Title of paper:

The Anatomical Society Core Embryology Syllabus for undergraduate medicine

Running head:

The Anatomical Society Core Embryology Syllabus for undergraduate medicine

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Abstract

A modified Delphi methodology was used to develop a consensus regarding a series of learning outcome statements to act as the foundation of an undergraduate medical core embryology syllabus. A Delphi panel was formed by recruiting stakeholders with experience in leading undergraduate teaching of medical students. The panel (n=18), including anatomists, embryologists and practising clinicians, were nominated by members of Council and/or the Education Committee of the Anatomical Society. Following development of an *a priori* set of learning outcome statements (n=62) by the authors, panel members were asked in the first of a two-stage process to 'accept', 'reject' or 'modify' each learning outcome, to propose additional outcomes if desired. In the second stage, the panel were asked to either accept or reject sixteen statements which had either been modified, or had failed to reach consensus, during the first Delphi round. Overall, sixty-one of sixty-two learning outcome statements, each linked to examples of clinical conditions to provide context, achieved an 80% level of agreement following the modified Delphi process and were therefore deemed accepted for inclusion within the syllabus. The proposed syllabus allows for flexibility within individual curricula, while still prioritising and focusing on the core level of knowledge of embryological processes by presenting the essential elements to all newly-qualified doctors, regardless of their subsequent chosen specialty.

Key words: embryology education; anatomy education; medical education; integrated curriculum; syllabus; undergraduate education.

Introduction

The Anatomical Society has previously published core anatomy syllabi for a range of health professions including; medicine which was revised and updated in 2016 (Smith et al., 2016a, Smith et al., 2016b), Nursing (Connolly et al., 2018) and Pharmacy (Finn et al., 2018). Each of the previous syllabi has focused on gross anatomy. This paper considers the position of embryology within the medical curriculum and presents an embryology syllabus for use within it.

Embryology, as a sub-discipline of anatomy, has been traditionally considered primarily to be of interest to specific specialities such as obstetricians and paediatricians, an understanding of developmental anatomy and teratology has a core role in multiple additional specialities (Lee et al., 2010, Mascio et al., 2011). While there is currently no consensus, or existing guidelines from regulatory bodies about the placement of embryological content within the medical curriculum, the time dedicated to this component averages at around 13 to 14 hours in undergraduate courses, and varies considerably between institutions, ranging from 0 - 50 hours (Carlson, 2002, Drake et al., 2002, Heylings, 2002, Gartner, 2003, Drake et al., 2014, Cassidy, 2016). Given these time constraints, and the lack of a laboratory component in many institutions (Drake et al., 2014), educators are required to make explicit choices about what level of content to retain within the core medical curriculum, as opposed to that best addressed within specialised post-graduate training programmes. The presented embryological syllabus seeks to take an outcomes-based approach (Harden, 1999b), to provide a core set of learning outcome statements (Harden, 1999a, Kennedy et al., 2007), prioritising and focussing on the core level of knowledge of embryological processes and presentations which is essential to all newly-qualified doctors, regardless of their subsequent chosen specialty. The aim of this study is to seek knowledge about a specific subject from relevant stakeholder groups in order to develop consensus for a core embryology syllabus for undergraduate medical students. This information will aid educators when constructing and implementing their curricula, including learning outcomes, activities and aligning to assessments. It is also intended to aid students in their learning, providing a clear outline as to what is expected of them as they progress through their medical curriculum.

The Delphi method is a structured methodology for establishing consensus on subjects used to determine *collegial knowledge* from experts; this is knowledge where there exists a shared, implicit understanding of a subject by experts, but which may not be verbalised

or spoken about, and the Delphi method makes this implicit knowledge explicit (Dalkey et al., 1969, Moxham et al., 2014, Smith et al., 2016c, Humphrey-Murto et al., 2017). There is no standard approach, and thus considerable variations of the method are described throughout the literature (Boulkedid et al., 2011), but it is typically characterised by a series of inquiry rounds to obtain the individual judgements and opinions of a group of experts on the issue under review (Powell, 2003, Moxham et al., 2014). For example, one approach begins with a *tabula rasa*, with no pre-existing content or assumptions, and all panel participants are solicited for options through a series of open-ended questions, eventually focussing down to achieve consensus through multiple rounds (Hasson et al., 2000). Another form, which is a modification from the original, starts with the initial generation of items for inclusion by a core group, whether from modification of existing materials, or a review of the relevant literature and evidence-base (Smith et al., 2016c, Humphrey-Murto et al., 2017, Finn et al., 2018).

Methods & Analysis

Ethics: Ethical approval for this study was obtained from both the Research Ethics Committee of the Royal College of Surgeons in Ireland (reference RCSI-REC1085) and the Ethics Committee at Hull York Medical School (reference 17 08).

Construction of the research group

The research group included all of the present authors. Four of the researchers participated in this study due to their roles as anatomists, with specific experience of teaching anatomy and embryology to undergraduate medical students (GF, JCH, CO, CS) and on postgraduate training courses (JH, CO, CS). Two authors (MO'S, JS) were selected due to expertise in Delphi methodology but were not involved in the revision of any anatomical content. Three of the authors (GF, CS, JS) had worked on the previously published core syllabus for medical students ((Smith et al., 2016a, Smith et al., 2016c) and one (CO) was part of the authoring team for the original medical undergraduate core-syllabus publication (McHanwell et al., 2007) from which this strand of research developed that was cited in the influential 2009 "Tomorrow's Doctors" report of the GMC (GMC, 2009).

Study Design

This study consisted of four distinct phases; (i) pre-screening (ii) Delphi round 1 (iii) Delphi round 2 (iv) post-screening syntax editing. Setting a level of consensus for a Delphi varies

within the literature (Latif et al., 2016) but typically ranges from 70 – 100%. The teaching of embryology can vary in both volume and design from institution to institution, mostly either fully or partially integrated and systems-based, but consensus was set at 80% to account for this variability (McBride and Drake, 2018).

Identification of the Delphi panel

Experts were identified for the Delphi panel by inviting nominations from members of both the Anatomical Society Council and the Education Committee. The aim was to identify 15 to 20 individuals for the Delphi process across a spectrum of expertise including: anatomists, embryologists, and practicing clinicians (Campbell et al., 1999, Akins et al., 2005, Boulkedid et al., 2011, Moxham et al., 2014). Nominees were required to meet one of two criteria: (1) an academic with responsibility for teaching embryology within an undergraduate medical curriculum, with a minimum of 5 years' experience or (2) an active clinician who both (a) practiced within a specialty requiring a knowledge of embryology and (b) had educational experience of an undergraduate medical curriculum (i.e. clinical lecturer or professorial role). Forty-seven nominees were identified by this process, from across the UK and Ireland (Figure 1). Three nominees were found to be uncontactable by the e-mail addresses identified, and so forty-four individuals were invited to take part in the Delphi study (Dalkey et al., 1969) of which seventeen invitees participated in the first Delphi round, and eighteen invitees participated in the second.

Pre-screen – initial outcome screening before Stage 1

Prior to commencing this study, there were no previously published embryology syllabi composed of learning outcome statements available to use as a starting point. Thus, we began this process by developing learning outcome statements drawn primarily from syllabi of the co-authors' institutions (Figures 2 & 3). Fifty-nine outcomes were derived from the RCSI's undergraduate medicine syllabus, with an additional four outcomes added from the Brighton and Sussex Medical School. A further four outcomes were then added following a review of the literature available to the authors at that time (Smith et al., 2016a, Fakoya et al., 2017). These steps were undertaken by the research team in order to minimise the risk of omitting relevant content, to reduce unnecessary rounds of refinement during the Delphi rounds by removing the obviously irrelevant, or duplicated, outcomes from the *a priori* set, and to ensure that the outcomes were written and phrased in line with current best practice (Kennedy et al., 2007).

This set of sixty-seven learning outcomes statements was systematically reviewed and discussed by the content experts within the research group (GF, JH, CO, CS) to ensure consensus and consistency with regard to phrasing and terminology used, and also to identify potential gaps in the syllabus (Figure 3). During these discussions, inclusion of twenty-three outcomes was confirmed with no alterations, while a further twenty-six outcomes were modified in some minor way, such as the rephrasing of an action verb, to ensure they would be easily understood and comply with the principles of writing clear learning outcomes. For an additional eight outcomes, while the content of the outcomes was deemed relevant, discussions resulted in more major modifications to the learning outcome statement for clarity (Figure 3). During the course of these teleconference discussions, an additional five learning outcome statements were proposed, debated, and then inserted to cover content not encompassed by the *a priori* set. Nine outcomes were deemed to have content similar to, or related to other learning outcome statements, and so were merged. While debating the relevance of this content, there was some discussion as to whether contextual clinical information, or examples of congenital conditions, should be included within the learning outcome statements, or whether this unnecessarily increased the specificity of the statements, and the complexity of their phrasing; a decision was made to keep the phrasing of the learning outcomes statements clear and comprehensive, and instead to incorporate specific examples or contextual information within an associated appendix (Finn et al., 2018). Furthermore, the research team explicitly discussed and agreed upon the use of the term *fetal*, as opposed to *foetal*, and the use of the term *embryonic* as opposed to *embryological* (Boyd and Hamilton, 1967). In total, sixty-two learning outcome statements were drafted and refined during this pre-screening phase, and then forwarded to the panel of stakeholders for the first round of this modified Delphi process for their expert review and response (Figures 2 & 3).

Generation of the survey

The sixty-two learning outcome statements were entered into Survey Monkey (Survey Monkey, Palo Alta, CA, USA) using an RCSI (Health Professions Education Centre) Account. Within the survey, participants were initially presented with a consent form, which they were required to read and agree to before then continuing to proceed on to the rest of the survey. Next, instructions for completion of the survey, and contact information for the research team were also included ahead of the outcomes for consideration. In addition, there were four demographic items. Participants were asked to indicate their institution, their principal role and whether or not their institution specifically teaches developmental

embryology, and if so, whether this was as a stand-alone module, or integrated throughout a systems-based curriculum. This information was recorded in order to describe the range of expertise within the panel. Learning outcomes were presented in sections (one focussed on terminology, the remaining nine on body systems). For each of the learning outcomes, check boxes were provided for the panel members to record their decisions at each of the two stages. Text-boxes were presented with each outcome to enable panel members to record their suggested modifications. Following each system, a free-text box was also provided for panel members so that they could, if they wished, record the reasons for their decisions or any other comment relating to the outcomes being reviewed. Prior to the survey being made live, the data-collection form was checked and piloted by the research team.

Stage Two: Delphi Round One

Participants who had been identified as potential panel members were emailed an invitation to participate, a participant information sheet and link to the online survey. The consent form was built into the survey and completion of the Delphi process was taken as implied consent. The Delphi survey was open for a total of eight weeks in order to maximize participation, with e-mail reminders sent at two, four and six weeks. Delphi panel members were asked to consider the learning outcomes within the draft syllabus, and asked to consider each statement and decide whether it should be included in the revised Embryology Core syllabus and, if so, in what form. Panel members were asked to accept (without modification), reject or accept with suggested modifications (if a modification is proposed, panel members will be asked to write the modification in the open comment text box). A free text box was also available at the end of each section of the draft syllabus, so that participants could propose additional learning outcomes for consideration. Seventeen panel members (39% of invitees) responded, providing a total of 137 free-text comments (Table 1).

Analysis and decisions were undertaken using the protocol developed by Smith et al for the Core Anatomy Syllabus (Smith et al., 2016c). All submitted free text comments were reviewed and assigned to one of the following categories (Table 1): Supportive (S), Contextual (C), Modify (M), Amend Typographical Error (ATE), Question (Q), Negative / not important (N) and Not Relevant (NR). No learning outcome statements were rejected at this phase. All learning outcomes achieving a consensus level of over 90% were accepted outright. Learning outcomes achieving a consensus level of between 81-90%

were accepted, but modified if there were suggestions that might increase the level of agreement. All suggested modifications were reviewed using the rules developed by Smith et al., for the Core Anatomy Syllabus (Smith et al., 2016c) and discussed (following collation and anonymisation) among the research team (JH, CS, GF) (Table 2).

Stage Three: Delphi Round Two

The revised syllabus was recirculated to the Delphi panellists, in the same manner as for Delphi Round One, being open for a total of eight weeks followed by e-mail reminders after two, four and six weeks (Figure 2). Members were asked to review sixteen learning outcome statements and associated clinical context examples which had not yet reached consensus in the first round, and to either to accept these learning outcomes without modification, or reject outright. The forty-six learning outcomes which achieved consensus during Delphi Round One were included in the survey, so that panel members could identify them as being part of the syllabus and identify potential gaps or duplication, but no further input was sought regarding their inclusion (Smith et al., 2016c). However, free text comments were still permissible for all sixty-two learning outcome statements, and 225 were received (Table 1). Potentially, some minor amendments (other than accept / reject) that could be considered on the foot of comments at this stage were removal of any duplicate content, and correction of grammatical or typographical errors.

Post-screen - final proofing post Delphi

The final step in this process was a review by the research group of the final list of learning outcome statements in order to ensure that no typographical or grammatical errors existed in the final draft (i.e. tetraology / tetralogy, outlline / outline).

Results

Delphi panel demographics and participations rates

Seventeen nominees participated in the Delphi panel during Round 1, with eighteen participating for Round 2. The majority of respondents to Round 1 and Round 2 primarily identified either as anatomists (n = 10), or clinicians (n = 9), from across the UK or Ireland, with most institutions teaching embryology within an integrated (systems-based) curricula.

Results for each Delphi stage

Figure 2 provides a summary of the overall number of learning outcomes reviewed at each stage of syllabus development and the number of outcomes retained following each of these stages.

Delphi Round One results

Sixty-two learning outcome statements were put to the Delphi panel for review during this first round. Forty-four invitations were sent to the panel nominees; seventeen nominees participated, providing responses to the learning outcome statements, including suggesting additions and / or modifications, and contributing a total of 137 free-text comments (Table 1). Nine learning outcomes statements achieved a lower level than the pre-agreed consensus level of 80%; of these, six were modified (Smith et al., 2016c), with three remaining unchanged, as comments and suggestions for modification were contradictory, with some panellists requesting removal or simplification of the outcome statement, and others suggesting that more detail be included (Figure 4).

Delphi Round Two results

Sixteen learning outcome statements were put to the Delphi panel for final review, as they either had not reached the 80% acceptance rate in the first Delphi round and/or had been modified following feedback from Round 1, and members were asked to either simply accept or reject these statements. Forty-four invitations were sent to the panel nominees; eighteen nominees participated, providing responses and comments. The 46 learning outcomes which achieved consensus during first Delphi round were included so that panel members could identify them as being part of the syllabus (Figure 4). However, free text comments were still permissible for all sixty-two learning outcome statements, and 225 were submitted (Table 1). At this stage, fifteen of the sixteen learning outcome statements were accepted, with one rejection, resulting in a total of sixty-one learning outcome statements included in the final syllabus (Figures 3 & 4).

Discussion

The Anatomical Society is the first to combine an outcomes-based approach with the rigor of a structured Delphi methodology (Harden, 1999b, Kennedy et al., 2007, Moxham et al., 2014). The utilisation of a Delphi methodology throughout this process, with consultation across diverse stakeholder groups, ensures this syllabus should strike the balance of being both inclusive of all necessary core content, while retaining the flexibility to be generally applicable across varied educational contexts and institutions (Moxham et al.,

2014). One potential limitation of the study is that of the panel size, with seventeen and eighteen respondents to Delphi Rounds One and Two, respectively. Nonetheless, the priority of a Delphi is to ensure that participants or panel members are chosen because of expertise in their field; when then identifying experts at the intersection of education and such a specialised discipline as embryology, this can be a small, select field. The panel members within this study met rigorous inclusion criteria, with representation from both career anatomists and clinical colleagues. Furthermore, the final number of panel members compares well when considering previous reviews of Delphi studies which report that a median of seventeen individuals (range 3 – 418) are typically invited to participate as panel members, with median response rates typically around 88 – 90% (Boulkedid et al., 2011).

Embryology as a separate sub-discipline and course has largely been superseded by integrated systems-based modules within many curricula, primarily delivered via large group lectures, with an average of 14 course hours (McBride and Drake, 2018). The time that can be devoted to teaching embryology within current curricula is limited, having reduced rapidly between 1955 and 1973, and remaining at or under an average 20 hours since (Gartner, 2003, Drake et al., 2009, McBride and Drake, 2018). Conversely, our understanding of related aspects such as genetics and epigenetics has advanced substantially, and fetal surgical interventions, both open and fetoscopic, are rising (Carlson, 2002, Chirculescu and Morris, 2008, Deprest et al., 2010, Drake et al., 2014, Cassidy, 2016). Educators are required to make explicit choices about what content to retain, and what may be omitted, and a number of our panel members specifically commented about time constraints with regard to teaching of embryology within their own programmes.

> *"As an academic and clinical Obstetrician and Gynaecologist I am very concerned re the reduced teaching in Embryology and its long term implications"*

While developmental or embryological syllabi have been previously published (Leonard et al., 2000, Fakoya et al., 2017, Das et al., 2018), the number of components within each of these means that they are incredibly detailed and granular, essentially listing all possible processes; the syllabus published by Fayoka et al is a list of over 250 topics, while Leonard et al list over 700 (Leonard et al., 2000, Fakoya et al., 2017). While that published by Das et al, for the Liaison Committee for Medical Education (LCME) and the

Commission on Osteopathic College Accreditation (COCA), is written in the form of learning outcome statements, aims and competencies, it is still extensive, with over 200 primary or secondary level outcomes (Das et al., 2018). However, we know from the literature that the average teaching time for embryology in most curricula is only 13 or 14 hours – so how many institutions truly have time to teach all 700 items on the list (Heylings, 2002, Drake et al., 2014)? What should they include, and what should they omit from these lists if needing to *"cut their cloth"* to the allotted time? So, the aim of the Anatomical Society has been to develop a syllabus of learning outcome statements advising on what is *absolutely core* for undergraduate students to know. The clinical correlates may or may not be used as examples of each of these processes, allowing for flexibility between curricula, while still providing some guidance or suggestions should course directors wish to expand on outcomes in more detail. Those who have the time to desire to incorporate more extensive embryological content into their curricula, perhaps as student-selected modules would be advised to revert to the previously published syllabi in these circumstances.

During the course of the study, the research team explicitly discussed variant terminology, such as *foetal* vs. *fetal*. While the use of terms such as *fetal* and *fetus* is more grammatically correct upon exploring their derivation from Latin and the historical records on this matter (Boyd and Hamilton, 1967), the use of anatomical terms such as oesophagus differs according to geographical location. So, while we have adopted the use of terms such as *haemopoeisis (vs. hemopoeisis or haematopoiesis)* and *oesophagus* within our syllabus, these may be modified according to local use and grammar. Additionally, while there were a few edits in the two Delphi phases with regard to the action verbs utilised in the learning action statements, individual institutions may wish to also tailor these for internal consistency within their local context, when embedding within their curricula. Alongside this provision of a core set of learning outcome statements, we have also developed a list of relevant clinical conditions, linked to each outcome, which may be used as optional examples to introduce clinical context during teaching activities, appropriate to individual institutional curricula (Finn et al., 2018). Regulatory frameworks such as the GMC outcomes for graduates require an understanding of basic sciences and the ability of a doctor to translate that knowledge into clinical practice (GMC, 2009). The embryology syllabus is designed with this in mind to enable junior doctors to be able to underpin common conditions that have embryological origins.

While the vast majority of our learning outcome statements were retained by the panel, albeit with some modifications, the one learning outcome that was rejected was that of venous embryology; while some adult remnants are visible and relevant to (and thus covered by learning outcomes on) fetal circulation, minutiae regarding subcardinal vein development, while interesting for specialists wishing to gain insight into renal venous asymmetry, time is perhaps better spent on more clinically relevant priorities. Thus, the following syllabus allows for flexibility within individual curricula, while still prioritising and focussing on the core level of knowledge of embryological processes and presentations which is essential to all newly-qualified doctors, regardless of their subsequent chosen specialty.

The Anatomical Society core embryology syllabus for undergraduate medical students:

The Anatomical Society and the expert Delphi panel of anatomy and medical educators recommend that the following learning outcomes should be achieved by all students upon graduation, to demonstrate a basic level of competence in the embryology:

Anatomical Terminology

1. Define the anatomical terms cephalic / cranial, rostral / caudal, anterior/ ventral and posterior / dorsal in relation to embryology
2. Describe the following basic anatomical planes: axial / transverse / horizontal, sagittal and coronal
3. Define the following terms: gamete (pre-embryo), embryo, fetus, trimesters of pregnancy, teratogen, mutagen

Gametogenesis to placentation

4. Explain the process of gametogenesis in males and females, and how common consequences of abnormal gametogenesis such as non-disjunction, translocations or deletions occur
5. Describe the main stages, and hormonal control, of follicular development and ovulation within the ovarian cycle
6. Describe the main stages of spermatogenesis
7. List the processes and phases of fertilisation, cleavage and zygote development up to and including blastocyst formation
8. Describe blastocyst implantation and trophoblastic invasion of the uterine endometrium, with regard to placental development and function
9. Describe the two layers (epiblast, hypoblast) and the specified cavities (amniotic, exocoelomic / primitive yolk sac) of the early conceptus
10. Describe the development of the chorionic (extracoelomic) cavity, secondary yolk sac and umbilical cord
11. Summarize the development and endocrine function of the placenta in the first, second and third trimesters of pregnancy
12. Describe the functional anatomy of the uterine and fetal-maternal circulation and the placental "barrier"
13. Explain how abnormalities of implantation and placental development occur
14. Discuss the structure and role of the amnion and amniotic fluid

Trilaminar disc and early embryonic period

15. Describe the embryonic process of gastrulation and the origin of the new germ layer (mesoderm) formed during this process
16. Explain the embryonic processes of neurulation, and the development of the neural tube and neural crest cells
17. Outline the process of mesodermal differentiation, and the subsequent development of somitomeres and somites
18. Describe embryonic folding and the development of the intraembryonic, or coelomic, cavity, and discuss the consequences and significance of this process

Musculoskeletal System

19. Describe the germ layers and steps involved in limb development
20. Compare and contrast the processes of endochondral and intramembranous ossification of bone
21. Explain how limb muscles develop and migrate to the limb buds, and how these muscles then become positioned with respect to dorsal and ventral surfaces of the limbs
22. Describe the formation and pattern of the upper and lower limb dermatomes
23. Identify some of the more common congenital limb abnormalities and explain how they occur.

Cardiovascular System

24. Identify the sites of haemopoeisis in the embryo, including during the yolk sac, hepatic and myeloid periods
25. Summarise how the primitive heart tube develops into the adult, four-chambered heart
26. Describe the normal processes of atrial and ventricular septation, and explain the development, physiology and clinical presentation of conditions such as septal defects or patent foramen ovale
27. Describe the normal development and potential congenital malformations of the conus cordis, truncus arteriosus and aortic arches
28. Compare and contrast the pre-and post-natal circulations, and explain how these changes at birth occur

Respiratory system and diaphragm

29. Describe the septum transversum and name its derivatives in the embryo and adult

30. Describe the development of the diaphragm and explain how congenital defects and hernias occur
31. Describe the embryonic development of the trachea, oesophagus and lungs

Gastrointestinal system

32. Summarise how embryonic folding leads to formation of the primitive gut tube, and describe its communication with the yolk sac
33. Identify the three parts of the primitive gut tube (foregut, midgut and hindgut) and their adult derivatives, and name the mesenteric attachments and blood supply to each part
34. Describe the development of the stomach and its musculature, and identify abnormalities of development such as pyloric stenosis or atresia
35. Describe the development of the greater and lesser omenta and explain how rotation of the stomach contributes to the formation of the omental bursa (or lesser peritoneal sac)
36. Describe the development of the spleen and explain its haemopoietic function in the embryo
37. Describe the origin of the liver bud and the development of the liver, biliary tree and gallbladder.
38. Describe the formation of the pancreas and its ducts, from ventral and dorsal buds
39. Explain the development of the midgut, including physiological herniation, rotation and retraction
40. Describe the role of the vitelline duct in midgut development and how it may abnormally persist and pathologically present in the neonate or adult
41. Describe the division of the cloaca with regard to the development of the hindgut and upper anal canal
42. Compare and contrast the origins, development and associated features of the upper and lower sections of the anal canal

Genitourinary system

43. Outline the stages of development of the urinary system within the embryo, including pro-, meso- and metanephros
44. Describe the development and ascent of the kidneys and the clinical conditions that may arise from abnormal development
45. Describe the processes of sex differentiation and gonadal development within the male and female embryo, including ovarian and testicular descent
46. Compare and contrast the development of the mesonephric and paramesonephric ducts in males and females
47. Explain the development of the paramesonephric duct and uterine development in the female, and the main abnormalities that may occur
48. Describe the roles of the allantois and cloaca with regard to urogenital embryology, and explain how abnormal development of these structures may lead to conditions such as patent urachus or internal fistulae
49. Describe development of the external genitalia and perineum in males and females and how common abnormalities occur
50. Outline the major chromosomal, genetic and epigenetic factors influencing sexual differentiation and determination, and explain how genetic conditions are diagnosed and treated

Head and Neck

51. Describe the development of the pharyngeal arches, and name both the normal adult derivatives and potential clinical abnormalities (i.e. cysts or fistulae) that may result from abnormal development
52. Describe the formation of the tongue, including mucosa, muscles and innervations
53. Describe the development of the thyroid gland, associated structures and developmental abnormalities such as thyroglossal cyst or fistula
54. Explain palatal and facial development, and identify the various forms of cleft lip and palate that may result from abnormal fusion of the embryonic facial processes
55. Describe the embryonic development of the eye and related extra-ocular structures, and explain how conditions such as coloboma may develop
56. Describe the embryonic development of the ear, from ectodermal and endodermal origins, and summarise how conditions such as congenital deafness may arise
57. Describe the development of the fetal skull and the functional significance and use of the fontanelles in physical examination.

Central nervous system & Endocrine system

58. Describe how neural crest cells migrate from the neural tube, and outline the functional roles that they perform in their target destinations (cranial, trunk, cardiac & vagosacral).
59. Describe spinal cord development and neural tube defects
60. Outline the development of the primary brain vesicles and the blood-brain barrier (prosencephalon, mesencephalon & rhombencephalon)
61. Describe the development of the endocrine glands (e.g. pituitary, adrenal)

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Comment classification	*Delphi Round One*		*Delphi Round Two*	
	n = 137	***Example(s)***	***n = 225***	***Example(s)***
Supportive (S)	14	• All of the above are extremely relevant to clinical practice eg prescribing in pregnancy, ectopic and miscarriages, understanding multiple pregnancies, prenatal screening and infertility • All of this very important in paediatrics and neonatal. essential for the understanding of cardiac problems at birth	182	• Yes • Accept • Essential for O&G and paediatrics • Essential knowledge to understand gender disorders etc.
Contextual (C)	10	• We also use cut-off of viable/non-viable (i.e. <23 weeks or thereafter) as working in neonatology • Point 25 is, in my view, troublesome knowledge that is very challenging to teach well. • This is becoming increasingly difficult to teach as time pressures in the curriculum increase	4	• This is not specific to embryology • Maybe not in depth the actual stages of spermatogenesis just know causes of low and azoospermia and treatment - this would be taught by a clinician and not require in depth knowledge
Modify (M)	102	• avoid use of twisting spiral which over eggs it! simply need to refer to modified segmental pattern of dermatomes due to flexion of limbs, though different in UL and LL • CLinical context - anal atresias	22	• Not clear what 'main stages' are from outcome alone. Name stages in outcome or 'Describe stages of spermatogenesis' • Modify • Additional clinical context: derivatives of neural crest
Amend Typographical Error (ATE)	6	• primitive not primative • it is neurulation not neuralation	2	• spelling mistake on metastases • Small typo noted - 2)) at end of clinical context
Question (Q)	5	• I know very few students (and academics) who truly understand this. I wonder if we should provide the basic principles of peritoneal development, and just describe the lesser sac in the adult? • what do you mean by brain barriers??	5	• Do you mean genetic conditions associated with sexual differentiation? • Epigenetic factors may be beyond the scope of the course? • Surely the significant clinical context is understanding the innervation of the diaphragm and the sequelae of cervical spinal injury?
Negative / not important	0		6	• this would be part of an O&G curriculum not needed within an embryological curriculum • Not a priority. • Not so sure that detailed explanation around syndrome / non syndrome needed at undergraduate level
Not relevant	0		4	• N/A

Table 1. Examples of free-text comments

1	*If all, or the majority of, comments suggest a particular change, then the learning outcome will be modified accordingly.*
2	*If contradictory comments are being made, then discussion between the research team members will be used to decide which changes should be adopted and which rejected. The basis of these decisions should be ensure clarity and reduce repetition.*
3	*In situations where one comment is felt by the research team to be especially apt, even if no other panel members' comments match, then this single comment could be used to modify a learning outcome.*
4	*Where a panel member makes a comment regarding inconsistency in terminology relating to a small number of learning outcomes, then the research team will discuss whether this inconsistency should be addressed across the whole syllabus and changes made.*
5	*Anatomical terminology follows the guidelines laid out in Terminologia Anatomica (1998).*
6	*All decisions are recorded.*
7	*These rules are applied, recognising that all changes will receive further scrutiny in Stage 3. Where any change results in lower levels of consensus being achieved, then the research team will restore the original learning outcome.*

Table 2. Rules developed by Smith et al., for the Core Anatomy Syllabus (Smith et al., 2016c)

Learning Outcome	Clinical context/condition/ procedure/system
Anatomical Terminology	
1	Frequently used when describing relationships
2	Important for understanding 2-dimensional images of 3-dimensional structures
3	Essential terms and definitions for embryology and congenital conditions; principles of teratology, including infectious and environmental
Gametogenesis to placentation	
4	Non-disjunction, translocations or deletions (Down's syndrome; Klinefelter's syndrome)
5	Contraception, infertility, assisted reproduction (IUI, GIFT, IVF, ICSI)
6	Infertility, assisted reproduction (IUI, GIFT, IVF, ICSI)
7	Contraception; multiple pregnancies
8	Ectopic pregnancy; contraception; placental morphology and adherence
9	Germ cell layers
10	Umbilical cord morphology and development
11	Placental morphology and adherence
12	Oxytocin and myometrial contractility; steroids and uterine perfusion; placental transfer of drugs
13	Placental morphology and abnormalities; multiple pregnancies; inspection of afterbirth (cotyledon retention, cordal vessels); hydatidiform moles
14	Oligohydramnios and polyhydramnios; amniocentesis; rupture of membranes; pulmonary hypoplasia
Trilaminar disc and early embryonic period	
15	Situs inversus; caudal dysgenesis
16	Spina bifida;
17	Vertebral fusions; hemivertebrae; scoliosis
18	Pericardial, pleural and peritoneal cavities
Musculoskeletal System	
19	Micromelia; syndactyly; club foot
20	Bone age; epiphyseal pathology (i.e. fusion, fracture, slipped)
21	Innervation; muscular agenesis (i.e. pectoralis major)
22	Clinical examination
23	Abnormailites such as meromelia, phocomelia, polydactyly; teratogenicity (e.g. thalidomide)
Cardiovascular System	
24	Haemopoeisis
25	Malrotation & dextrocardia

26	Ventricular and atrial septal defects;
27	Tetralogy of Fallot; co-arctation of the aorta; transposition of the great vessels; aortic arch remnants and variants;
28	Patent ductus arteriosus
Respiratory system and diaphragm	
29	Bare area of the liver and implications for metastases
30	Diaphragmatic hernias
31	Tracheo-oesophageal defects (fistula, atresia)
Gastrointestinal system	
32	Endodermal intestine; vitelline fistula
33	Implications for metastases; mesenteric ischaemia; abdominal pain
34	Pyloric stenosis or atresia
35	Lesser sac anatomy; epiploic foramen (of Winslow)
36	Accessory spleen
37	Mesodermal and endodermal components within the liver; biliary atresia; variable biliary tree anatomy
38	Pancreas divisum, annular pancreas, variable anatomy of the duodenal papillae
39	Duodenal and intestinal atresias; malrotations; omphalocoele; gastroschisis
40	Meckel's diverticulum; vitelline fistula; vitelline cyst
41	Cloacal abnormalities (fusion, fistulae)
42	Contrasting histological and anatomical features; anal atresias
Genitourinary system	
43	Renal dysplasia, agenesis, polycystic kidneys
44	Pelvic kidneys; horseshoe kidney
45	Undescended testes; maldescended testes; testicular tumours; infertility
46	Duplex ureters
47	Uterine malformations (bicornis; bicornis unicollis; didelphys)
48	Patent urachus; urachal cyst or fistula; exstrophy of the bladder
49	Hypospadias; epispadias; environmental oestrogens and anti-androgens; congenital adrenal hyperplasia; ambiguous genitalia
50	Turner syndrome; disorders of sexual development
Head and Neck	
51	Branchial cysts and fistulae
52	Microglossia; macroglossia; ankyloglossia (fusion of lingual frenulum)
53	Thyroglossal cyst or fistula; pyramidal lobe
54	Cleft lip; cleft palate
55	Coloboma; Persistent pupillary membrane (PPM)
56	Congenital hearing loss, both syndrome and non-syndrome

57	Physical examination of fontanelles; microcephaly; craniosynostosis; meningocoele; hydrocephalus diagnosis
Central nervous system & Endocrine system	
58	Facial development; adrenomedullary cells; pigment cells; Hirschsprung's disease; carcinoid (neuroendocrine tumours)
59	Spina bifida; anencephaly
60	Hydrocephalus; anencephaly; toxicity; transfer of drugs
61	Parathyroid glands; activation of HPG axis; minipuberty; ectopic or accessory adrenal tissue

Table 3. Contextual information to support the integration of outcomes into the curriculum.

Figure legends:

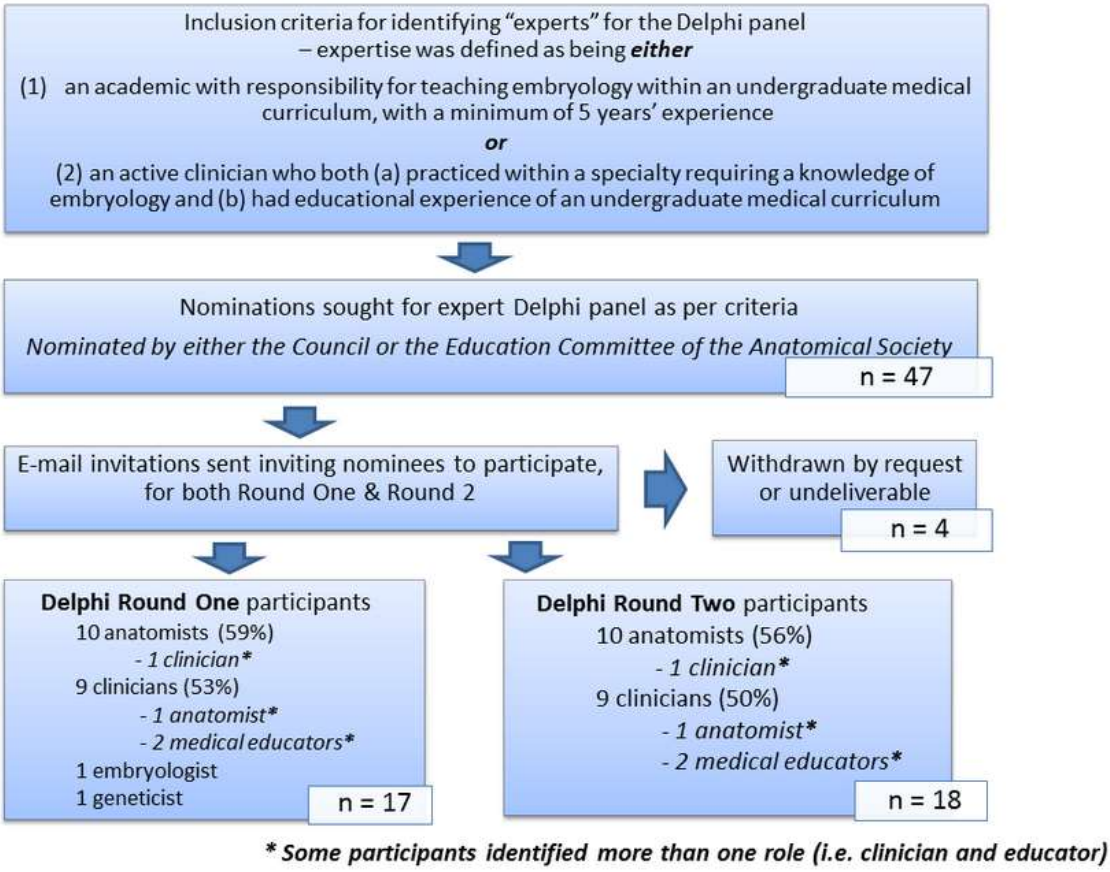

Figure 1 – Delphi panel members; inclusion criteria, identification, invitation and participation

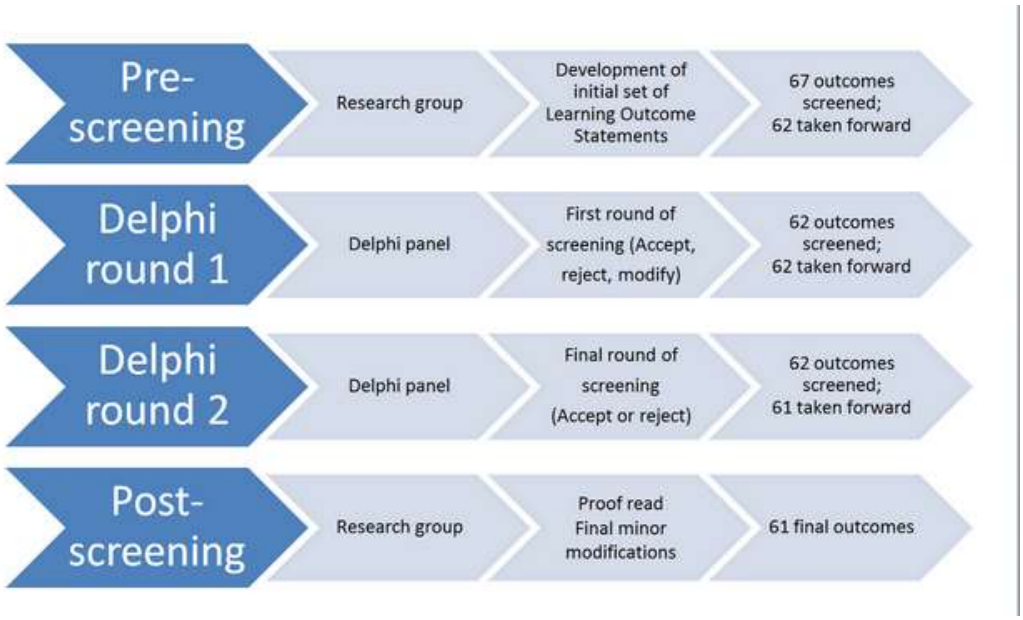

Figure 2 – The key stages of the Delphi process (Finn et al., 2018)

Development of initial learning outcomes

n	*Source*	*Example*
20	RCSI - unmodified	Describe the germ layers and steps involved in limb development
39	RCSI - modified	**Original:** Understand how abnormalities such as hydatidiform moles and ectopic pregnancies occur **Amendment:** Explain how abnormalities of implantation and placental development (such as hydatidiform moles and ectopic pregnancies) occur
4	Brighton and Sussex Medical School	Describe the embryological origin of the GI system, including its folding and how it informs the blood supply of the adult gut
4	Literature	Placenta as a barrier and exchange of substances (Fakoya et al., 2017)

a priori set, discussed & debated among research group = 67

n	*Decision*	*Example*
17	Keep • No modifications	Explain the twisting spiral pattern of the dermatomes on the limbs
30	Keep with Minor amendment • Substitution of a synonym, or addition / removal of < 4 words	***A priori:*** Discuss the septum transversum and name its derivatives in the embryo and adult ***Amendment:*** Define the septum transversum and name its derivatives in the embryo and adult
10	Keep with major amendment • Major rephrasing - addition / removal of >5 words	***A priori:*** Describe the process of neural tube formation, and explain the origin of the neural crest cells, their migration and eventual destinations ***Amendment:*** Describe how neural crest cells migrate from the neural tube, and outline the functional roles that they perform in their target destinations (cranial, trunk, cardiac & vagosacral).
5	Additional outcome added • Additional outcome discussed and added during screening of a priori outcomes	Describe the development of the fetal skull and the functional significance and use of the fontanelles in physical examination.
1	Remove • Outcome deemed not relevant and removed entirely	Outline the main stages, and hormonal control, of endometrial development within the menstrual cycle
9	Merge with other outcome • Relevant content, merged with another learning outcome statement (or associated appendix)	Describe how teratogens may affect limb development

Delphi Round One = 62

Figure 3. Formulation and modification of learning outcome statements during the development phase

Delphi Round One = 62 LOs circulated to panel

n	*Decision*	*Example(s)*
49	No alterations to learning outcome or clinical context box	Describe the formation of the pancreas and its ducts, from ventral and dorsal buds (*Pancreas divisum, annular pancreas, variable anatomy of the duodenal papillae)*
3	Minor alteration (i.e. single word) to learning outcome	***A priori:*** Define the septum transversum and name its derivatives in the embryo and adult ***Amendment:*** Describe the septum transversum and name its derivatives in the embryo and adult
3	Major alteration to learning outcome (i.e. rewritten)	***A priori:*** Explain the twisting spiral pattern of the dermatomes on the limbs ***Amendment:*** Describe the formation and pattern of the upper and lower limb dermatomes
5	Correction of typographical error	***A priori:*** Explain the embryonic processes of ***neuralation***, and the development of the neural tube and neural crest cells ***Amendment: neurulation***
5	Addition / alteration to clinical context box	**Unchanged LO:** Outline the major chromosomal, genetic and epigenetic factors influencing sexual differentiation and determination, and explain how genetic conditions are diagnosed and treated ***A priori clinical context:*** *Turner syndrome; hermaphrodites; pseudohermaphrodites* ***Amendment to clinical context:*** *Turner syndrome; disorders of sexual development*

Delphi Round Two = 62 LOs re-circulated to panel
46 – accepted in Delphi Round One, no decision required
16 – accept or reject

n	*Decision*	*Example*
15	Accept	Summarise how embryonic folding leads to formation of the primitive gut tube, and describe its communication with the yolk sac
1	Reject	Outline the venous system of the early embryo and fetus and identify those embryonic veins which persist in the adult

Final syllabus = 61 outcomes

Figure 4. Development and modification of learning outcome statements and clinical context amendments during Delphi rounds 1 & 2