Journal of Biomedical Systems & Emerging Technologies

Petrenko VM, J Biomed Syst Emerg Technol 2018, 5:2

Review article

Open Access

Spiralization in the Construction and Development of Bio-Systems

Petrenko Valeriy Mikhaylovich*

Rehabilitation of Immobile Patients, Karbisheva str, 6-2-65, St. Petersburg, 194021, Russian Federation

***Corresponding author:** Petrenko Valeriy Mikhaylovich, Senior Research Associate, Rehabilitation of Immobile Patients, Karbisheva str, 6-2-65, St. Petersburg, 194021, Russian Federation, E-mail: deptanatomy@hotmail.com

Received date: September 26, 2018; **Accepted date:** October 12, 2018; **Published date:** October 19, 2018

Abstract

Spiralization plays an important role in the construction of bio-systems at different levels of individual organization, starting with proteins and DNA. The development of bio-systems, including embryos, occurs through the unevenness their growth in different directions, which leads to their deformation, including the spiralization at different points of mobility of the bio-systems. The spiralization of the developing organ is accompanied by deformation of its mesentery and mesenteric vessels with the division of primary veins into secondary veins and primary lymphatic vessels. Damaging factors can determine the excessiveness of organ spiralization and its mesentery, such as, ischemia of the walls and death of epithelial cells. This promotes the germination of connective tissue through defects in the epithelium into the cavity of the organ with the formation of its congenital occlusion. Such a critical situation in the normal development of the organ is resolved by anlage of its lymphatic bed, facilitating the removal of blood containing the "fragments" of embryonic structures from the organ and preventing the occurrence of violations in its development.

Keywords: Biosystem; Construction; Development; Cell; Uneven growth; Spiralization

Introduction

In Philosophy, it is well known that the development of the world takes place in a spiral. The development of material systems, including bio-systems, is in one form or another, connected with their growth. The now famous law Minot [1] concerning the uneven growth as the main mode of development was proclaimed more than a century ago. Thompson [2] later stated that the morphogenesis of the body and organs is determined by the speed of their growth in different directions. Svetlov [3] introduced the term "differentiating growth": A significant part of the differentiation is carried out by uneven growth. Development occurs under certain conditions, which can cause uneven growth (or in a more general form-movement) of the developing system, by uneven resistance to growth in different directions within the system's environment [4].

This paper discusses the result of uneven growth of developing systems i.e., its deformation-curvature with a violation of the original shape in one form or another. A variant of such deformation is the spiralization resulting from uneven movement (growth) of the object along its length at different points of mobility. The phenomenon of spiralization is very common in the material world (from molecules to galaxies). Various manifestations of spiralization are found at all levels of the structural formation of living organisms: Genetic, molecular, cellular and tissue [5-8]. Spiralization in the study of embryonic organogenesis has been shown it to be a prerequisite for the occurrence of congenital anomalies in its redundancy [9].

Spiralization and Molecular Bases of Life

There is extensive literature on the problem of the spiralization for the most important biomolecules (DNA and Proteins) [10-16], but there are practically no comparisons of the peculiarities of the spiralization of such biomolecules and assessment of their value.

DNA, like proteins, has primary, secondary and tertiary structures. The sequential arrangement of nucleotides in the polynucleotide chain is the primary structure of the DNA, while the sequential arrangement of amino acid residues in the polypeptide chain is the primary structure of the protein. In both cases, the primary structure is made of long linear polymers, but with different compositions. The composition of DNA and proteins is specific for each species of living organisms, and the DNA and proteins of each individual organism are characterized by a specific primary structure of polynucleotides and polypeptides.

The classical model of the DNA's secondary structure consists of two antiparallel polynucleotide chains, twisted into a double helix, like a spiral staircase. The secondary structure of the protein may have a different configuration-α-spiral (typical of enzymes) or folded β-structure (structural proteins such as collagen).

The formation of the tertiary structure of nuclear DNA reflects the process of organization of chromosomes, and consists of multiple superspiralizations of the DNA molecule involving the formation of protein complexes, mainly with histones, and the participation of enzymes. As a result of successive packaging, the linear dimensions of the DNA molecule are reduced by 10 times. This is necessary to place a huge DNA molecule in a small volume of the cell nucleus in both eukaryotes and prokaryotic cells. Superspiralization is an important property of DNA, which depends on the flow of virtually all DNA-dependent processes in the cell, such as DNA replication, transcription and recombination. Superspiralization of DNA molecules greatly facilitates the breeding of complementary chains needed to initiate replication and transcription.

The tertiary structure of DNA resembles the quaternary structure of proteins (compounds of two or more polypeptides bound together and with other possible substances). Folding into tangles occurs in tertiary proteins (primarily with spiral secondary structures) and in quaternary proteins. Thus, protein (or DNA) compacting is achieved and, as a result, the protein and DNA take up much less space, but if the morphogenesis of tertiary and quaternary proteins characterized by self-organization, DNA supercoiling exercise proteins. Those proteins that form cells, tissues, organs and organisms by interacting with each other and with other substances, including nucleic acids [17].

Spiralization and Organogenesis

Human and animal bodies are composed of organs and vessels that probably began with nemerteans. Such organisms are autonomous, exhibiting more or less complex structures of their different types of cells and tissues. In organs, working tissues are combined by means of tissue channels of loose connective tissue, which continue into the vessels through intercellular clefts and transcellular pathways of the endothelium. Such tissue complexes, including vessels, also carry out inter-organ communications. Each organ has its own, more or less isolated vascular bed with certain pathways of blood inflow and outflow. Tissues, as systems of cells and systems of organs, including their circulatory connections, are not autonomous and represent transitional formations in the structural organization of the individual. In this hierarchy, three levels are basic: Cell-organ-organism [4].

The cell and intercellular connections are the first level of autonomous structural, supramolecular organization of an individual biosystem, in which the molecular basis of life is usually considered to exist. The organ is an autonomous part of a multicellular organism – separate (tissues do not exist in isolation), self-governing, with a certain form and structure (a structural complex of certain tissues), occupying a certain position within the organism, and performing specialized functions.

The cell is limited from the environment by the plasma membrane (plasmolemma), the organism is limited by skin, mucous membranes, or similar formations. The organs are limited by serosa, capsules, fascia, etc. All three levels of individual organizations have their own circulatory system, although very different in complexity. Tissues and organ systems do not have their own boundary membranes and circulatory systems. It is a sign of isolation that distinguishes the cell, organ and organism into independent levels in the hierarchy of individual organization.

Unlike organism and cells, organs are not capable of self-reproduction by reproduction, and the cell are (organ even more so) not part of independent body. The phenomenon of spiralization is therefore, a particularly important consideration at the cellular level (see previous section of this article) and at the level of organs in the body. Different definitions of spiral and spiralization are given in the literature [7,18-21]. From my point of view, spiralization is an uneven twisting throughout the rotation of the (quasi)linear structure, with the predominance of the length of the object, accompanied by its deformation (straight plank → spiral chip when planning plank).

During development, this is achieved by uneven growth of the object as a result of different levels of mobility/fixation of its parts throughout. The early embryo, as a whole, undergoes spiralization, which is important for differentiation of its body [4]. These are some examples from human anatomy: Multiple loops of the small intestine, Papillary lines of the fingers, and the Cochlea of the inner ear all correspond to the shape of the spiral. As an example from embryo anatomy: Twisting of the direct mid-gut during its intensive elongation with the formation of small intestine loops. At the same time, the twisting and mesentery of the small intestine occurs with deformation of the mesenteric vessels, the division of primary veins into secondary veins and primary lymphatic vessels.

The oesophagus, stomach, duodenum, pancreas and other organs are also subjected to spiralization. The basis of this process is an intensive uneven growth of organs in a dense environment with other organs, in a space limited by the walls of the abdominal or other cavity. The value of the limiting growth factor for spiral morphogenesis is clearly seen in the case of formation of 7 ileum loops in the umbilical hernial sac of the human embryo that does not contain other organs (a week earlier than the appearance of the jejunum loops in the abdomen) [9,22-25].

More detail on the value of spiralization for embryonic organogenesis was studied by me on example of the human duodenum. Epithelium proliferates and fills the cavity of its anlage, this causes a violation of recanalization which leads to congenital obstruction of the duodenum. It is located between the stomach and the umbilical intestinal loop, which "turns" in opposite directions. As a result, the duodenum gradually acquires the shape of a coil of a stretched spiral with a narrowing of bends between the segments of the coil, thus contributing to the formation of epithelial "plugs" in the cavity of the bends in embryos 6th week-under the mouths of the pancreatic ducts and in the duodenojejunal flexure. Simultaneously, proliferating mesenchyme strongly compacted and compresses the capillaries in the intestinal wall with the deterioration of blood supply to the epithelium. As a result, there are many small cavities in the epithelium (physiological cell death).

At the beginning of the 7th week, the mesenchyme loosens due to the formation of a network of reticular fibers and the production of hyaluronic acid. At this time of development, the intestinal cavity and blood vessels in the intestinal wall expand, and the epithelial "plugs" disappear.

The slowdown in liver growth, with its relative decrease and the beginning of secondary adhesions of the peritoneum leading to the end of duodenum spiralization on the 8th-9th weeks. At the same time, its recanalization is being completed. Near the duodenojejunal flexure are a large superior mesenteric artery and vein, they and their branches supply blood to the duodenum and its mesentery. The artery and its branches have the adventitia, starting at the 5th week, which increases their resistance to the pressure of the rapidly growing organs. The adventitia of the vein is determined on the 8th week, when in the lumen of the vein are the artery with branches and surrounding connective tissue. Intussusception constricts and divides the cavity of the vein. Part of the tributaries flowing into its side pockets is turned off from the bloodstream. This hinders blood flow and causes ischemia of the intestinal wall. Damaging factors can determine the excessiveness of the spiralization and the narrowing of the flexures, wall ischemia and destruction of epithelial cells of the duodenum. This latter situation promotes the germination of the connective tissue through defects in the epithelium into the cavity of the organ with the formation of its congenital occlusion of the internal type. Such a critical situation in the normal development of the organ is resolved by anlage of its lymphatic bed: the central channel of the primary superior mesenteric vein becomes a secondary vein with an adventitial membrane, its side pockets are separated in the form of chains of lymphatic cracks with an endothelial lining. At 8.5 to 9 weeks, such cracks merge into the mesenteric lymphatic vessels which improve organ drainage. The secondary adhesions of the peritoneum radically change the anatomical and topographical relationships of the internal organs of the abdominal cavity in fetuses, and the anlage of lymph nodes ("soaking" of macrophages and lymphocytes in the stroma of intussusceptions of blood vessels in the cavity of lymphatic vessels) – the structure of the lymphatic system. Both processes are associated with the pressure of rapidly growing organs on the walls and the contents of the fetal abdominal cavity. Excessive pressure of organs and peritoneal adhesions can cause congenital obstruction of the duodenum of the external type, abnormal deformations of its blood and lymphatic bed.

Conclusion

Spiralization plays an important role in the construction of bio-systems at different levels of individual organization, starting with proteins and DNA. The development of bio-systems, including embryos, occurs through the unevenness their growth in different directions, which leads to their deformation, including the spiralization, at different points of mobility of the bio-systems. Damaging factors can determine the excessiveness of organ spiralization and its mesentery, such as, ischemia of the walls and death of epithelial cells. This promotes the germination of connective tissue through defects in the epithelium into the cavity of the organ, with the formation of its congenital occlusion. Such a critical situation in the normal development of the organ is resolved by anlage of its lymphatic bed, facilitating the removal of blood containing the "fragments" of embryonic structures from the organ, and preventing the occurrence of violations in its development.

References

1. Minot Ch (1910) A laboratory text-book of embryology. W.B. Saunders Company, London.
2. Thompson DW (1942) On Growth and Form. Cambridge University Press, Macmillan, New York.
3. Svetlov PG (1978) Physiology (mechenics) of development Leningrad.
4. Petrenko VM (2016) About human constitution: Introduction in general human anatomy. M.-Berlin: Publ h Direct-Media
5. Cook T (1979) The curves of life. Dover, New York.
6. Habib Z, Sakai M (2005) Spiral transition curves and their applications. Scientiae Mathematicae Japonicae 61: 195-206.
7. Kurnosenko A (2010) Applying inversion to construct planar, rational spirals that satisfy two-point G2 Hermite data. Computer Aided Geometric Design, 27: 262-280.
8. Postolaki A (2014) Bionics, bisymmetry and biomechanics at the basis of modern knowledge of the structure of the body and dentoalveolar-facial system. Noosphere
9. Petrenko VM (2017) Embryonic bases of arising of human duodenum congenital occlusion. M.-Berlin: Publ h Direct-Media.
10. Pauling L, Corey RB, Branson HR (1951) The structure of proteins: Two hydrogen-bonded helical configurations of the polypeptide chain. Proc Nation Acad Sci 37: 205-211.
11. Pauling L, Corey RB (1951) Atomic coordinates and structure factors for two helical configurations of polypeptide chains. Proc Natl Acad Sci USA 37: 235-240.
12. Dolgikh DA (2011) Protein engineering. M.: Institute IT
13. Kondratyev MS (2009) Investigation of the mechanism of the organization of helical structures of oligopeptides: Dissertation candidate of physical and mathematical Sciences. Pushchino: Institute of theoretical and expertise Biophysics of RAS.
14. Valenti A, Perugino G, Rossi M, Ciaramella M (2011) Positive supercoiling in thermophiles and mesophiles: Of the good and evil. Biochem SocTrans 39: 58-63.
15. Koster DA, Crut A, Shuman S, Bjornsti MA, Dekker NH (2010) Cellular strategies for regulating DNA supercoiling: A single-molecule perspective. Cell 142: 519-530.
16. Witz G, Stasiak A (2010) DNA supercoiling and its role in DNA decatenation and unknotting. Nucleic Acids Res 38: 2119-2133.
17. Petrenko VM (2018) About molecular and structural bases of life organization J Biomed Syst Emerg Technol 5: 119.
18. Wang Y, Zhao B, Zhang L, Xu J, Wang K, Wang S (2004) Designing fair curves using monotone curvature pieces. Computer Aided Geometric Design 21: 515-527.
19. Yoshida N, Saito T (2006) Interactive aesthetic curve segments. The Visual Computer 22: 896-905.
20. Xu L, Mould D (2009) Magnetic curves: Curvature-controlled aesthetic curves using magnetic fields. In: Deussen, O., Hall, P. (Eds.) Computational Aesthetics in Graphics, Visualization, and Imaging. The Eurographics Association.
21. Ziatdinov R, Yoshida N, Kim T (2012) Analytic parametric equations of log-aesthetic curves in terms of incomplete gamma functions. Computer Aided Geometric Design 29: 129-140.
22. Petrenko VM (1986) Embryonal development of human duodenum. Arch anat 91: 60-66.
23. Petrenko VM (1988) Embryonal pre-conditions of origin of congenital occlusion of human duodenum Arch anat 95: 67-74.
24. Petrenko VM (1989) Bud of lymphatic bed of duodenum: morphological pre-conditions, structure and significance. Arch.anat. 96: 56-61.
25. Petrenko VM (2018) How life is maked? Anatomy of the search. M Berlin: Publ h Direct-Media.