does not move up, since the distal part of the sixth aortic arch persists as the ligamentum arteriosum."[14]

This movement appears designed to drag the left RLN downward as the abdominal cavity elongates. Sadler also notes that because the

> "… musculature of the larynx is derived from mesenchyme of the fourth and sixth brachial arches, all laryngeal muscles are innervated by branches of the tenth cranial nerve, the vagus nerve. The superior laryngeal nerve innervates derivatives of the fourth brachial arch, and the recurrent laryngeal nerve derivatives of the sixth branchial arch."[15]

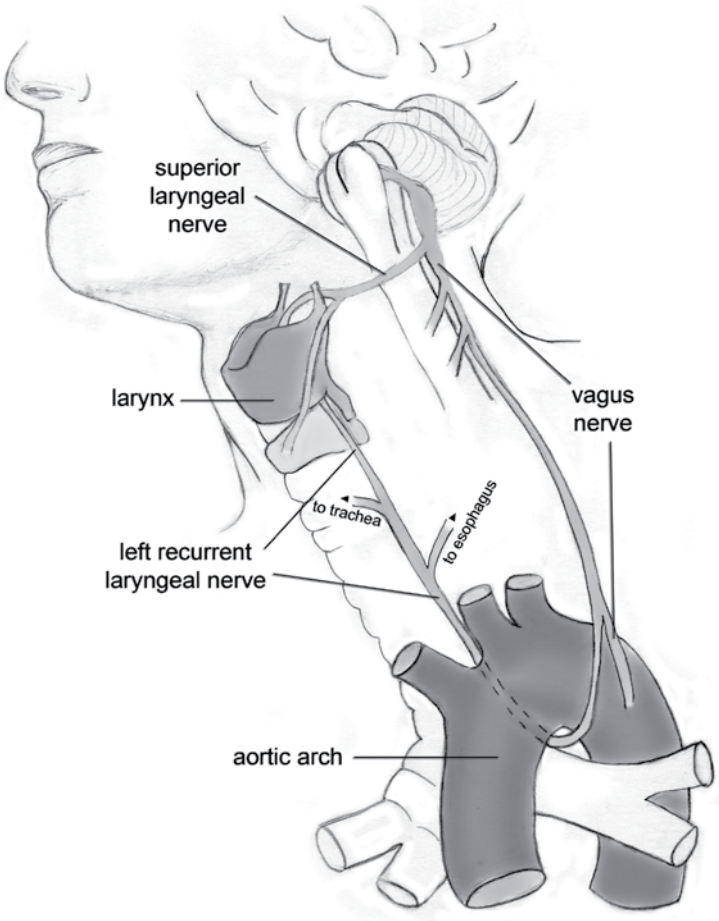


Figure 2. A diagram of the left recurrent laryngeal nerve which branches off from the vagus nerve. Note that the superior laryngeal nerve transverses directly to the larynx, and the recurrent laryngeal nerve innervates several structures as it travels back up to the larynx.

The body must function as a living functional unit, requiring ligaments and internal connections to secure various related structures together, while also allowing for both growth and body/organ movement required for the flexibility necessary for normal daily activities. For the laryngeal nerve, the ligamentum arteriosum functions like the hyoid bone to allow movement. Nerves cannot normally be severed during foetal development and then regrown somewhere else, nor can the body sever nerves to allow the movement of existing nerves elsewhere where they reconnect (figure 2).

Other cases exist of one nerve splitting off early and providing direct innervations, and another taking what seems like a circuitous route. One example is the phrenic nerve (c3, c4, c5 fibers), which arises in the neck and descends to the diaphragm. This is a necessary trajectory since the pericardium and diaphragm arise in the septum transversum (a thick mass of cranial tissue that gives rise to parts of the thoracic diaphragm and the ventral mesentery of the foregut) in the neck area of the early embryo. It then migrates caudally (toward the tail bone) as the embryo enlarges by differential growth of the head and thorax areas, taking the nerve with it. A diaphragm could not have evolved step-wise since a partial diaphragm with a defect results in an imperfect chest–abdomen separation, and even a small defect results in herniation of the gut contents into the chest—which either compresses the lungs or results in strangulation of the gut.

For all these reasons Prothero's claims quoted below are both incorrect and poorly considered:

> "Not only is this design wasteful, but … the bizarre pathway of this nerve makes perfect sense in evolutionary terms. In fish and early mammal embryos, the precursor of the recurrent laryngeal nerve [is] attached to the sixth gill arch, deep in the neck and body region."[1]

The RLN similarity in all vertebrates, including fish and mammals, is due to similar embryo and foetal development as a result of developmental constraints and similar morphology as an adult. It is not because we evolved

from fish, as Prothero claims, something which fossil or other evidence does not support.

Other functions of the RLN

Furthermore, the recurrent laryngeal nerve branches serve several other organs, including the upper esophagus, the trachea, the inferior pharynx, and the circopharyngeus, providing both motor and sensory branches that require its existing design.[16,17] This arrangement allows the structures *below* the larynx to receive signals slightly sooner than the larynx to prepare them for laryngeal action when such function is imminent.

In addition "the laryngeal branch splits up into other branches before entering the larynx at different levels."[16] Neuroanatomists describe larynx innervation as very complicated and they are still trying to work out the specific targets of its nerve branches. The fact that left RLN also gives off some fibers that connect to the *cardiac plexus* is also highly indicative of developmental constraints because the nerve must innervate both the larynx (in the neck) and the heart (in the chest).

A complex issue still being researched is how the incredibly complex nerve–muscle system, consisting of nerve fibers and the laryngeal muscles, arises from the neural crest and dorsal somites respectively in the early embryo and migrates anteriorly into its final position. Claiming that the RLN is poorly designed without explaining how the nerve structure design, its function, and its ultimate origination and connections in the brain developed from embryo to an adult is meaningless. Thus, the claim that it has to loop up the distance from the ligamentum arteriosum for no reason is invalid.

The redundant pathway design

Some innervations to the larynx travel directly to it, including the *sensory internal laryngeal nerve* and the *motor external laryngeal nerve*. Two other nerves, the left and right *superior laryngeal nerves*, branch off close to the larynx to provide this structure with direct innervation. The superior laryngeal nerve branches off the vagus at the middle of the *ganglion nodosum* and receives a branch from the superior cervical ganglion of the sympathetic nervous system.[18]

Aside from the developmental reasons for the circuitous route of the RLN, potential benefits of overlapping sensory and motor innervations exist when one of the nerves is slightly longer. Better understanding the laryngeal innervation will help us to understand the necessity for the slightly longer route for a nerve, but a strong hint is provided from the fact that the two nerves regulate different vocal responses.

The superior laryngeal nerve divides into internal and external branches. The external branch controls an internal laryngeal muscle, the cricothyroid muscle[19] and innervates muscles responsible for an increasing pitch. The various other branches of the recurrent laryngeal nerve innervate muscles responsible for functions including reducing pitch, controlling loudness, and vocal fatigue. The three main branches of the RLN innervate several muscle bundles including the Thyoarytenoid muscle, the posterior Cricoarytenoid muscle and the lateral Cricoarytenoid muscle. Damage to the nerves that innervate these muscles affects articulation, and when articulation is impaired, speech is perceived as "slurred" or "garbled".[20]

Paralysis of the *superior laryngeal nerve* (the non-circuitous nerve) causes difficulty in increasing voice loudness, producing a high pitch, and results in vocal fatigue and an inability to sing because the vocal cords lack their normal tone and cannot sufficiently lengthen. In contrast, paralysis of one or more of the three branches of the *recurrent laryngeal nerve* can result in a weak voice that sounds like Mickey Mouse. In severe cases, paralysis of the vocal cords can result.[19]

One patient, who suffered from a traumatic rupture of his aortic arch in a car accident, required an aortic graft that left him with a damaged left RLN. The only adverse result was that his voice was feeble, but his articulation was unaffected. He speaks perfectly well but cannot project his voice due to the fact that the laryngeal muscles have multiple innervations and the set, *as a unit,* control its function (Interview with Dr Vij Sodera).

Another reason why the laryngeal nerve branches (both of which branch off the vagus) are located both above and below the larynx is that this design allows some preservation of function if either one is interrupted. The redundant pathway also provides some back-up in case of damage to one of the nerves.

Last, several studies found that the existing path occupies "a relatively safe position in the tracheoesophageal groove" between the trachea and esophageus[21] that renders it less prone to damage or injury than a more direct route.[22]

The RLN in Giraffes

The example favoured by those who claim that the RLN is poorly designed is the giraffe (figure 3). Prothero wrote that the giraffe RLN "traverses the entire neck twice, so it is fifteen feet long (fourteen feet of which are unnecessary!)."[1] Dawkins claims that in humans

> "… the route taken by the recurrent laryngeal nerve represents a detour of perhaps several inches. But in a giraffe, it is beyond a joke—many feet beyond—taking a detour of perhaps 15 feet in a large adult!"[3]

Dawkins added that the "length of the detour taken by the recurrent laryngeal" required a team of anatomists to simultaneously work on different stretches of the nerve to tease out the RLN, which he notes is "a difficult task that had not, as far as we know, been achieved since Richard Owen, the great Victorian anatomist, did it in 1837." The difficulty is due to the fact that the RLN "is very narrow, even thread-like in its recurrent portion" and consequently

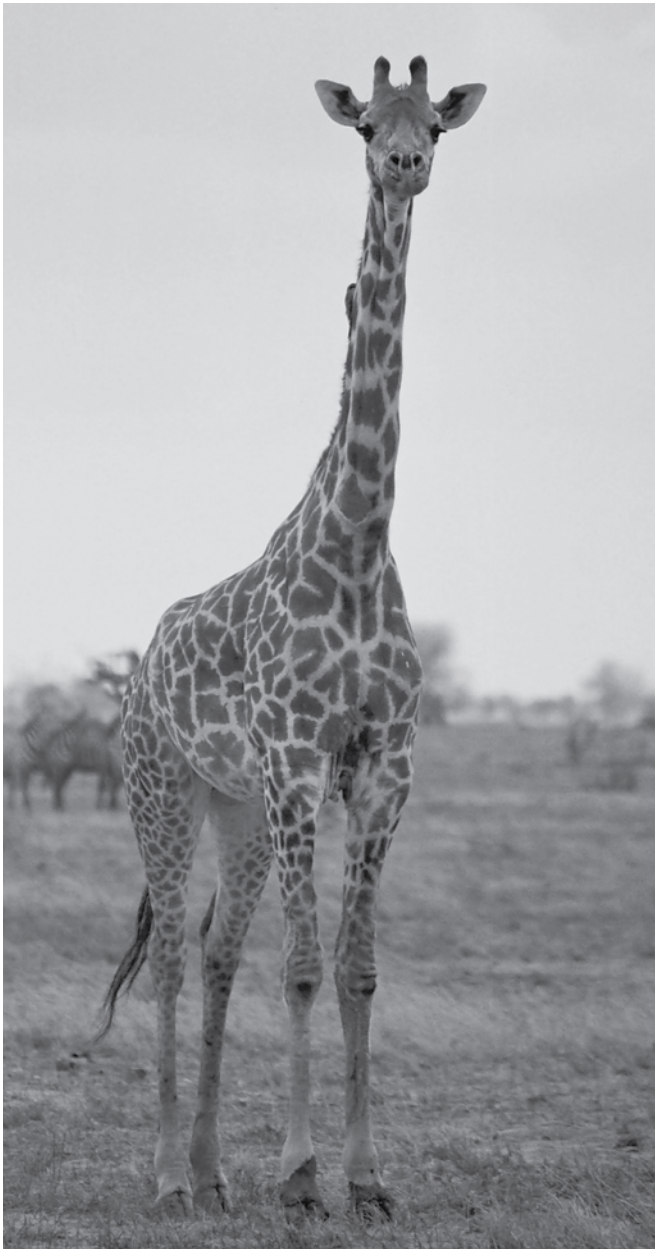


Photo by: Hollie Jeans, SXC

Figure 3. A giraffe illustrates an extreme example of the required length of the left recurrent laryngeal nerve, yet the system functions very effectively. Many other complex design features are also needed to create the famous long giraffe neck.

> "… is easily missed in the intricate web of membranes and muscles that surround the windpipe. On its downward journey, the nerve (at this point it is bundled in with the larger vagus nerve) passes within inches of the larynx, which is its final destination. Yet it proceeds down the whole length of the neck before turning round and going all the way back up again … I found my respect for Richard Owen (a bitter foe of Darwin) going up. The creationist Owen, however, failed to draw the obvious conclusion. Any intelligent designer would have hived off the laryngeal nerve on its way down, replacing a journey of many metres by one of a few centimetres."[23]

Many of the same comments that relate to humans discussed above also apply to the giraffe. The giraffe embryo lacks a neck and lengthens, as does the human embryo, only much more because its neck is designed to be much longer than in humans. Consequently, it moves the RLN down with it as the neck lengthens. Dawkins claims the giraffe's neck lengthened over evolutionary time, even though no evidence exists for giraffe neck evolution.[24] He concludes that "the cost of the detour—whether economic cost or cost in terms of 'stuttering'—gradually increased" as the neck evolved.[25]

It is true that the significant difference in lengths of the right/left RLN results in the impulses arriving at the giraffe laryngeal muscles at slightly different times, but the impulses along the longer route of the left RLN are adjusted for by the brain in order for the right/left larynx muscles to function smoothly. This indicates forethought in design to compensate for the developmental constraints resulting in right/left RLN length differences. Although giraffes do not talk, thus cannot stutter as Dawkins claims, and make very little noise, they do have a functional larynx.

Dawkins then claims that as the "giraffe's neck began to approach its present impressive length, the *total* cost of the detour might have begun to approach the point where—hypothetically—a mutant individual would survive better if its descending laryngeal nerve fibres hived themselves off from the vagus bundle and hopped across the tiny gap to the larynx.[26] Dawkins recognizes that this mutation is not feasible because the mutation required

> "… to achieve this 'hop across' would have to have constituted a major change—upheaval even—in embryonic development. Very probably, the necessary mutation would never happen to arise anyway. Even if it did, it might well have disadvantages—inevitable in any major upheaval during the course of a sensitive and delicate process. And even if these disadvantages might eventually have been outweighed by the advantages of bypassing the detour, the *marginal* cost of each millimeter of *increased* detour *compared with the existing detour* is slight. Even if a 'back to the drawing board' solution would be a better idea if it could be achieved, the competing alternative was just a tiny increase over the existing detour, and the *marginal* cost of its tiny increase would have been small. Smaller, I am conjecturing, than the cost of the 'major upheaval' required to bring about the more elegant solution."[26]

Dawkins' argument here is an excellent and valid argument against the whole evolution-by-mutations theory of evolution. He concludes that his main point is that "the recurrent laryngeal nerve in any mammal is good evidence against a designer" but

> "… is exactly the kind of thing we expect from evolution by natural selection, and exactly

the kind of thing we do *not* expect from any kind of intelligent designer … If this were designed, nobody could seriously deny that the designer had made a bad error. But, just as with the recurrent laryngeal nerve, all becomes clear when we look at evolutionary history."[26]

Conclusions

The left recurrent laryngeal nerve is not poorly designed, as claimed by Darwinists, but rather is evidence of both good and intelligent design. No evidence exists that the design causes any disadvantage, and much evidence exists in favour of the conclusion that the existing design results from developmental constraints and also serves to fine-tune laryngeal functions. The arguments presented by evolutionists are incorrect and have discouraged research into the specific reasons for the existing design.

The constraints resulting from foetal development are actually similar to the evolutionists' argument. The only difference is that there are two different developments involved, 1) ontogeny, which is referred to in this paper, and 2) phylogeny which is referred to by evolutionists. The evolutionary 'proof' becomes worthless when an equally valid explanation exists based on the individual's historical development, the ontogeny.

To argue that the RLN is poorly designed is to imply that God should have used different embryo development trajectories for all the structures involved to avoid looping the RLN around the aorta. One who asserts that the RLN is a poor design assumes that a better design exists, a claim that cannot be asserted unless an alternative embryonic design from fertilized ovum to foetus (including all the incalculable molecular gradients, triggers, cascades and anatomical twists and tucks) can be proposed that would document an improved design exists. Lacking this information, the 'poor design' claim is an 'evolution of the gaps' explanation. Each alternative embryonic design or developmental pathway would likely result in its own unique set of constraints, also giving the false impression of poor design.

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