



What should medical students learn in immunology? Developing a consensus-based curriculum framework for a spiral medical curriculum

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Abstract

Background Immunology is the foundation for modern medical practice across infection, allergy, autoimmunity, transplantation, and cancer, yet is widely perceived by undergraduate medical students as being complex and difficult to learn. Curricular reform, including the adoption of integrated and spiral models, presents opportunities to improve learning through repeated exposure and clinical contextualisation, but also risks content dilution, fragmented sequencing, and reduced disciplinary coherence. The aim of this study was to develop a consensus-based framework defining core immunology content and guiding principles for implementation within a spiral undergraduate medical curriculum.

Methods A three-phase consensus development process involving faculty (Phase 1 questionnaire), a Curriculum Development Panel (Phase 2 structured discussion), and medical alumni (Phase 3 questionnaire) was used. Outputs were synthesised into a curriculum framework comprising core immunology content domains, guiding principles for sequencing and depth, and operational guidance ('Dos and Don'ts') for implementation in a spiral curriculum.

Results Stakeholders agreed a set of core immunology content domains appropriate for undergraduate medicine and endorsed guiding principles emphasising early conceptual grounding, progressive clinical application, limiting excessive molecular detail in early years, and aligning content with assessment. Alumni responses validated the perceived importance of clinical contextualisation and staged progression of expected knowledge from early medical school to graduation.

Conclusion This consensus-derived framework provides practical guidance for curriculum planners and clinician-educators implementing immunology teaching within integrated spiral programmes. Although developed within one institutional reform context, it is articulated at the level of domains and guiding principles to support adaptation for use across undergraduate medical curricula.

Keywords Consensus-based study · Curriculum development · Immunology education · Medical education · Spiral curriculum · Undergraduate medical education

Introduction

Immunology underpins modern medical practice across infection, allergy, autoimmunity, transplantation, and cancer [1, 2]. Advances in vaccinology, biologic therapies, immune checkpoint inhibitors and cellular therapies have transformed clinical care across medical specialties, with immunology-related drugs accounting for a substantial proportion of new therapeutics entering clinical practice [3]. As a result, immunology should be regarded as a foundational science essential to safe and effective medical practice.

The immune system comprises coordinated innate and adaptive components that protect the host while maintaining

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tolerance to self [1]. Dysregulation contributes to a broad spectrum of disease, including allergy, autoimmunity, immunodeficiency and malignancy. Allergic disease affects up to 10% of the global population and as many as 50% of young people in the Global North [4]. In parallel, Inborn Errors of Immunity (IEIs), previously considered rare paediatric conditions, are increasingly recognised to present across the lifespan, with up to 50% of cases presenting in adulthood [5]. Increasing prevalence of autoimmune disease and cancer with immune-related complications from disease or therapy further emphasise the importance of immunology across all areas of medicine [6, 7].

Despite its clear clinical relevance, immunology is widely perceived by medical students as complex and difficult to learn [8]. The discipline requires integration of concepts from cellular biology, genetics, biochemistry, anatomy and physiology [9, 10]. Students enter medical school with highly variable prior exposure to these foundational sciences, making it challenging to pitch content at an appropriate level, particularly in the earlier years [11]. Although students recognise immunology as important for clinical practice, difficulties assimilating and retaining knowledge are frequently reported [8].

This may be partly due to how immunology is taught at medical schools. Historically, immunology has been taught as a discrete preclinical subject within discipline-based curricula, often separated from clinical application. Traditional curricular models influenced by the Flexnerian separation of basic and clinical sciences have been associated with poor long-term retention of foundational science knowledge [12]. Presenting foundational science without explicit clinical context may limit students' ability to transfer knowledge to clinical problem solving [13].

In response, medical education has increasingly adopted integrated curricula that aim to align foundational sciences with clinical practice [13, 14]. Integration may be horizontal, vertical, or spiral in nature [15]. Spiral curricula are characterised by repeated revisiting of topics with increasing complexity, explicit linkage of new learning to prior knowledge, and progressive development of learner competence [16]. Learning theory supports spiral integration as a means of enhancing retention and facilitating transfer of knowledge to clinical contexts [12, 17, 18].

However, implementation of spiral curricula presents some challenges for foundational sciences, including immunology. Integration across time and disciplines risks inappropriate sequencing, duplication, excessive reductionism, or omission of essential content if not carefully planned [19, 20]. Foundational sciences may be particularly vulnerable within integrated curricula, especially in later clinical years where explicit disciplinary ownership may be reduced

[20]. Maintaining disciplinary coherence while supporting meaningful integration remains a key challenge for those involved in curriculum development. These challenges highlight the need for structured, transparent approaches to curricular decision-making that can balance disciplinary integrity with integration.

Curriculum design inevitably involves important decisions regarding content selection, depth and sequencing. These decisions are influenced not only by educational theory and evidence, but also by professional judgement, clinical priorities, regulatory requirements and contextual constraints [13]. Consensus-based approaches can support groups to collaboratively make curriculum design decisions about content, sequencing and integration [19]. Supporting group decisions is particularly relevant for interdisciplinary subjects such as immunology, where teaching spans multiple foundational sciences and clinical contexts and is delivered by a diverse group of educators. Previous discipline-led efforts have used iterative consensus approaches to define core immunology topics [21, 22], but have not been tailored to spiral medical curricula, with limited attention to integration, and with stakeholder input largely confined to immunology subject content experts [21, 22].

Despite the widespread adoption of integrated and spiral curricula, there remains limited discipline-specific guidance to support coherent undergraduate immunology teaching across such programmes [10, 23]. In practice, this leaves curriculum teams to make repeated, localised decisions about what immunology content to include, how deeply to teach it, and where to position it across years and modules, often without a shared reference point. Curricular guidance articulated at an appropriate level can support local curriculum planning while remaining adaptable across institutions using integrated or spiral models [15, 16].

The introduction of a new spiral undergraduate medical curriculum at an Irish medical school created a concrete local need for such a framework. Curriculum planners required a discipline-specific approach to support decisions about what immunology content should be taught, at what level, and in which contexts, while remaining aligned with national guidance and local curricular constraints. The aim of this study was to develop a consensus-based curriculum framework for immunology within a spiral undergraduate medical curriculum, comprising core immunology content domains, guiding principles for sequencing and depth, and operational implementation guidance. Although developed in response to local curricular reform, the framework is articulated at a transferable level intended to support adaptation for use in other integrated or spiral undergraduate medical programmes.

Methods

Study design and setting

A structured, three-phase, consensus-based approach was used to define core immunology content and guiding principles for delivery within a spiral undergraduate medical curriculum. Consensus-based approaches have been widely used in healthcare and medical education across a broad range of curricular areas [24–26].

The study was conducted during the implementation of a new spiral undergraduate medical curriculum at an Irish medical school. The new curriculum prioritised early clinical exposure, horizontal and vertical integration, and longitudinal revisiting of foundational sciences across the programme. This study focused on immunology as a foundational science within that programme. Data collection occurred between 2021–2022 across three phases, with cross-phase synthesis and framework development completed in 2022.

Ethical approval

Ethical approval was obtained from the RCSI Research Ethics Committee for the Consensus Development Panel (CDP) (REC202009005). Ethical approval was not deemed necessary for the anonymous, consultative survey-based components (Phases 1 and 3), which were conducted in line with institutional procedures for faculty/alumni consultation.

Stakeholder identification and recruitment

Stakeholders were purposively sampled to represent expertise in immunology, clinical practice, medical education and curriculum leadership as well as post-graduation perspectives. Participants were drawn from the following groups across the study phases:

- Clinical immunologists involved in undergraduate teaching and clinical or laboratory service provision
- Clinicians from medical and surgical specialties with regular exposure to immunology-related conditions
- Foundational science educators involved in teaching immunology and related sciences
- Medical education faculty with responsibility for curriculum design
- Medical alumni who had completed undergraduate medical education and progressed into clinical practice

Potential participants were identified through internal departmental lists, curriculum committees and alumni networks. Invitations were issued by email, and

the consensus process was conducted over the period March–May 2021. Sampling was expertise-driven rather than intended to be statistically representative, consistent with the exploratory and applied aims of the consensus process.

Inclusion of alumni was intended to capture perspectives on the adequacy and clinical relevance of undergraduate immunology teaching following transition into clinical practice. It was not possible to consult current students due to their participation in other research at the time and institutional concern regarding survey fatigue.

Analytic approach

Quantitative and qualitative analyses were undertaken iteratively throughout the consensus process. Following each phase and round, quantitative data were summarised descriptively to assess levels of agreement, while any free-text responses were analysed using direct content analysis to identify areas of convergence, ambiguity and disagreement. These analyses directly informed decisions regarding progression between phases, revision or exclusion of content items, and development of guiding principles. Integration of quantitative and qualitative findings occurred throughout the study and informed development of the final consensus-based framework. This analytic approach was applied consistently across all phases, with phase-specific details outlined below.

Consensus process overview

The consensus development process comprised three sequential phases. Data collection and analysis were embedded within each phase to inform the subsequent stage and cross-phase analysis. The phases are summarised in Table 1.

Phase 1: Faculty questionnaire (Preliminary principles and proposed mapped domains)

Instrument and content

A 15-item electronic faculty questionnaire (Appendix 1) was developed specifically for this process to elicit immunology content requirements relevant to undergraduate medical training within an integrated spiral curriculum. The questionnaire also included five demographic items and eight free-text items addressing immunology knowledge required for integration with foundational sciences, system-based modules (Years 1–2), clinical modules (Years 3–5) and immune-mediated clinical presentations. No items were compulsory. The questionnaire

Table 1 Overview of multi-phase consensus process. Together, the outputs of these phases contributed to the development of a consensus-based curriculum framework

Phase	Participants	Data Collection Method	Purpose	Output
Phase 1	Faculty	Questionnaire	To identify immunology content requirements and elicit preliminary guiding principles to inform curriculum design	Preliminary guiding principles and proposed mapped immunology content domains
Phase 2	Curriculum Development Panel	Structured panel discussion	To apply expert judgement to prioritise essential content, refine guiding principles, and determine appropriate sequencing and depth within a spiral curriculum	Agreed core immunology content domains, refined guiding principles, and delivery priorities
Phase 3	Alumni	Questionnaire	To validate and contextualise prioritised content and guiding principles from a post-graduation clinical perspective	Validated content priorities and contextualisation of expected immunology knowledge and skills
Cross-phase Synthesis	Research Team	Analytic synthesis	To integrate findings across all phases and support synthesis for framework development	Operational 'Dos and Don'ts' informing implementation of the curriculum framework

was developed by the lead author in consultation with two supervisors (a clinical immunologist and a foundational scientist) and pilot-tested by a senior clinical lecturer to maximise clarity, relevance and face validity.

Data collection

The questionnaire was disseminated electronically between 29 and 31 March 2021 to 71 faculty members involved in undergraduate medical teaching. Faculty were drawn from all years and modules of the undergraduate programme to capture perspectives beyond those teaching immunology alone. Respondents were given two weeks to complete the survey, with a reminder issued after one week.

Analysis and outputs

Quantitative responses were summarised descriptively. Free-text responses were analysed using direct content analysis and organised into a curriculum-mapping matrix structured by foundational discipline, system-based module, clinical module and vertical theme. Duplicate responses were removed and semantically similar terms merged. General comments were analysed thematically to identify cross-cutting issues related to sequencing, depth and integration.

The primary outputs of Phase 1, which formed the initial components of the curriculum framework, were: a set of overarching principles to guide approaches to immunology teaching, and an initial, mapped set of proposed immunology content domains spanning foundational sciences, system-based modules and clinical disciplines. Together, these outputs provided the structured basis for discussion and prioritisation during the Consensus Development Panel meeting.

Phase 2: CDP (prioritisation and refinement)

CDP composition and procedure

A CDP was convened to review and refine outputs from Phase 1 in the context of national and local curriculum guidance. Twenty-two stakeholders were invited to participate and 16 attended the meeting held online on 15 April 2021. CDP members included clinical immunologists, immunopharmacology educators, module and year leads, and representatives of the institutional curriculum transformation group. The goal was to prioritise essential content, determine appropriate sequencing within a spiral curriculum and identify feasible approaches to delivery.

The CDP meeting lasted 90 min and was chaired by the experienced immunology module lead to facilitate discussion, manage group dynamics and ensure balanced participation. Prior to the meeting, participants received a summary of Phase 1 outputs, an abbreviated national pathology curriculum for immunology, local curriculum inclusion criteria, and a list of proposed core clinical cases with immunology relevance.

Data collection and decision-making

During the CDP, Phase 1 proposals were reviewed systematically by discipline and module. Discussion focused on prioritising essential immunology content, determining appropriate sequencing within a spiral curriculum, and identifying preferred delivery approaches. Consensus was operationalised pragmatically as agreement of expert opinion sufficient to guide curricular decision-making, with majority agreement (> 50%) used where unanimity was not achieved and unresolved items progressed to Phase 3 for wider validation. The meeting was recorded and transcribed with participants' prior consent.

Analysis and outputs

CDP transcripts and contemporaneous notes were analysed using direct content analysis to identify areas of agreement, clarification, modification, prioritisation, delivery approach and timing within the curriculum. Outputs from Phase 2 comprised refinement of the curriculum framework through:

- an agreed set of core immunology content domains appropriate for undergraduate medical education ('what');
- guiding principles ('why' and 'when');
- operational guidance to be validated in Phase 3.

Phase 3: Alumni questionnaire (validation and contextualisation)

Instrument development and content

A 21-item electronic questionnaire (Appendix 2) was developed to validate guidance arising from Phases 1 and 2 and to capture perspectives from medical graduates in clinical practice. Items included Likert-scale ratings of key guidance, selection of priority clinical cases for reinforcing immunology principles, and expectations regarding immunology knowledge for early medical students compared with newly-qualified doctors. A final open-ended item invited general comments. The questionnaire was piloted with alumni professional staff and a senior lecturer prior to dissemination.

Data collection

The questionnaire was distributed via the institutional alumni office between 27 May and 10 June 2021. Medical graduates from the preceding 50 years were eligible, reflecting the aim of capturing perspectives on preparedness across stages of clinical practice rather than cohort-specific outcomes. Targeted sampling was used to ensure representation across all recognised medical specialties. Participation was anonymous and voluntary.

Analysis and outputs

Quantitative responses were analysed descriptively and reported as proportions of respondents per item. Free-text responses were analysed using direct content analysis to identify areas of endorsement, concern or suggested refinement. Phase 3 outputs were used to confirm, contextualise or refine recommendations generated in earlier phases.

Cross-phase synthesis and framework development

Findings from all three phases were integrated using cross-phase synthesis to identify recurring observations related to content prioritisation, sequencing, integration and feasibility within a spiral curriculum. These observations were synthesised to inform the development of a concise set of guiding 'Dos and Don'ts' intended to support curriculum planners and clinician-educators implementing immunology teaching within integrated undergraduate medical programmes.

Results

Overview of participation

Data were generated across three phases. In Phase 1, 30 faculty members responded from 71 invited (response rate 42%). In Phase 2, 16 stakeholders participated in the CDP (16/22 invited; 73%). Phase 3 included responses from medical alumni across a broad range of graduation years, specialties and practice settings.

Phase 1: Faculty questionnaire (content identification and mapping)

Faculty respondents represented all years of the undergraduate medical programme and 12 of 18 academic departments (67%). Respondents included educators from five foundational sciences and ten clinical disciplines, with 93% reporting direct involvement in undergraduate medical teaching. A range of academic ranks participated, including senior/lecturers, module/year leads, heads of department and deputy deans. Of the 30 respondents, 25 were clinicians, representing 19 clinical disciplines. The mean time to complete the questionnaire was 12 min (range 4 to 80 min). Response rates for specific questions ranged from 20–70%.

Preliminary guiding principles for immunology teaching design and delivery

Respondents proposed a number of suggestions relating to the organisation and delivery of the curricular content that were synthesised into guiding principles for the curriculum design. These are summarised below with illustrative quotes.

Responses consistently emphasised **importance of understanding of normal immune function, tailored for the early years of the programme** to balance complexity, alongside immune-mediated disease mechanisms, diagnostic principles, and management or prevention strategies, before covering clinical application. For example:

'Specific immunology lectures should be given early in the medical curriculum. This will give the student an appreciation for immunology applications in the clinical setting. Given the breadth of immunology in disease manifestation, diagnostics and treatment it will be included in most general clinical lectures.'

'Initial basic introductions integrated into the case-based learning, with spiralling of depth and breadth throughout the programme - to level appropriate for intern practice.'

While the majority of respondents supported early introduction of core immunology concepts, several emphasised the need for **careful alignment with students' level, other learning and explicit linkage** to potential system-based modules and clinical presentations at appropriate points. For example:

'Just need to make sure the content is pitched correctly for year 1 students and spiralled appropriately.'

'Introduction of the topic needs to be carefully located & paced as an integral part of the total content.'

Some respondents raised concerns about the potential for curriculum overload and excessive molecular or mechanistic detail in early years, with respondents advocating **prioritisation of clinically-relevant concepts and principles over detailed molecular pathways** at the outset. Some provided specific suggestions about what could be included. For example:

'I think a simple overview of how the immune system goes wrong (i.e. by highlighting all the categories e.g. hypersensitivity, allergy, infection etc.) is sufficient..., with a simple case study such as allergy.'

'Need to avoid postgraduate-level content.'

Free-text responses also identified challenges associated with integration in a spiral curriculum, including risks of duplication across modules, variable depth of coverage and potential loss of disciplinary coherence and emphasised the **need for careful planning and review**. For example:

'Students may lose sight of the different aspects of immunology that they have been interacting with through each module without those aspects being extremely well sign-posted in that specific module.'

Initial set of proposed core immunology content domains mapped to curricular elements

Faculty identified immunology knowledge requirements spanning core immunopathological domains, including inflammation, infection and immunodeficiency, allergy, autoimmunity, transplantation and transfusion medicine, and cancer immunology. Across responses, these domains were framed in relation to their interfaces with foundational sciences, system-based modules and clinical disciplines, rather than as stand-alone topics. To synthesise these data for curriculum planning, faculty proposals were consolidated into a set of core immunology content domains, with illustrative examples of their integration across foundational sciences, system-based modules and clinical disciplines. Mapping was intended to capture areas of convergence and curricular relevance, rather than to provide exhaustive coverage of all possible immunology content domains, and to support coherent integration within a spiral undergraduate medical curriculum (Table 2). At this stage, the guiding principles and mapped domains functioned as formative inputs to the consensus process, intended to surface priorities and assumptions rather than to constitute a finalised curriculum framework.

Together, these outputs formed the initial components of the curriculum framework, which was subsequently refined, validated, and operationalised across Phases 2 and 3.

Phase 2: CDP (prioritisation and refinement)

The Phase 1 outputs, comprising formative guiding principles for immunology teaching and an initial curriculum-mapping overview of content domains, formed the primary input to the CDP. The function of Phase 2 was not to generate new content, but to apply expert judgement to the Phase 1 outputs in order to prioritise essential content, determine appropriate sequencing within a spiral curriculum, and identify feasible approaches to delivery in the context of national and local curriculum guidance. Phase 2 therefore represented the point at which formative inputs from Phase 1 were prioritised and refined into an agreed set of core content domains and guiding principles appropriate for undergraduate medical education.

Sixteen stakeholders participated in the online CDP, representing 73% of those invited. Participants comprised ten clinicians and six academic scientists, with representation from clinical immunology, immunopharmacology education, a range of medical and surgical specialties, and curriculum leadership across all years of the undergraduate medical programme. Four invited participants were unavailable due to prior clinical commitments, and two did not respond.

Table 2 Immunology content domains and their integration across the undergraduate medical curriculum with illustrative examples

Immunology Content Domain	Key Conceptual Focus	Foundational Science Interfaces	System-Based Module Integration (Illustrative)	Clinical Discipline Integration (Illustrative)
Innate and Adaptive Immunity	Organisation and coordination of innate and adaptive immune responses; immune cell development	Anatomy (lymphoid organs), Physiology (barrier function), Pathology (inflammation), Microbiology (host defence)	Respiratory (host defence, infection), Gastrointestinal (mucosal immunity)	Medicine, Paediatrics, Surgery
Inflammation and Immune Dysregulation	Acute and chronic inflammation; cytokine signalling; systemic inflammatory responses	Pathology (acute/chronic inflammation), Physiology (ARDS, shock), Biochemistry (cytokine signalling)	Cardiovascular (atherosclerosis, myocarditis), Respiratory (ARDS), CNS (vasculitis)	Medicine, Anaesthetics & Critical Care, Psychiatry
Infection and Immunodeficiency	Host–pathogen interaction; primary and secondary immunodeficiency; immune compromise	Microbiology (pathogenesis), Pathology (immune-mediated damage), Genetics (inborn errors of immunity)	Respiratory (TB, pneumonia), Renal (post-infectious GN)	Medicine, Paediatrics, General Practice
Allergy and Hypersensitivity	Mechanisms of allergic disease; drug allergy; anaphylaxis	Pathology (hypersensitivity), Physiology (airway responses), Pharmacology (biologics)	Respiratory (asthma), ENT (rhinosinusitis)	General Practice, ENT, Anaesthetics
Autoimmunity	Loss of immune tolerance; organ-specific and systemic autoimmune disease	Pathology (autoimmune injury), Genetics (susceptibility), Biochemistry (autoantibodies)	Endocrine (T1DM, thyroid disease), CNS (MS), GI (IBD)	Medicine, Rheumatology, Endocrinology
Transplantation and Transfusion Immunology	Allograft rejection; immunosuppression; transfusion reactions	Pathology (rejection), Pharmacology (immunosuppressants)	Renal (transplant), GI (liver transplant)	Surgery, Obstetrics & Gynaecology, Anaesthetics
Cancer Immunology and Immunotherapy	Immune surveillance; tumour evasion; immunomodulatory therapies	Pathology (cancer biology), Biochemistry (cell signalling), Pharmacology (biologics)	Respiratory (lung cancer), Breast, GI	Oncology, Medicine
Immunological Investigation and Diagnostics	Principles, interpretation, and limitations of immunological testing	Pathology (diagnostics), Biochemistry (protein chemistry), Microbiology (serology)	Integrated across systems	All clinical disciplines
Vaccination and Population Immunology	Principles of vaccination; herd immunity; public health impact	Microbiology (vaccine-preventable disease), Population health	Respiratory, Paediatrics	General Practice, Paediatrics
*Psychoneuroimmunology and Chronic Disease	Interaction between immune dysfunction, chronic illness, and mental health	Psychology, Physiology, Pathology	CNS, chronic disease modules	Psychiatry, Medicine

*Included as an illustrative example of interdisciplinary integration identified by some respondents, rather than as a universally prioritised core domain

Review of Phase 1 outputs alongside national pathology curriculum guidance and local curriculum development criteria resulted in agreement on a set of core immunology content domains appropriate for undergraduate medical education.

CDP members consistently emphasised that immunology teaching should prioritise clinical relevance and explicitly support diagnostic reasoning and patient management across disciplines, rather than detailed molecular mechanisms in the early years of training. For example, discussion focused on distinguishing immunology concepts required for universal undergraduate competence from those better suited to postgraduate training, with emphasis placed on early recognition and clinical reasoning rather than detailed mechanistic classification. Concerns were raised regarding overall burden and the need to align early immunology teaching with students' developing foundations in cell biology and biochemistry.

The CDP endorsed alignment with national pathology curriculum guidance for immunology as a reference

framework for core content [27]. Broadly relevant clinical competencies were prioritised, with particular emphasis on drug allergy assessment, documentation and emergency management as essential skills for all graduating doctors. With respect to immunodeficiency, the CDP agreed that undergraduate teaching should focus on recognition of clinically-relevant 'red flags', while detailed classification and management of rare primary immunodeficiencies were considered more appropriate for postgraduate training.

Preferred delivery approaches included case-based learning to contextualise immunology concepts, supported by visual learning resources such as video animations, and explicit alignment with assessment to reinforce learning. More detailed immunopharmacology and advanced molecular mechanisms were considered more appropriate for later stages of the curriculum. Content areas for which consensus was incomplete or contested were progressed to Phase 3 for wider validation.

Phase 3: Alumni questionnaire (validation and contextualisation)

Phase 3 sought to validate and contextualise guiding principles and core content domains arising from Phases 1 and 2 by incorporating perspectives from medical alumni in clinical practice. Forty-nine alumni completed the questionnaire (49/408; 12%), representing a broad range of graduation years, clinical specialties and practice settings across multiple countries. The median time since graduation was 15 years, providing insight into preparedness for clinical practice beyond undergraduate training.

Medical alumni strongly endorsed recommendations arising from earlier phases. Use of clinical cases to contextualise immunology principles was rated as very or extremely important by 81% of respondents, while emphasis on clinically-relevant immunology skills applicable to all doctors was rated as very or extremely important by 76%. These findings aligned closely with the prioritisation judgements made by the CDP.

Additional priorities rated as very or extremely important included the availability of explanatory learning resources, such as video animations (68%), and adoption of national pathology curriculum guidance to support curricular coherence (66%). Alumni responses consistently supported simplified early teaching of immunology concepts, with progressive introduction of complexity aligned to increasing clinical exposure and clinical responsibility.

Responses relating to expected knowledge levels demonstrated clear differentiation between early medical students and newly-qualified doctors. Alumni expectations supported staged progression of depth and responsibility within a spiral curriculum, reinforcing Phase 2 decisions to prioritise foundational understanding and universal clinical competencies early, with more advanced immunology and immunopharmacology addressed later in training. These findings informed refinement of the curriculum framework rather than modification of core content domains.

Cross-phase synthesis: Development of 'Dos and Don'ts'

Cross-phase synthesis integrated findings from all three study phases to identify recurring challenges and priorities relevant to the integration of immunology within a spiral undergraduate medical curriculum. Across stakeholder groups, consistent themes emerged relating to risks of curriculum overload, inappropriate sequencing of immunology concepts relative to students' foundational knowledge, fragmentation of content across modules and years, and reduced visibility of foundational science in later clinical phases

of training. There was also strong convergence around the importance of early conceptual grounding, longitudinal reinforcement of core immunology principles, explicit clinical contextualisation, and alignment with assessment to support learning and retention.

In addition to themes arising directly from stakeholder data, cross-phase synthesis incorporated analytic reflection by the research team, informed by engagement with curriculum implementation during a period of active curricular reform. Together, stakeholder-derived priorities and analytic reflection were used to develop a concise set of operational 'Dos and Don'ts'. These are intended to support curriculum planners and clinician-educators in translating agreed core clinical science content domains and guiding principles into coherent, feasible teaching across integrated and spiral undergraduate medical programmes.

Operational guidance for spiral integration of clinical science 'Dos and Don'ts'

Dos

- Use online meetings, with polling options where appropriate, and record discussions with participant permission to support transparency and review.
- Use a mix of methods and steps in reaching consensus, rather than relying on a single rigid methodology.
- Involve established faculty with structural knowledge of the institution and curriculum to support feasibility and sustainability.
- Maintain a live, shared repository of plans, schedules, documents and curriculum maps to support coordination and coherence.
- Involve multiple stakeholder groups, including clinicians, scientists, teaching faculty and graduates, to ensure relevance across contexts.
- Engage alumni and alumni offices to harness post-graduation perspectives on preparedness for clinical practice.
- Use vertical themes to structure integration of immunology across years, modules and clinical contexts.

Don'ts

- Do not attempt detailed curriculum mapping too early in the curriculum design process, before core principles and priorities are agreed.
- Avoid long questionnaires with excessive open-ended free-text items that may limit response rates and analytic clarity.
- Do not take a passive approach to integrating foundational science within spiral curricula; explicit planning and signposting are required.

The consensus-based immunology curriculum framework

The consensus-based curriculum framework emerging from this study comprises the agreed core immunology content domains (the ‘what’), the guiding principles governing their sequencing and depth (the ‘why’ and ‘when’), and the operational ‘Dos and Don’ts’ (the ‘how’) that operationalise these elements for curriculum planning and delivery.

Discussion

Principal findings and contribution

This study developed a consensus-based curriculum framework to support undergraduate immunology teaching within a spiral medical curriculum. Through a structured, multi-phase process involving faculty, curriculum leaders and medical alumni, core immunology content domains were identified, prioritised and validated. This addresses a recognised gap in discipline-specific guidance for immunology education within integrated and spiral curricula, where foundational sciences risk fragmentation and loss of coherence [10, 20, 23].

The principal contribution of this work lies in combining content specification with operational guidance. Previous curriculum recommendations in immunology have focused on learning outcomes or topic lists [27], with limited attention to sequencing, depth or implementation within integrated curricula. By explicitly linking agreed content domains with guiding principles for delivery, the present framework supports both curriculum design and enactment, and addresses the vulnerability of immunology within spiral curricula, where foundational sciences are increasingly fragmented.

Immunology as a vulnerable foundational science in spiral curricula

Immunology occupies a distinct position within undergraduate medical education. It underpins clinical practice across infection, allergy, autoimmunity, transplantation and cancer [1, 2] yet lacks a natural anatomical or system-based ‘home’ within integrated curricula. As a result, content is often dispersed across modules and years, increasing the risk of fragmentation, duplication and inconsistent depth of coverage [19, 20]. Spiral curricula aim to enhance learning through repeated exposure and increasing complexity [15, 16]. However, without explicit planning, spiral integration may exacerbate rather than resolve challenges for foundational sciences, particularly where disciplinary

ownership becomes diffuse in later clinical years [20]. The emphasis across all phases of this study on early conceptual grounding, longitudinal reinforcement and clinical contextualisation reflects both learning theory and stakeholder experience, and aligns with evidence that explicit linkage between foundational science and clinical application supports retention and transfer of knowledge [12, 17].

Consensus-based methods for curriculum coherence

Curriculum design decisions regarding content selection, sequencing and depth are rarely determined by empirical evidence alone and often require expert judgement informed by professional practice and contextual constraints [13]. In such contexts, consensus-based approaches provide a transparent mechanism for synthesising diverse perspectives and supporting defensible decision-making [24, 28]. This study deliberately avoided rigid adherence to a single labelled consensus methodology, instead prioritising comprehensive reporting of CDP composition, data sources and analytic processes, consistent with recommendations in the consensus-methods literature [24, 28]. The three-phase design allowed for content generation, expert prioritisation and validation through post-graduation perspectives, enhancing both credibility and relevance. Inclusion of medical alumni aligns with calls for broader stakeholder involvement in curriculum design and provides insight into preparedness for clinical practice [29].

Similar multi-phase data collection methods have previously been used to build consensus in immunology curriculum design in the USA [21, 22]. However, these were conducted within undergraduate health science contexts [22], or focused only on host defences within microbiology teaching for medical students [21]. Moreover, input had been confined to the immunology subspecialist teaching community within their geographical location, was primarily centred on content lists, and offered minimal practical guidance on integrating immunology within a spiral curriculum.

While much of the existing immunology medical curriculum literature addresses as entirely separate entities the immunological aspects of laboratory pathology [30–32], related disciplines like microbiology and infection [21], or allergy [33–35], our work considers these components together more comprehensively and in the context of a spiralled medical curriculum. This curriculum was designed to reflect current local clinical and teaching practices to ensure graduates acquire the knowledge and skills needed for safe clinical practice. Our approach contributes a novel and transparent methodology comprising a structured, consensus-based framework for incorporating core immunology content domains into the new curriculum, including

principles for sequencing, and fills recognised gaps in the literature by moving beyond topic lists to provide operational guidance for spiral integration.

The multi-phase consensus approach adopted herein proved helpful in linking content generation (Phase 1) with expert prioritisation (Phase 2) and post-graduation validation (Phase 3) through complementary methods of data collection. This study was also unique in its deliberate representation of feedback from a wide range of stakeholders, including practising clinicians in multiple disciplines (not simply limited to immunology subspecialties), faculty scientists and teachers (ranging from junior to senior levels), and international medical alumni of the university (representing a diverse range of ages and nationalities). This extensive sampling was an asset in counterbalancing the “immunology-only” perspectives common in prior curricula [21, 22].

The curriculum framework as an implementation strategy

A key methodological contribution of this study is the development of a curriculum framework that explicitly links agreed core immunology content domains with guiding principles for sequencing and depth within a spiral curriculum, and with operational guidance to support implementation. Rather than producing a prescriptive syllabus or topic list, the framework is positioned intentionally at a level that supports coherent curriculum design while remaining adaptable to diverse institutional structures and resources. This approach recognises the heterogeneity of integrated and spiral curricula and the limitations of overly detailed or rigid curricular prescriptions, and preserves flexibility to respond to local curricular constraints and priorities [19].

Within this framework, the ‘Dos and Don’ts’ function as an operational expression of agreed priorities, translating core domains and guiding principles into practical guidance that supports enactment in real-world curricular contexts. By making explicit both what should be prioritised and how integration can be supported, the framework addresses common implementation challenges identified across study phases, including curriculum overload, inappropriate sequencing of content, excessive molecular detail in early years, and misalignment between teaching and assessment. Similar implementation-focused strategies have been advocated in other areas of medical education to bridge the gap between curricular intent and educational practice [20].

In the authors’ home institution, curriculum integration is typically achieved through “module planning groups” including the relevant teaching faculty involved in delivery as the key stakeholders. While the consensus framework described herein has not been used to date by other

foundational sciences in the institution, the current work demonstrates that outputs from the multi-phase immunology consensus framework could “plug into” the local governance structure and be applied to other foundational sciences in the future.

Implications for curriculum planners and clinician-educators

For curriculum planners, this framework provides structured guidance for prioritising immunology content and integrating it coherently within spiral curricula. Explicit articulation of core domains and guiding principles supports curriculum mapping and helps safeguard foundational science content during reform, particularly in later clinical years where disciplinary visibility may diminish [20]. For clinician-educators, the findings emphasise the importance of clinical contextualisation and alignment with assessment in reinforcing the relevance of immunology for students. Prioritisation of universally relevant competencies, such as drug allergy assessment, reflects stakeholder recognition of immunology knowledge required across specialties and aligns with national guidance on core immunology competencies [27]. Although developed for immunology, the framework may be transferable to other foundational sciences facing similar challenges within integrated medical education curricula.

The success of curricular change depends on many factors, not least resource allocation and faculty development along with an organizational structure and leadership that cultivates a cooperative climate to encourage internal networking and participation [36, 37]. As many academic departments remain structured around individual disciplines and practising clinicians become ever more subspecialised, moving away from traditional discipline-specific teaching requires greater central organisation, collaboration and co-ordination within and between disciplines to facilitate integrated teaching, while also asking educators from basic science or clinical disciplines to step outside their comfort zone [14, 38, 39].

Ownership among all stakeholders from different disciplines, alongside structures for collaboration between departments and students, are crucial for managing the change process, and key in ensuring the long-term sustainability of curricular reform [40, 41]. For successful integration, individual lecturers require a greater understanding of the content and structure of the entire curriculum when preparing their own learning activities to ensure that content builds on what has already been taught by other disciplines and to make links between content explicit [42]. To facilitate this goal, curriculum mapping processes can be used to ensure core concepts are deliberately revisited

with progressive complexity, ensuring longitudinal coherence across the spiral, while identifying redundancies and gaps [43].

To support sustainability, ongoing review and updating of immunology content should be embedded within existing curriculum governance structures which could be aligned with 5-year accreditation cycles with the medical accreditors [44], with periodic cross-disciplinary review cycles to ensure alignment with evolving clinical practice and scientific advances. Maintaining a shared curriculum map which can be facilitated by dedicated software e.g. Akari [45], and by reconvening a representative stakeholder group at defined intervals, may help preserve coherence and prevent fragmentation as the curriculum evolves.

Accordingly, curricular inclusion of emerging topics (in which our understanding can rapidly evolve) to facilitate the integration of basic and clinical sciences, and to increase clinical relevance, must be balanced with the inclusion of well-established content to prevent curricular over-crowding [46].

Strengths, limitations, and future research

Strengths of this study include inclusion of multiple stakeholder groups spanning undergraduate teaching, curriculum leadership and post-graduation clinical practice, and use of a structured, transparent consensus process consistent with best practice recommendations [24]. The development of practical implementation guidance through cross-phase synthesis addresses a recognised limitation of many curriculum consensus studies. While derived from a single institutional context, the framework emphasises transferable guiding principles of content prioritisation, sequencing, and integration rather than institution-specific curricular structures [15]. Although direct student participation was not feasible during the study period, inclusion of alumni perspectives provided insight into preparedness for practice and retrospective evaluation of undergraduate immunology teaching. Evaluation of educational outcomes following implementation was beyond the scope of this study and represents a key area for further research.

Conclusion

This study provides a rigorously-developed, consensus-based framework to support immunology teaching within spiral undergraduate medical curricula. By combining agreed core content domains with practical ‘Dos and Don’ts’ derived through cross-phase synthesis, the framework offers guidance for maintaining clinical relevance and disciplinary coherence during curriculum reform. While focused on

immunology, the approach may inform curriculum development for other foundational sciences within integrated medical programmes.

Appendix 1: faculty questionnaire

Introduction

In THEP 2, immunology will be introduced in Foundations for Practice Modules in Year 1, and then integrated horizontally and vertically throughout the curriculum.

In advance of a meeting on the 15th of April, we would appreciate your input on the content, cases and delivery of immunology for the new spiralled curriculum.

(No questions are mandatory, please answer any questions that you can contribute to).

1. What RCSI Academic Department are you in?

2. How would you describe your faculty role in RCSI (choose all that apply) Clinician

Academic/Scientist
Head of Department
Year Lead
Module Lead
Senior Lecturer
Lecturer/Tutor
Other (please specify)

3. What location are you based in?

Dublin
Bahrain
Perdana
Other (please specify)

4. What are your areas of specialist interest? (E.g. within clinical practice, research)

5. What years, modules and topics do you teach in the RCSI undergraduate medical curriculum?

Year 1
Year 2
Year 3
Year 4
Year 5
Other

6. Within the areas you teach- what topics, clinical presentations or diseases will require an understanding of immunopathology? Please provide specific examples under the categories below:

Inflammation
Autoimmunity
Infection and Immunodeficiency
Immune System and Cancer
Allergy
Transfusion, Transplant and Rejection
Other

7. For the topics/presentations/diseases listed above, please provide specific examples of what immunology knowledge is required in relation to:

- A- Normal Immune system
- B- Immunodiagnostics
- C- Disease Management/Prevention

8. How do you see immunology integrating with other Foundational Disciplines in Year 1 and beyond?

- Pathology
- Microbiology
- Biochemistry
- Anatomy
- Physiology
- Pharmacology
- Psychology
- Other

9. How do you see immunology integrating with the following Vertical Themes of THEP 2?

- Clinical Skills
- Inter-professional Learning
- Student Choice
- Learning Environment
- Population Health and Healthcare Delivery
- Personal & Professional Identity (including—professionalism, leadership, self-awareness, resilience, managing self, and engaging with patients, colleagues and communities)

Other

10. How do you see immunology integrating with the following System Based Modules in Year 1 & 2?

- Cardiovascular
- Respiratory
- Endocrine & Breast
- Renal GU
- GIHEP
- CNS
- Other

11. How do you see immunology integrating with the following clinical Disciplines in Years 3–5?

- Medicine
- Surgery
- ENT
- Ophthalmology
- Orthopaedics/MSK
- Anaesthetics
- General Practice
- Psychiatry
- Medicine and Surgery of Childhood
- Obstetrics and Gynaecology
- Other

12. How do you see immunology integrating with the following modules in Years 1–5?

Year 1 & 2—Student Choice- (Themes- the World around You, Health and Well-being, Introduction to Clinical practice, Research and Science, Humanities)

Year 2—Preparation for Clinical Placement (Navigating the hospital learning environment, common signs, symptoms & investigations, using fundamentals in formulating differential diagnosis, role of MDT, principles of good prescribing)

Year 3—New Technologies in Medicine- (Role of new technologies- how research, professionalism, clinical leadership and improvement science contribute to introduction in clinical practice)

Year 3—Student Selected Project (Appraise literature, conduct and report a research/audit project)

Year 4 & 5- Clinical Electives, Clinical Clerkship/Sub-internship (Apprenticeship model –learning while being embedded in a clinical team)

Year 5- Preparation for Intern Practice (Develop skills to manage challenging clinical scenarios and nuances experienced by interns- through simulation, feedback, workshops and reflective assignments. Emphasis on professional behavior, clinical reasoning, practical prescribing skills, medical ethics, communication skills, and legal medicine)

Other

13. Are there any immunology related topics/presentations/diseases which you feel are too complex to be introduced in Foundations for Practice in Year 1?

14. Are there any immunology related topics/presentations/diseases which are well suited to be developed within a specific module?

15. Please provide any other comments or feedback

Appendix 2: medical alumni questionnaire

Introduction

In the new RCSI medical curriculum, immunology will be introduced in the first weeks of Year 1 (rather than year 2/3) and then integrated throughout the medical curriculum.

We would appreciate your input on the content, cases and delivery of immunology for the new spiraled curriculum- to ensure all RCSI medical graduates have the knowledge and skills required to practice as an Intern/1st Year Resident/Post Graduate Year 1 (PGY1) Doctor.

Please answer any questions you can- in the following sections:

- Demographics
- General Recommendations
- Clinical Cases
- Therapeutics
- Additional comments

(This questionnaire is anonymous and should take less than 10 min to complete.)

Demographics (questions 1–4)

1. What year did you graduate from RCSI?

2. What are your areas of Board Certification/Division of Specialist Registration?

3. What are your current areas of Clinical Practice or Specialist Interest? (E.g. within clinical practice or research)

As above

Other/additional (please specify)

4. What country have you most recently practiced in?

General Recommendations (questions 5–10)

The following 6 recommendations are based upon the results from a staff questionnaire, an RCSI curriculum planning meeting and a comparison of the current curriculum with national guidelines for pathology in Irish Medical Schools.

Please rate how important each recommendation is.

4- Extremely important

3- Very important

2- Somewhat important

1- Not so important

0—Not at all important Other (please specify)

5. Immunology content from Year 2/3 must be simplified and appropriately sequenced for introduction into the first weeks of Year 1, with therapeutics kept to a minimum.

6. Clinical cases should provide context to enhance learning and reinforce immunology principles for broad application across multiple disciplines.

7. Clinical immunology skills relevant to all doctors should be reinforced throughout the curriculum, e.g. taking an allergy- focused history- with an emphasis on drug allergy assessment, management and documentation.

9. Students should understand the role of a clinical immunologist and the immunology lab in diagnostics, patient care, and healthcare systems.

10. Video animations explaining core immunology concepts should be available for students online.

11. The Irish national pathology curriculum guidelines for immunology (Faculty of Pathology, RCPI) should be adopted locally in RCSI. (See abbreviated learning outcomes below for your reference).

1. Abbreviated National Pathology Curriculum: Immunology learning outcomes: Understand the basic components & organisation of the immune system, and their contribution to disease.

2. Understand defences against infection, including natural barriers, innate and acquired immunity. Understand the role of the immune system in controlling infectious diseases and in cancer immunotherapy.
3. Describe the cellular & molecular basis of the inflammatory response; understand the mechanisms.
4. Understand immune regulation/dysregulation in terms of self-tolerance/autoimmunity and the development of immune-related diseases including hypersensitivities.
5. Understand the rationale for vaccination; principles of vaccine development, types and adverse events.
6. Outline the main immunodeficiencies, their clinical signs, and the necessary diagnostic investigations.
7. Understand the immunological basis of allergic reactions (differentiate from allergy mimics) & the importance of an allergy-focussed history. Explain assessment, documentation, emergency management and subsequent investigation of potential drug allergies.
8. Understand the immunological basis of transfusion-related reactions and basic principles of transplantation.
9. Understand the Role of the Immunologist in healthcare delivery, diagnostics and patient care in the context of the organisational structure of pathology services. Identify and communicate effectively when immunology services are required.
10. Recognise the importance of laboratory diagnosis in patient care. Understand basic principles of immunoassays, flow cytometry and their clinical diagnostic applications. Understand assays clinical performance parameters, limitations, efficiency and ethical considerations in test selection, interpretation and communication of results to minimise patient and population harm.

Clinical Cases (questions 11–14)

We hope to create supplementary, self-guided online cases to reinforce immunology principles with broad applications across multiple disciplines.

Please select the 2 most suitable supplementary clinical cases within each of the systems/disciplines below.

11. Central Nervous System (Select 2)

Cerebral vasculitis

Gullian Barre Syndrome

Meningitis

Multiple sclerosis

Myasthenia gravis

Other (please specify)

12. Renal-Genitourinary (Select 2)

Allergic interstitial nephritis

ANCA associated renal vasculitis

Anti-GBM (Goodpasture) Disease

IgA nephropathy
Lupus nephritis
Post streptococcal glomerulonephritis
Other (please specify)

13. Cardiovascular (Select 2)

Myocarditis
Pericarditis
Rheumatic Fever/rheumatic heart disease
Vasculitis
Other (please specify)

14. Medicine (Select 2)

Eczema
Immune-related adverse events by immune checkpoint inhibitors

Penicillin allergy
Psoriasis/Psoriatic Arthritis
Rheumatoid arthritis
Secondary Immunodeficiency
Other (please specify)

Therapeutics (questions 15- 20)

A limited amount of therapeutics will be introduced with immunology in Year 1, but further knowledge and prescribing skills must be developed before graduation.

Please **complete any sections you can** and **click "Done"** at the bottom of the screen, to submit your answers when you have finished.

For each therapy- Please indicate what is appropriate for a 1st Year Medical student vs an Intern/1st Year Resident/PGY1, in relation to the required level of understanding/skills, as outlined below:
A- Basic Understanding – e.g. Mechanism of action, common side effects

B- Detailed Pharmacology- e.g. Pharmacodynamics/kinetics, CI, monitoring, interactions etc

C- Prescribe Supervised- Competent to safely prescribe with supervision

D- No knowledge required- Knowledge not necessary for safe practice

15. Allergic Disease

	Year 1 Student	Intern/PGY1
Adrenaline/Epinephrine		
Leukotriene antagonist (eg Montelukast)		
Antihistamines (e.g. Cetirizine, Loratadine, Chlorphenamine)		
Anti IgE (e.g. Omalizumab)		
Anti IL-5 (e.g. Mepolizumab, blocks receptor Eosinophil)		
Anti IL-4 alpha (e.g. Dupilumab, blocks IL-4 and IL-13)		
Other (please specify)		

16. Inflammatory-Disease

	Year 1 Student	Intern/PGY1
NSAIDs–COX-1 inhibitors (e.g. Aspirin, Ibuprofen, Diclofenac)		
NSAIDs- COX-2 inhibitors (e.g. Celecoxib)		
Gout—(e.g. Colchicine, Allopurinol, Probenecid, Rasburicase, Febuxostat)		
Soluble IL-1 receptor antagonist (e.g. Anakinra)		
Anti- IL-6 receptor antagonist (e.g. Tocilizumab)		
Other (please specify)		

17. Transplant/Immunosuppression

	Year 1 Student	Intern/PGY1
Azathioprine (6 M P)		
Mycophenolate		
Cyclosporine		
Tacrolimus		
Anti CD3 (e.g. Muromonab, Anti-Thymocyte Globulin/ATG)		
Anti-IL-2 receptor antibody/anti CD-25 (e.g. Basiliximab)		
Other (please specify)		

18. Autoimmunity Broad

	Year 1 Student	Intern/PGY1
Glucocorticoids		
Cyclophosphamide		
Methotrexate		
Leflunomide		
Sulfasalazine (5-ASA)		
Hydroxychloroquine		
Intravenous Immunoglobulin (IVIG)		
Plasma exchange		
Anti-CD20 (e.g. Rituximab)		
Other (please specify)		

19. Autoimmunity- specific

	Year 1 Student	Intern/PGY1
Anti TNF alpha (e.g. Infliximab, Etanercept, Adalimumab)		
CTLA4 agonist (e.g. Abatacept)		
Anti IL12 & 23 (e.g. Ustekinumab)		
Anti- IL-17 (e.g. Secukinumab)		
Janus kinase inhibitor (e.g. Tofacitinib)		
Phosphodiesterase -4 inhibitor (e.g. Aprelimast)		
alpha4-beta7- integrin inhibitor (e.g. Vedolizumab)		
Other (please specify)		

20. Malignancy

	Year 1 Student	Intern/ PGY1
Check point inhibitors- Anti-PD1, anti-PD-L1 (e.g. Nivolumab, Pembrolizumab)		
Check point inhibitors- Anti CTLA-4 (e.g. Ipilimumab)		
Chimeric Antigen Receptor (CAR) T cell therapy		
Preventive vaccines (e.g. HPV/Cervical Ca, Hep B/Hepatocellular)		
Intravesical BCG		
Other (please specify)		

Additional Comments (question 21)

21. Please provide any additional comments or feedback below.

Thank you for your time.

Click "Done" to submit your responses.

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