International Journal of Anatomy and Applied Physiology (IJAAP)
ISSN: 2572-7451

An Innovative Technique in Anatomy Pedagogy: The Flexagon as a Model of Gastrulation in Embryology

Research Article

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Abstract

Research confirms anatomy is considered the corner stone subject within the medical curriculum and in clinical procedures ensuring safe medical practice by surgeons, doctors and a diverse range of medical specialists. Anatomists agree that understanding embryology is essential for gaining a comprehensive understanding of anatomy providing the necessary, essential, context to ensure accurate diagnosis and treatment of patients. These two widely agreed opinions seem to be at odds with the reduced time and resources devoted to anatomy and embryology within medical education in the United Kingdom and elsewhere. The objective of this short paper is to promote learning activities that will inspire anatomy educators to delve deeper into medical embryology and help make important concepts such as invagination more understandable through kinaesthetic experience. Construction of an innovative technique for teaching anatomy generally and gastrulation specifically is proposed. Our proposed learning activity points to the need for studies looking at how learners respond to acquiring knowledge this way. Whether learners perform better upon assessment because of this activity could be examined through a pre/post-test study. Pedagogical strategies that engage the student while requiring active participation on their part has been demonstrated to be an effective learning tool when teaching anatomy. Embryonic morphogenesis involves the process of gastrulation occurring at the third week of human development. A 3-Dimensionality of gastrulation involves the transformation of a one-dimensional blastula (a single plane of epithelial cells) into a multidimensional, multi-planar structure referred to as the gastrula. Human embryos are triploblastic organisms displaying multidimensional embryonic cell planes identified as ectoderm, mesoderm, and endoderm.

A lessor known and under-appreciated role of gastrulation is the establishment of a tensegrity based architecture informing emerging organ formation and a multidimensional, biomolecular chiral based body-plan predicated upon a north-south (cranial/caudal) axis with dorsal/ventral and selective right and left symmetry. This proposed innovative teaching technique includes the architectural first principles of tensegrity during gastrulation making these difficult concepts easier to comprehend. From a pedagogical point of view gastrulation has proven to be a most difficult concept for anatomists to teach and for students to grasp. Research demonstrates the importance concerning knowledge of medical embryology for the anatomist and medical student alike. To help solve this problem this short paper provides a novel, yet fun approach, to teaching complicated, vital, underpinning aspects of embryogenesis essential for undergraduate medical students.

Keywords: Embryology; Pedagogy; Gastrulation; Morphogenesis; Tensegrity.

Introduction

"*It is not birth, marriage, or death, but gastrulation, which is truly the most important time in your life.*"

Lewis Wolpert (1986)

Research confirms that anatomy is considered to be the corner stone subject within the medical curriculum and in clinical procedures to ensure safe medical practice by surgeons, doctors and a wide diverse range of medical specialists [1-3]. Anatomists would agree that understanding embryology is essential for gaining a

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Received: September 21, 2021
Accepted: October 19, 2021
Published: October 20, 2021

Citation: Karen Kirkness, John Sharkey, Joanne Avison. An Innovative Technique in Anatomy Pedagogy: The Flexagon as a Model of Gastrulation in Embryology. *Int J Anat Appl Physiol.* 2021;7(5):209-210. doi: http://dx.doi.org/10.19070/2572-7451-2100040

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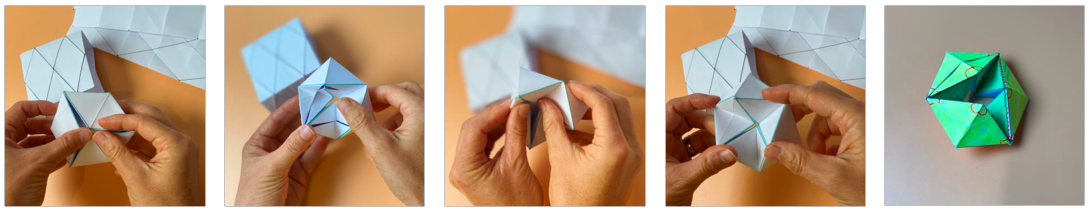
Figure 1 (a, b, c, d, e). From a single piece of paper students are instructed in the folding technique that results in a 3D hexaflexagon representing a multi-dimensional, folded, paper embryo. The activity, while being fun, is informative providing both a kinaesthetic and visual experience of several important processes including invagination, blastula folding and 3-Dimensionality.



(a) (b) (c) (d) (e)

Figure 2. Adding colours to the constructed hexaflexagon allows for a more pronounced visual experience.

comprehensive understanding of anatomy and teratology [4]. Alarmingly, the overall continuing decline in anatomy and embryology hours in medical schools is well documented [5]. Teaching anatomy is an innate challenge and anatomy educators view embryology as notoriously hard to teach and to learn while the challenging subject matter can become even more difficult with the reduction in emphasis as a subject. Medical students have fewer hours to learn anatomy, and many see little point in learning embryology other than to pass exam questions [6]. The authors address this unfortunate decline in interest in embryology using a novel learning technique aimed at making the concept more accessible while inspiring greater interest in embryology as a fascinating subject that serves to illuminate anatomical knowledge as part of long-term clinical professionalism and medical related competencies [7]. Knowledge of anatomy has been identified as critical within the operating room [1].

With students following simple instructions the result is a multi-dimensional folded paper embryo that anatomists can interact with and use to reinforce the process of invagination/enfolding during gastrulation (Fig 1). The origami action of folding the paper reinforces the concept of morphological constraints arising from internal mechanical circumstances of biologic geometry and force transmission [8]. Research has shown that by introducing a 3-Dimensional aspect to both the visual and kinaesthetic learning a greater visio-spatial appreciation is gained supporting a broader understanding of anatomy and embryology [9]. A lessor known and under-appreciated role of gastrulation is the establishment of a tensegrity based architecture informing emerging organ formation and a multidimensional, biomolecular chiral based body-plan predicated upon a north-south (cranial/caudal) axis with dorsal/ventral and selective right and left symmetry [10]. The 3D hexaflexagon, representing a multi-dimensional, folded, paper embryo (Fig 1) is offered as the ideal teaching tool to support anatomy educators when explaining the mechanical forces of morphogenesis and embryological development.

Conclusion

As medical and clinical training pathways evolve student learning needs and their educational preferences need also to evolve.

The aim of this paper is to propose that a greater understanding of the stages of embryonic folding can be achieved through folding one's own origami flexagon, or 3D hexaflexagon (aka "kaleidocycle") (Fig 2). A better understanding of embryology in the wider context of anatomy will better serve the medical student. Anatomy educators are crucial members of all medial teaching faculties ensuring under-graduate and post-graduate medical students gain an anatomically accurate and detailed education required to operate in a patient focused safe, appropriate and effective manner. We trust that our proposal will help anatomy educators move one step closer in achieving that goal.

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