

Anatomical Models of Embryogenesis: Enumerating the Mechanism from Fertilization to Gastrulation

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How to cite this paper: Ibiabuo, P.B. and Belema, D.B. (2026) Anatomical Models of Embryogenesis: Enumerating the Mechanism from Fertilization to Gastrulation. *Journal of Biosciences and Medicines*, **14**, 1-12.

<https://doi.org/10.4236/jbm.2026.1410001>

Received: August 6, 2026

Accepted: October 7, 2026

Published: October 10, 2026

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Abstract

This study is a studio-anatomical fabrication report describing the design and fabrication of physical models representing selected stages of early human embryonic development. The work uses clay modelling, silicone moulding, fiber-glass-resin casting, pigmentation, and finishing to produce durable three-dimensional teaching specimens. The manuscript describes the anatomical reference framework, fabrication process, and intended educational application of the models. Models were fabricated at approximately $\times 250$ linear magnification, with a base measurement of approximately 20×25 cm per model. No educational-effectiveness study, student assessment, or formal learning-outcome measurement was undertaken; therefore, the models are a selected 3-dimensional anatomic representation for educational benefits and teaching resources. Their educational effectiveness was not assessed in the present study. The work was presented to the department of Human Anatomy, University of Port Harcourt, Rivers State, Nigeria.

Keywords

Fertilization, Morula, Blastocyst, Post-Implantation Embryo

1. Introduction

Embryology, the study of development from fertilization through the fetal period, involves dynamic morphological changes that are difficult to appreciate fully from static two-dimensional illustrations alone. This fabrication report describes the development of physical anatomical models representing selected stages from fertilization through early post-implantation development. The manuscript focuses

on fabrication, anatomical reference, and potential educational utility; it does not measure learning outcomes or establish educational effectiveness.

1.1. Difficulty Obtaining Embryos

Human embryos are not routinely available as teaching specimens because of ethical, legal, practical, and logistical constraints [1]-[3]. The small scale and three-dimensional nature of early development can also make developmental relationships difficult to appreciate from two-dimensional representations alone [4] [5]. Physical models therefore provide a potential tangible representation of developmental morphology for teaching, although their educational effectiveness requires separate evaluation [6].

1.2. Risk and Preservation Concerns

For educational purposes, physical models can avoid the need to obtain, preserve, or handle actual embryonic material while providing a practical representation of developmental stages. Ethical issues surrounding reproductive technologies and stem-cell-derived gametes are distinct from the fabrication of anatomical teaching models and are therefore not used here to claim that the models themselves have been validated as ethically neutral [7].

1.3. Novel Teaching Paradigms

The use of clay for Anatomical models is a backbone for understanding abstract developmental process, because they depict three-dimensional appearances of embryonic development [8]. Three-dimensional resources can complement conventional and digital teaching approaches. Back et al. described the use and expectations of learning-management and e-learning tools among medical students [9], while other studies have specifically examined three-dimensional resources in embryology teaching. The present models are intended to complement, rather than replace, standard textbooks, atlases, digital resources, and instructor-led teaching.

1.4. An Ethical Imperative

The ethical considerations surrounding embryological research and education are important. Human embryo models have generated specific ethical questions concerning the boundaries and governance of human embryology [10]. The present study did not use human embryos, human embryonic specimens, human participants, or identifiable human data. The physical models were fabricated from non-human materials. The pictorial reference materials used to design the models are identified below, and the authors will ensure that any copyrighted source illustrations are used with appropriate attribution or permission.

1.5. The Imperative of Visual Learning

Visual and three-dimensional representations may assist learners in appreciating developmental morphology, but this fabrication study did not assess memory, ex-

amination performance, or other learning outcomes. Previous studies of embryology teaching have reported educational benefits from selected three-dimensional or hands-on approaches [6] [11]-[15]; these findings provide context rather than evidence of effectiveness for the present models.

1.6. Avoiding Adverse Effects from Preservatives

The utilization of preservative fluids in the maintenance of biological specimens may introduce practical concerns such as odour and chemical exposure. Anatomical models provide a non-toxic and odourless alternative for the study of embryological processes, thereby facilitating a more conducive learning environment. This study therefore uses physical models to avoid dependence on preserved embryonic specimens.

1.7. Purpose of the Study Model

The purpose of this study was to fabricate physical models that represent selected stages of early human embryonic development. The models are intended as supplementary anatomical teaching resources. Their educational effectiveness, anatomical measurement accuracy, durability in routine teaching, and impact on student learning were not formally evaluated in this study.

1.8. Enhancing Educational Accessibility

Physical models may be particularly useful where access to sophisticated imaging technologies or preserved specimens is limited. Three-dimensional embryology resources have been investigated in medical education, including digital 3D models, hands-on low-cost models, and physical or printed embryological models [6] [12]-[15]. In the present paper, these studies are cited to establish context and potential educational relevance, not to claim that the current models have demonstrated learning benefits.

2. Method of the Study

Studio-Anatomical Approach Was Employed:

1st Stage: Critical Analysis of Pictorial Representation. The study commenced with analysis of standard human embryology/anatomy reference illustrations representing the selected developmental stages. The anatomical reference framework identified for this manuscript comprises Gray's Anatomy: The Anatomical Basis of Clinical Practice, Embryology at a Glance, and Developmental Biology [1] [2] [5]. These sources were used to cross-check developmental terminology, sequence, and relationships of the structures represented. For each model, anatomical fidelity was assessed qualitatively by comparing the presence, relative position, continuity, and spatial relationships of the major labelled structures with the corresponding reference illustrations. Because no quantitative morphometric validation against human embryonic specimens or imaging datasets was performed, the models are described as anatomically referenced rather than formally validated.

2nd Stage: Translation of Pictorial Representation. Malleable clay was utilized to model the selected developmental stages using specialized modelling tools. Models were fabricated at approximately $\times 250$ linear magnification, with a base measurement of approximately 20×25 cm per model.

3rd Stage: Making of Negative Molds. Silicone rubber was applied over the clay models to capture their contours, followed by a layer of Plaster of Paris mixed with water (1:1 ratio) to reinforce and shape the negative molds.

4th Stage: Application of Release Agent and Creation of Positive Molds. Petroleum jelly served as a release agent to facilitate the separation of positive and negative molds. A mixture of calcium carbonate (CaCO_3) and accelerating and catalyzing agents was prepared, followed by impregnation with polyester resin. Fiberglass matting was applied and allowed to cure for approximately 15 minutes.

5th Stage: Finishing with Abrasives and Pigmentation. Abrasives were employed to refine surface textures of the cured positive moulds. Pigments were then applied according to the selected reference representations to illustrate morphology. Cellulose clear lacquer was applied as a fixative and to enhance durability.

Ethics and Source Attribution. No human embryos, human embryonic specimens, human participants, or identifiable human data were used in this fabrication study. The models were constructed from clay, silicone rubber, Plaster of Paris, fiberglass, polyester resin, pigments, and finishing materials. Reference illustrations were used as anatomical source material.

3. Result

Pre-Fertilization Stage:

The outcome of the model is demonstrated in **Figure 1** below is the model depicting the pre-fertilization stage illustrates the structure of the ovum just before fertilization occurs. Key structures include the corona radiata, zona pellucida, and the secondary oocyte awaiting fertilization by spermatozoa.

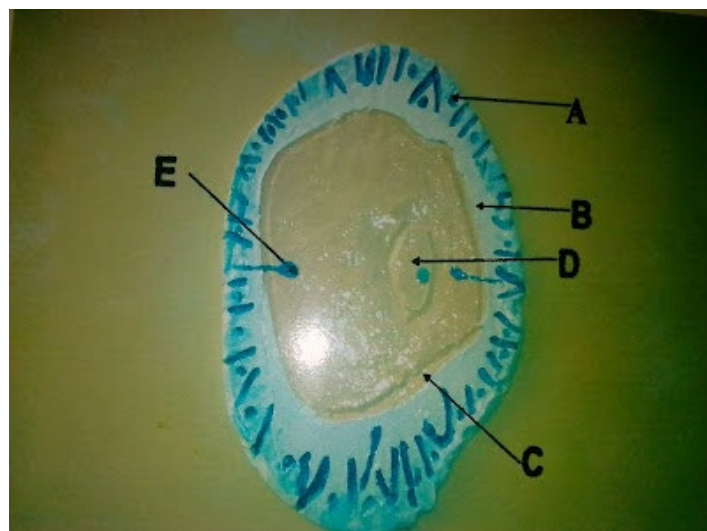


Figure 1. Model showing a pre-fertilization stage of an ovum.

Keys:

- A - Corona radiata
- B - Zona pellucida
- C - Perivitelline space
- D - Secondary oocyte
- E - Spermatozoa

Figure 2 demonstrates the fertilized ovum/zygote during the immediate post-fertilization period. The model depicts male and female pronuclei, centrosomal structures, chromosomes, and polar bodies within the zona pellucida. Pronuclei are appropriate to the zygote stage before completion of syngamy and are not retained in the later morula model.

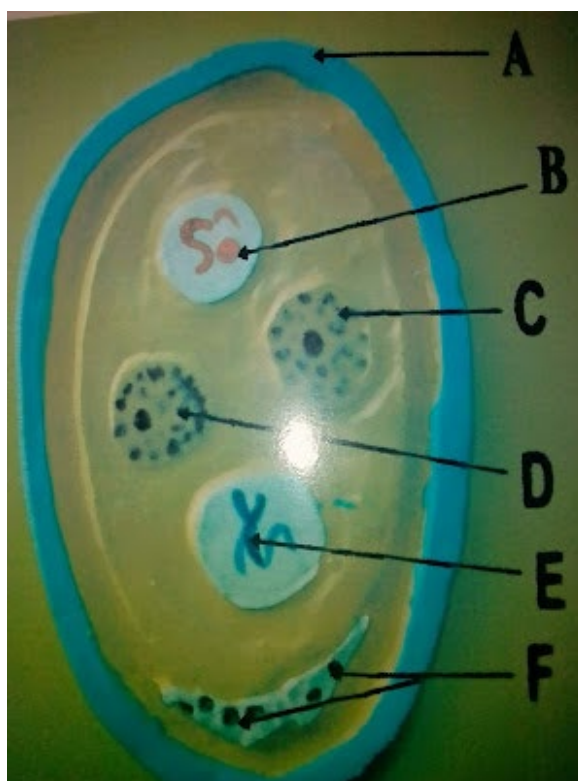


Figure 2. Model of a fertilized ovum (1 - 2 days after ovulation).

Keys:

- A - Zona pellucida
- B - Centrosome or Centrosphere
- C - Male Pronucleus
- D - Female Pronucleus
- E - Chromosomes
- F - Polar Bodies

Figure 3 represents the four-cell cleavage-stage embryo with potential ability to further divide. The model visibly depicts four major blastomere compartments with two polar bodies enclosed by the zona pellucida.

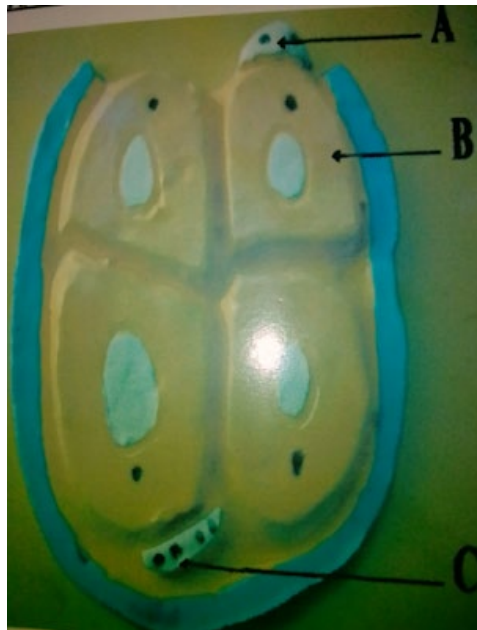


Figure 3. Model of a morula (2 - 3 days after ovulation).

Keys:

- A - First polar body
- B - Cells of the morula (Observe the broken zona pellucida; indicating more than 4 blastomeres)
- C - Second polar body

Figure 4 represents the blastocyst/early implantation stage. The blastocyst contains an inner cell mass (embryoblast) and trophoblast and is undergoing implantation during this period. Differentiation of the trophoblast into cytotrophoblast and syncytiotrophoblast is represented in the model.

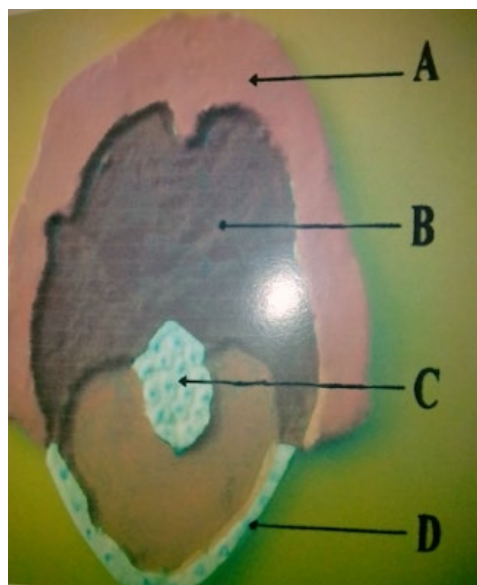


Figure 4. Model of a blastula (7 - 7.5 days after ovulation).

As development progresses, the blastula model shows the formation of a hollow, fluid-filled structure called the blastocyst. This stage involves the differentiation of cells into an inner cell mass (embryoblast) and an outer layer of trophoblast cells, crucial for implantation and further embryonic development as represented below in **Figure 4**.

Keys:

- A - Syncytiotrophoblast
- B - Cytotrophoblast
- C - Embryoblast or inner cell mass
- D - Trophoblast

Figure 5 represents a late second-week/early third-week post-implantation embryo. The model includes the embryonic area, yolk sac, amniotic cavity, connecting stalk, chorionic cavity/extraembryonic coelom, and trophoblastic structures. Gastrulation begins around day 15 post-fertilization with formation of the primitive streak and conversion of the bilaminar embryonic disc toward a trilaminar organization. Because the present model does not explicitly demonstrate the primitive streak or the complete sequence of germ-layer formation, it is described more conservatively as a late second-week/early third-week post-implantation model rather than being labelled simply as a “gastrula.”

The gastrula stage model without a Primitive Streak is shown in **Figure 5**. represents a more advanced embryo with distinct germ layers and specialized structures. It includes the formation of the embryonic area, allanto-enteric diverticulum, yolk sac, and chorionic cavity, essential for the development of organ systems and body plan.



Figure 5. Late second-week/early third-week post-implantation embryo (approximately 13 - 15 days post-fertilization) - model of a gastrula without primitive streak (13 - 15 days after ovulation) (model of a gastrula (13 - 15 days after ovulation)).

Keys:

- A - Syncytiotrophoblast
- B - Embryonic area

- C - Connecting stalk
- D - Allanto-enteric diverticulum
- E - Yolk sac
- F - Exocoelomic cyst
- G - Cytotrophoblast
- H - Chorionic cavity containing extraembryonic coelom
- I - Amniotic cavity
- J - Intervillous space or Lacuna
- K - Extraembryonic mesoblast
- L - Villous stem

4. Discussion

Embryonic development, from fertilization through early post-implantation stages, transforms a single-celled zygote into a multicellular organism through processes that are difficult to appreciate from two-dimensional illustrations alone. Physical anatomical models such as those fabricated here offer an alternative, tangible way of viewing this developmental morphology, and may complement textbooks, atlases, digital resources, and instructor-led teaching [9]. Published studies of other three-dimensional and hands-on embryology interventions - including digital 3D models, crocheted and printed models, and student-constructed models - have reported favourable educational outcomes in some settings [6] [8] [11]-[15].

A parallel effort to make embryonic development tangible and observable is underway in developmental biology research itself, through stem cell-derived embryological models. These synthetic systems represent a critical frontier in developmental biology, offering a pathway to study complex morphogenetic processes from fertilization through gastrulation without the ethical constraints inherent in using human embryos. They provide a scalable platform to elucidate the origins of developmental disorders and advance infertility research, yet they simultaneously introduce profound moral dilemmas regarding their ontological status and potential for sentience [16]. The persistent challenge in validating these structures stems from the inherent tension between achieving high-fidelity recapitulation of natural development and maintaining enough morphological divergence to remain outside the regulatory purview of traditional embryo research [17] [18]. Furthermore, the lack of a field-wide consensus on defining and classifying these models complicates standardization efforts, as different ontological perspectives—ranging from viewing embryoids as simple cell aggregates to complex human-like entities—create fragmented regulatory landscapes [19]. Consequently, researchers often prioritize internal phenotypic consistency over standardized external validation, as defining a “gold standard” for synthetic embryos remains elusive amid evolving regenerative medicine frameworks [20] [21]. Moreover, the ability of these constructs to integrate self-organization with exogenous bioengineering signals enables the exploration of developmental lineages that were previously inaccessible, even as the technical difficulty of achieving perfect fidelity

limits their immediate translational adoption [22] [23]. By intentionally arresting the maturation of these models prior to the development of integrated organ systems, scientists can effectively mitigate the ethical concerns associated with creating human life in vitro while still deriving substantial data on early developmental pathways [24] [25]. This developmental staging strategy, however, is frequently hindered by high variability and low formation efficiency, which prevent these aggregates from achieving the strict structural hallmarks required for formal biological classification [26]. Furthermore, the frequent emergence of developmental aberrations in these synthetic mouse and human models, when measured against natural biological benchmarks, underscores the persistent struggle to establish reliable, high-fidelity metrics for validation [27]. Because these models currently lack established developmental milestones comparable to natural counterparts, governing bodies must instead adopt nuanced frameworks that define zones of moral concern rather than relying on arbitrary temporal or structural limits [28].

These stem cell-derived models, while powerful for research purposes, remain inaccessible for routine teaching use, constrained by cost, technical expertise, and the same regulatory and ethical scrutiny that governs their broader application. Physical anatomical models therefore continue to serve a distinct and complementary role: unlike wet-preserved biological specimens, which carry a risk of inflammatory or irritant response from the preservatives used to maintain them, the physical model developed here offers a safe, reusable, and ethically unconstrained way of visualizing developmental morphology for educational settings.

5. Limitations

It is important to mention the limitations of this study regarding anatomical models showing early embryonic development:

Biological Accuracy and Validation. Models were designed with reference to standard embryological sources, but anatomical fidelity was assessed only qualitatively by the authors, not through quantitative morphometry, independent expert panel review, or comparison with human embryonic imaging or specimens. Future work should include independent anatomical expert review and, where feasible, comparison with validated imaging or reference datasets.

Educational Impact. The models were not evaluated by learners in this study. No claims of improved understanding, retention, examination performance, or learning efficiency can be made from this work; this single statement applies to every reference to educational value made elsewhere in this manuscript. Future studies should use appropriate pre/post or comparative educational outcome measures.

Ethical and Source-Use Considerations. No human embryos or human specimens were used; ethical considerations here concern responsible use of reference materials, materials disposal, and attribution or permission for copyrighted source images. Broader ethical questions concerning human embryo models [10] are noted as context and are not resolved by this fabrication work.

Practical Translation and Durability. Feasibility of fabricating and using these models may be lower in settings with limited resources or fabrication expertise, and models may not withstand extended wear in routine teaching use without degradation.

In sum, this study is a studio-anatomical fabrication report describing physical models of selected early human embryological stages. The models may have potential as supplementary teaching resources, but their educational impact and formal anatomical validity remain to be established through future studies.

6. Conclusion

In sum, the anatomical study of early embryonic stages from fertilization to gastrulation provides important pedagogic and ethical perspectives. Physical anatomical models can provide a tangible representation of developmental processes and may complement conventional teaching resources [1] [6]. Their educational value should, however, be confirmed through appropriately designed learning-impact studies.

Author Contributions

Both Authors conceptualized, fabricated, penned, and reviewed the manuscript before submission. There was no funding for this work.

Conflicts of Interest

The authors declares no conflicts of interest regarding the publication of this paper.

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