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# Basic histology knowledge gaps in Moroccan university students: Curriculum achievement and persistent misconceptions

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**Abstract**

This quantitative study evaluated basic histology knowledge among 302 first-year Moroccan university students through a questionnaire based on the Bloom's taxonomy on knowledge, comprehension, and application levels across four tissues (epithelium, connective, muscle, and nervous), assessing curriculum achievement and misconceptions. Students achieved partial descriptive competence in epithelium classification but exhibited also systemic relational failures—worst in connective tissue (78-100% failure rates, 70.2% average partial/incorrect responses)—revealing three prevalent misconception clusters (15-94%): extracellular matrix/matrix confusion (epithelium composition 67% and bone hydroxyapatite 94%), fiber/gland morphology errors (82-87%), and neuron/muscle structural conflations (45% axon misclassification). These kinds of knowledge gaps hinder the development of students' biological and biomedical laboratory skills in accordance with secondary and university curricula. Student-centered, active learning strategies integrated with virtual microscopy platforms can prevent infrastructure constraints and visualization deficits, and support students' meaningful tissue identification. Effective pedagogical practices are needed to achieve the learning objectives of the curricula, to strengthen students' motivation and correct their misconceptions, and to harmonize histology teaching in secondary education and higher education.

**Keywords:** histology learning, Morocco, misconceptions, university students, knowledge gaps

## INTRODUCTION

Histology, also known as microscopic anatomy or micro-anatomy, is a branch of anatomy that uses a microscope (García et al., 2019). Research in histology focuses at the cellular level on tissue structures and functions (de los Ángeles Cambrón-Carmona et al., 2016), which are complex, diverse and usually invisible to the human eye (Thompson et al., 2020). A solid understanding of histology requires prior knowledge of basic anatomy and deeper grasp of how the body is constructed, functions, and undergoes pathological change (Chapman et al., 2020). The understanding the nature of cells and cellular processes in the life of organisms is therefore essential for mastering histology.

Knowledge of cells and tissues constitutes basic content knowledge that is closely linked to students' skills, values, and attitudes in learning processes. General learning skills include concentration, perception, memory, information processing, and time


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**Contribution to the literature**

- This study offers views to design key aspects that promote students' meaningful and effective histology learning. It also describes students' basic knowledge and achievement of the learning objectives at undergraduate level in histology studies.
- It describes the difficulties and misconceptions about histology that can hinder learning histology.
- It recommends student-centered learning methods to reduce these learning gaps in histology and promote critical thinking.

management. Subject-specific skills include critical thinking, creative thinking, scientific collaboration, and scientific communication (Ennis, 1989). Critical thinking is reasonable, reflective thinking that is focused on deciding what to believe or do (Stiggins, 1991); it is particularly important for understanding natural sciences, because natural sciences are empirical, subject-specific sciences (Ennis, 1989). Creative thinking emphasizes exploring ideas, generates multiple possibilities, and accepting several possibilities rather than just one (Begbie, 1970).

Scientific work also requires teamwork and collaboration: students should learn to discuss histological issues using appropriate symbols, signs and concepts. From this perspective, histology is a useful discipline not only for learning biological and medical subjects, but also for developing broader scientific competences (Brenner, 2022; Hortsch, 2023).

The teaching of histology is commonly organized into two main parts with different learning goals according to the dual-processing theories of learning (De Neys, 2006; Evans et al., 2013). The first part consists of didactic lectures focusing on nomenclature and factual information that a learner may memorize and repeat without a deep understanding of the material. The second part consists of histology laboratory sessions, where students are required to identify microscopic structures using analytical thinking. This second part relies on learned theoretical knowledge and demands deeper reasoning from the student. The two components are consecutive and interdependent; both are necessary for mastering the content knowledge of histology (Hortsch, 2023). Omitting either part tends to reduce students' overall knowledge (Gribbin et al., 2022).

Histology includes many details that can be difficult to remember and relate to one another, and this complexity often leads students to perceive the subject as challenging (Mansouri et al., 2020). University undergraduate students frequently report histology as one of the most difficult biological disciplines (Sant'Anna et al., 2022). The tissue-type histology is a foundational laboratory exercise used in many courses. It helps students to understand the complexity of tissue function (Felszeghy et al., 2019; Sotgiu et al., 2022), a system of tissues, and the deeper meaning of concepts related to cell structures (Dikmenli, 2010). However, many students do not like histology (Vemu et al., 2019) and may therefore have a poor understanding of histology-related questions (Vedartham, 2018). This generates difficulties in conceptualizing histological phenomena and can lead to fundamental misconceptions (Sesli & Kara, 2012). A misconception can be defined as a perception or a mental model that deviates from the prevailing scientific understanding of the time (Badenhorst et al., 2015). As a result, both students and teachers find histology a challenging subject (Sherman & Jue, 2009). Learning difficulties arise from several factors, including a lack of a coherent reference framework for the histology teaching in higher education, insufficient mastery of the histology content knowledge by students, limited or inadequate practical and tutorial work, reduced instructional time, and cognitive deficiencies carried over from secondary education (Burk et al., 2013; García et al., 2019). Another contributing factor is that histology is often perceived as unattractive or disconnected from clinical practice, which further reduces student motivation (García et al., 2019).

In recent years, technology-supported applications have been increasingly used alongside traditional teaching methods to facilitate histology education and promote student-centered learning (Sharmin et al., 2021). Virtual laboratories (Lee et al., 2018), e-learning platforms (Joaquim et al., 2022), digital images (Francis et al., 2023), and various animations and videos are among the alternative education strategies that have emerged with advances in information and communication technology (Campos-Sánchez et al., 2014). However, a solid grasp of this visual discipline still requires a high-quality iconography, which is best built through repeated observations of microscope slides during practical activities (Burk et al., 2013).

Deficits in subject content knowledge and learning skills affect students' performance. Previous studies have shown that technological advances are transforming the way histology is taught (Coleman, 2009; Hortsch, 2023). Students' interest in studying biology could be increased by using more interactive augmented reality and virtual reality methods (Brenner, 2022; Heidger et al., 2002; Sáez-López et al., 2020). The challenge is to develop interesting and intellectually demanding learning tasks suitable for learning in small groups that offer meaningful active learning experiences through teacher-student collaboration in virtual microscopy (Then et al., 2023). Many schools now combine individual microscopes and histological tissue sections, small-group study using video microscopes, and virtual microscopy within structured laboratory sessions (Bloodgood, 2012; Then et al., 2023). Recent curricula increasingly incorporate self-directed, active learning in small groups and to make field learning more student-centered (de los Ángeles Cambrón-Carmona et al., 2016; Jurjus et al., 2018; Khalil et al., 2013). The traditional lecture-based format for teaching histology is no longer considered fully sustainable (Hortsch, 2023; Smirle et al., 2012). Therefore, it is necessary to integrate innovative teaching approaches with traditional teaching methods, especially in medicine and healthcare, where interactive education systems that combine basic education and clinical training are of great importance (Rinaldi et al., 2017). New educational materials, such as interactive smart models and mobile applications may also offer advantages over older formats (Bolatlı & Taş, 2023; Rinaldi et al., 2017).

If histology teaching is not updated to meet current educational and technological requirements, the share of histology in the curricula may be further reduced in the future (Eng-Tat et al., 2023). It is therefore important to take students’ expectations and guidance needs into account when planning learning objectives and teaching methods, practical sessions, and tutorials. Histology, as a longitudinal and visually intensive discipline, presents a specific challenge for students. It requires close supervision and teaching models that mobilize abundant images and data from multiple sources (Hortsch & Mangrulkar, 2015; Vali-Betts et al., 2021). The central visual component of histology demands that students learn to analyze and interpret micrographs (Kumar et al., 2006; Mione et al., 2016; Zaidi et al., 2017).

Learning visuospatial cognitive skills is essential for success in histology studies (Helle et al., 2010). In teaching, it is useful to develop these students’ skills through practical applications in a clinical context to increase students’ affinity with microscopic anatomy (Teshome, 2022). Eng-Tat et al. (2023) report that many generations of students have struggled with histology, finding it “enormously dry” and the nomenclature extremely complicated. Students often resort to rote memorization of tissue characteristics rather than using pattern recognition and meaningful learning (Ausubel, 1968), making it difficult to apply this knowledge and skills on tests (Brenner, 2022; Vemu et al., 2019).

Traditional education methodologies have been reshaped by the introduction of new approaches (Cheng et al., 2017). Students express a preference for hybrid formats guided by pathologists and welcome more clinical context during histology lessons (Eng-Tat et al., 2023). To increase the relevance of histology, integrating histology into coordinated secondary and higher education curricula can support students’ understanding of structure-function relationships of cells and tissues, and to connect histological observations to biochemical reactions, physiological processes, pharmacological interactions, and pathological changes (McBride & Drake, 2018; Maity et al., 2023).

Research shows that histology laboratory sessions that include active learning opportunities reduce the need for teacher-centered instruction (Yen et al., 2014). Other innovative teaching methods, such as flipped classroom strategies and game-based learning, have been used successfully to improve student engagement with learning of histology content knowledge (Moro & McLean, 2017), although they remain relatively rare in university histology courses (Felszeghy et al., 2019; Gilliland, 2017; Li & Guo, 2014; McLean, 2018).

The flipped histology model has been shown to improve knowledge gains and to be perceived as interesting and engaging by students (Cheng et al., 2017; Rajprasath et al., 2018).

Saverino et al. (2022) highlight that students perceive a clear difference between theoretical lectures and practical courses. They express a strong need for face-to-face interaction with instructors and peers, particularly to ask questions and clarify concepts.. Peer-assisted learning in histology courses and e-learning for preparing practical and dissection sessions can increase students’ freedom of expression and self-confidence (Janczyk & Plendl, 2010).

One innovative approach is the use of live digital imaging of microscopic slides on SMART boards, which has had a strongly positive impact on histology learning and understanding (Higazi, 2011). Project-based learning has also been shown to improve students’ understanding of disease processes (Syaidah et al., 2020). Another digital approach, the HistoNFC system, stores histological images and data in a shared database, allowing them to be accessed at any time; reviews of the system have been very positive (Medina et al., 2019). Students reported that digital tools significantly increased their confidence in learning histology fundamentals and improved their attention and satisfaction. In teamwork-based histology classes, the transition to the WEBMICRO-SCOPE® teaching scenario was also well received, as it enhanced motivation and deeper understanding of histological concepts (Felszeghy et al., 2017).

Overall, histology teaching has clearly moved towards digitization and remote/distance components through the use of virtual microscopy and online platforms (Pesesse et al., 2023). Morphological disciplines such as histology must continually refine their didactic techniques to adapt to these changes (Tauber et al., 2021). The introduction of the massive open online course (MOOC) aimed to expand access to digital resources and foster interaction among students and instructors (Gardair et al., 2016). Integrating

MOOC-style elements into histology teaching—both in classroom and online settings—has been associated with higher student satisfaction, commitment, and motivation, and with easier achievement of expected learning objectives (Multon et al., 2018; Pesesse et al., 2023).

Assessment data suggests that many first-year students can take responsibility for their learning in diverse environments that combine multiple resources (Moro & McLean, 2017). Although these strategies are generally associated with a motivating learning environment (Gribbin et al., 2023), disciplines, such as histology, may still require more active scaffolding from instructors, as all students should not only convey the cellular architecture of metazoan organisms, but they should also develop their ability to perform scientific analysis of image-based data and be able to connect cell and organ structures with corresponding functions (Hortsch, 2023). Light microscopes remain a traditional tool in teaching laboratories for developing histological skills (Coleman, 2009; Paulsen et al., 2010), but digital images obtained via information and communication technology now offer additional means to train these skills (Coleman, 2009; Heidger et al., 2002). In various fields, studies indicate that augmented reality and virtual reality can enhance learners' motivation, promote self-directed learning, and affect academic performance positively (Chimmalgi & Hortsch, 2022; Yilmaz & Batdi, 2021). These methods can help students deepen their understanding of the learning material (Yoon et al., 2012).

According to the Bloom's taxonomy, cognitive skills can be organized along a continuum from simple to complex, represented by six hierarchical levels of skills: knowledge, comprehension, application, analysis, synthesis, and evaluation (Rajprasath et al., 2018). Traditional teaching methods often focus only on the first three levels presenting lower order cognitive abilities, whereas the last three involve higher order ones (Brenner, 2022). This framework helps characterize the level at which learners operate and allows instructors to align teaching activities with the complexity of learning objectives (Athanassiou et al., 2003; Bissell & Lemons, 2006).

In view of the above, histology can be seen as a foundational discipline that supports an integrated understanding of tissue structure and function. However, most existing research on histology teaching and learning has been conducted in Western or highly resourced contexts, and there is a lack of empirical data on the basic knowledge and conceptual difficulties of Moroccan first-year undergraduate students in biology and health sciences (SVI/STU tracks). This population faces particular challenges related to the transition from secondary to university education, limited prior exposure to practical histology, and specific linguistic and curricular constraints. At the same time, many universities in Morocco are reducing the time allocated to histology while increasing the use of digital tools, with little evidence on how students' basic knowledge and misconceptions evolve in this context.

Our study aims to clarify the basic histology content knowledge of university undergraduate students (first year SVI/STU) at university, and to assess the extent to which they have achieved the stated learning objectives. In addition, we identify students' misconceptions and alternative conceptions, because supporting students to absorb scientific information and correct erroneous ideas is crucial for effective learning (Pekel & Hasenekoğlu, 2020). Misconceptions that are deeply rooted can be difficult to modify, so it is important to consider them explicitly when designing and implementing histology courses (Cheng et al., 2021; Darici et al., 2021; Qing et al., 2022; Vemu et al., 2019). The previous considerations lead to the following research questions (RQs):

**RQ1:** What is the level of basic histology content knowledge of Moroccan first year undergraduate students in relation to courses objectives?

**RQ2:** Which kinds of misconceptions or alternative conceptions do Moroccan first year undergraduate students have regarding tissue types?

The working hypotheses we have adopted in this study are as follows:

1. The basic histology knowledge of Moroccan first year undergraduate students is limited.
2. The Moroccan first year undergraduate students do not fully achieve the learning objectives of the histology course during their university studies.

The results of this study may inform histology education not only in Morocco but more broadly, since understanding students' basic knowledge and misconceptions is essential for planning and improving histology teaching at the university level.

## MATERIAL AND METHODS

### Research Design

In Morocco, histology is taught as a common module in the first year of the SVI (life sciences) and STU (earth and universe sciences) programs, and SVI students continue to study it also in subsequent years. The main aim of histology teaching is to enable students to identify the four basic tissues (epithelium, connective tissue, muscle tissue, and nervous tissue) and to describe their structure and function (knowledge and comprehension level), and to develop their visual observation skills (application and synthesis level), as specified in Moroccan university programs.

A questionnaire-based research design was specifically selected to quantitatively assess students'

**Table 1.** Histology specification table

| Histology (10 to 12 hour lessons) | | Number of elements to be assessed | | | Calculate weight | n |
|---|---|---|---|---|---|---|
| Chapters | Section | To know | To apply | Total | | |
| Chapter 1. General introduction | | 4 | 1 | 5 | 8.0% | 2 |
| Chapter 2 : Epithelial tissues | | 17 | 6 | 23 | 38.0% | 8 |
| | Definition and identify on illustration | 2 | 1 | 3 | 5.0% | |
| | 2.1. Cover tissue | 7 | 3 | 10 | 16.5 % | |
| | 2.2. Glandular tissue | 8 | 2 | 10 | 16.5 % | |
| Chapter 3. Connective tissues | | 11 | 2 | 13 | 21.0% | 4 |
| | Definition, constituents and categories | 3 | 1 | 4 | 6.0% | |
| | 3.1. Skeletal tissues: Cartilaginous and bone tissues | 6 | 0 | 6 | 10.0% | |
| | 3.2. blood tissue | 2 | 1 | 3 | 5.0% | |
| Chapter 4. Nervous tissues | | 9 | 0 | 9 | 15.0% | 3 |
| | General organization | 1 | 0 | 1 | 2.0% | |
| | 4.1. Neurons | 3 | 0 | 3 | 5.0% | |
| | 4.2. Synapses | 2 | 0 | 2 | 3.0% | |
| | 4.3. Neurology | 3 | 0 | 3 | 5.0% | |
| Chapter 5. Muscle tissue | | 10 | 1 | 11 | 18.0% | 3 |
| | Generalities & definition | 1 | 0 | 1 | 2.0% | |
| | 5.1. Smooth muscle cell | 3 | 0 | 3 | 5.0% | |
| | 5.2. Skeletal striated muscle cell | 3 | 0 | 3 | 5.0% | |
| | 5.3. Cardiac muscle cell | 3 | 1 | 4 | 6.0% | |
| Total workforce | | 51 | 10 | 61 | 100% | 20 (17 to know & 3 to apply) |
| Percent weight | | 84% | 16% | | | |

Note. n: Number of questions

achievement of these histology learning objectives and to identify common learning difficulties. This approach aligns directly with the RQs regarding histology content mastery, application skills, and student perceptions, building on prior studies documenting histology learning challenges (Brenner, 2022; Cheng et al., 2021; Darici et al., 2021; García et al., 2019; Gribbin et al., 2023; Qing et al., 2022; Vemu et al., 2019).

## Survey Instrument

The questionnaire was developed based on the histology module content (**Table 1**), which covers four major tissue classes plus introductory concepts. Questions were weighted 84% "to know" (17 items) and 16% "to apply" (3 items) to reflect the module's actual content distribution (51 "to know" elements out of 61 total elements), prioritizing foundational knowledge mastery before higher-order application skills as per program objectives.

Content validity was established through subjective expert review by histology specialists, biology didactics experts, and biology educators from École Normale Supérieure-Marrakech. Experts evaluated item relevance, clarity, and alignment with module specifications (**Table 1**) using standard content validity criteria; no major revisions were required following this review. The instrument was pretested with 30 undergraduate students (not included in the final sample), confirming comprehensibility. Instrument reliability was high (Cronbach's α = 0.961), indicating excellent internal consistency.

The questionnaire includes 29 questions concerning basic content knowledge of histology chosen according to the different themes covered in the concepts taught in high school courses, practical work, and tutorials. It covers all tissue types: epithelial (surface/glandular), connective (structure/function/types, bone, blood), nervous, and muscle tissues, plus five program-specified knowledge items. Personal data included gender, age, academic year, and prior module validation.

Content validity was confirmed by histology specialists, biology didactics experts, and educators from École Normale Supérieure-Marrakech, assessing relevance, clarity, and alignment (**Table 1**) using standard criteria; no major revisions needed. The instrument was pretested with 30 undergraduates (excluded from final sample) for comprehensibility. Reliability was excellent (Cronbach's α = 0.961).

**Data analysis** used Excel and SPSS v26. **Wright Map analysis** (Rasch model) generated a variable map positioning all 29 histology items by difficulty and 302 students by ability on a single logit scale (**Figure 1**). On this scale, higher logits indicate greater item difficulty (right panel) and higher student competence (left panel), enabling direct person-item comparisons. Students positioned above most items demonstrate mastery of challenging content; those below primarily easy items exhibit partial competence.

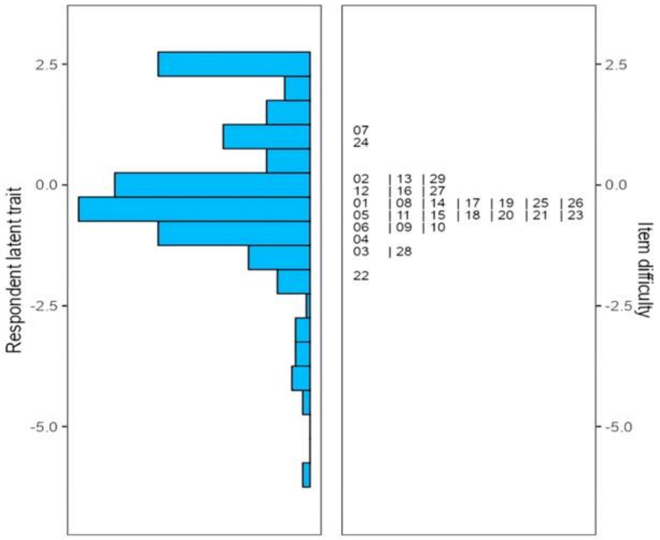


**Figure 1.** Wright's map (variable map representation) of the Rasch model for tissue item comprehension (Source: Authors' own elaboration)

**Egane scores** derived from item response theory, quantified tissue-specific mastery: positive values (> 0) indicate strong assimilation; scores near zero (≈ 0) reflect average performance; negative values (< 0) indicate poor mastery (**Figure 2**). These Rasch-based metrics systematically mapped knowledge strengths and gaps across histological domains.

### Participants and Procedure

A total of 302 first-year SVI (life sciences) and STU (earth and universe sciences) students, plus second-year SVI biology students, participated voluntarily. This targeted population represents all students enrolled in the common histology module. The sample included 50.9% repeaters, reflecting typical Moroccan academic patterns and enabling analysis of prior module validation effects (significant via Chi-square test), which enhances the study's ecological validity and generalizability to real academic contexts.

Questionnaires were administered in classroom settings at the end of autumn session classes, with researchers present to clarify ambiguities and reduce exam-like anxiety. This procedure enhanced response reliability while minimizing comprehension errors. Although teacher proximity could introduce social desirability bias, Chi-square analyses confirmed no significant gender ($p > 0.05$) or age correlations, supporting response validity.

## RESULTS

The description of the results proceeds in the order of the RQs. First, students' basic content knowledge of histology at a general level and their knowledge of individual tissue types are described (**RQ1**), followed by the description of the students' misconceptions and alternative conceptions concerning tissue types (**RQ2**).

### Analysis of Knowledge Questions by Items

#### *Students' knowledge concerning the major families of tissues*

**Figure 3** reveals significant gaps in basic tissue classification knowledge. 74% answered incorrectly (40%) or partially correctly (34%) when identifying characteristics of major human tissue types (epithelium, connective, muscle, nervous).

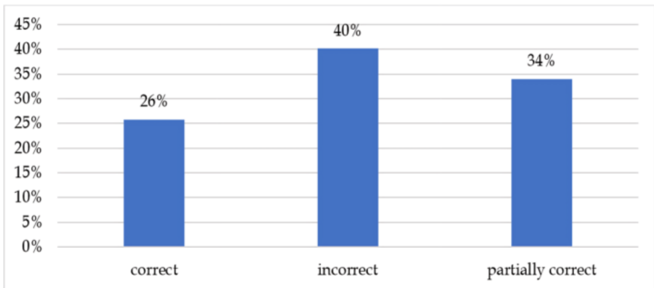


**Figure 3.** Student answers: Basic tissue classification (Source: Authors' own elaboration)

#### *Surface and glandular epithelium*

**Figure 4** reveals profound gaps in epithelial tissue characterization. Despite 8 questions on surface/glandular epithelium, 83% of students provided insufficiently correct responses, with 98% unable to specify key characteristics (cell shape, layers, and functional specialization) and 73% failing to identify non-existent glandular epithelium types.

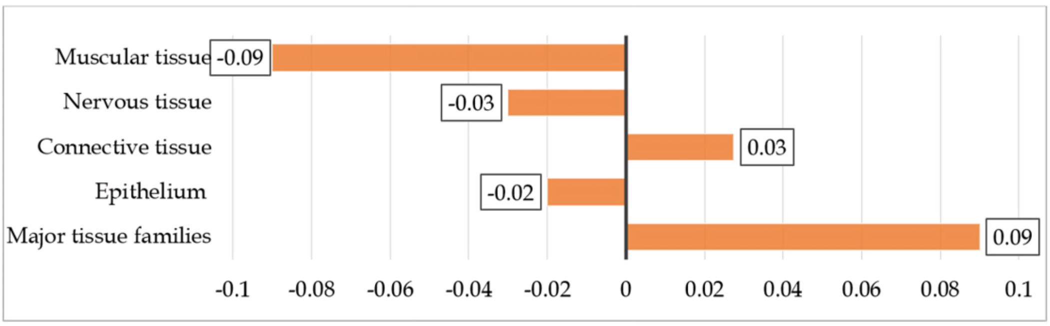


**Figure 2.** Undergraduate university students' responses concerning tissue items (Source: Authors' own elaboration)

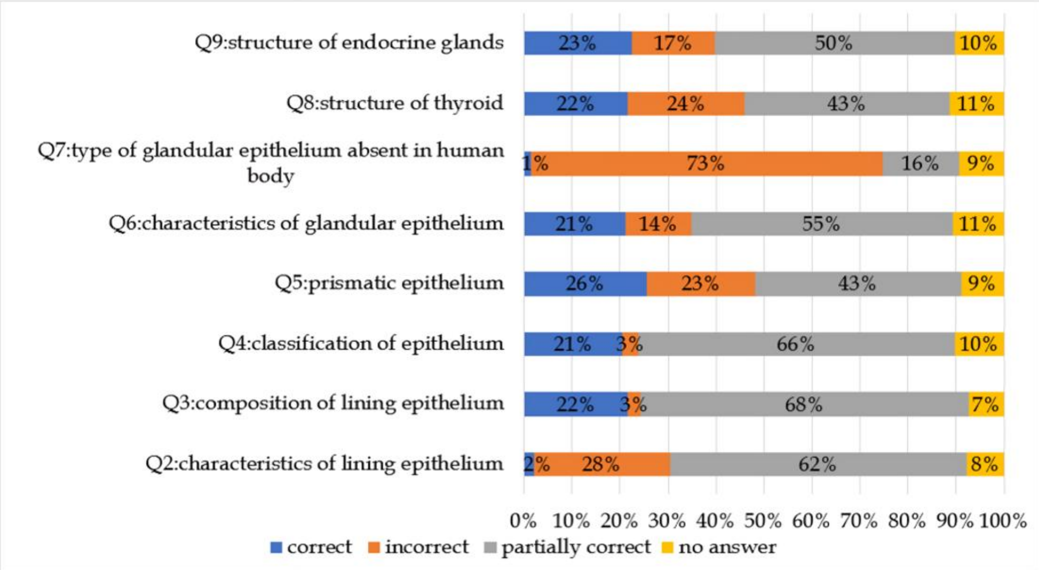


**Figure 4.** Surface and glandular epithelium response patterns (Source: Authors' own elaboration)

### *Connective tissues*

**Figure 5** reveals that connective tissues are the area of knowledge in which students perform the worst, with failure rates of 78 to 100% for the 12 questions, despite accounting for 35% of the curriculum, which far exceeds the gaps observed in other areas.

Three main groups of misconceptions emerge (**RQ2**): confusion about the matrix (85%; Q13); poor identification of fibers (74% to 100%; Q14-Q15-Q16/Q19), including total failure on reticular fibers (Q16) and loose connective tissues (Q19); and inability to identify basic characteristics (78%; Q11-Q12), dismissing ubiquity, organic support, regulation of blood exchange, and epithelial structuring roles. These trends extend uniformly to specialized tissues: blood cells (98% deficit, Q24; 74% unfamiliarity with hematopoiesis/red marrow location, Q23) and bone tissue (approximately 75% identification difficulties and 100% incorrect answers on hydroxyapatite, Q20-Q22). This analysis reveals systemic gaps in fundamental concepts rather than isolated errors in individual questions.

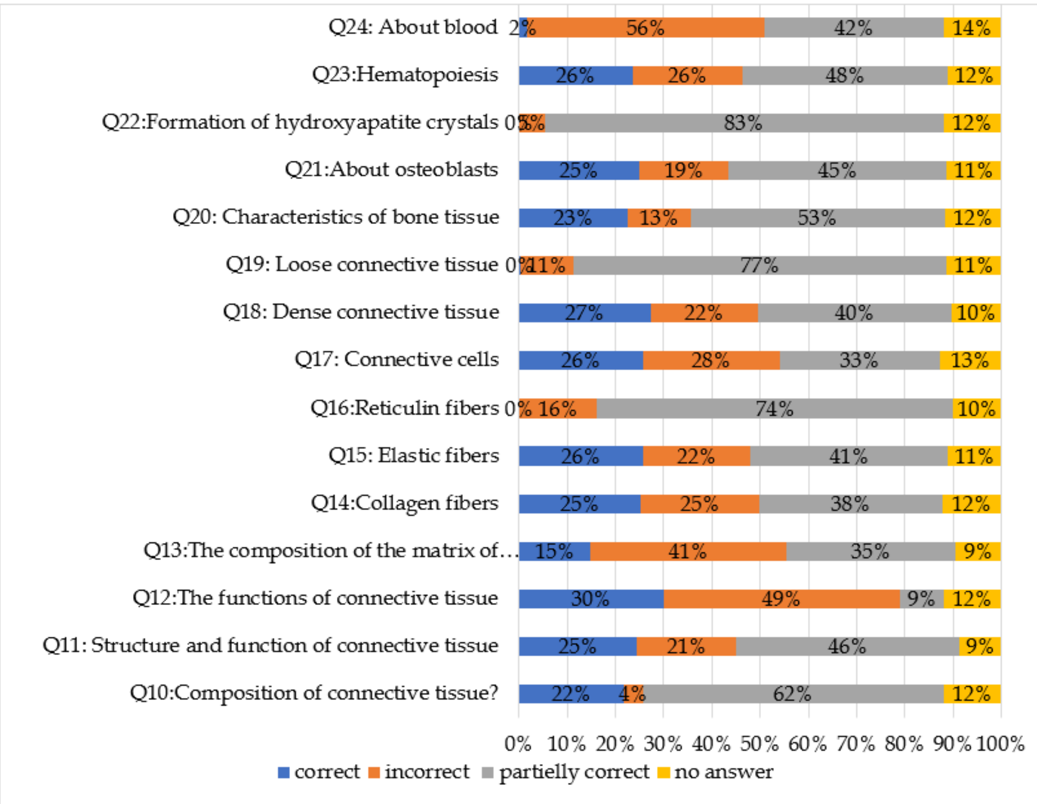


**Figure 5.** Student answers: Connective tissue characteristics (Source: Authors' own elaboration)

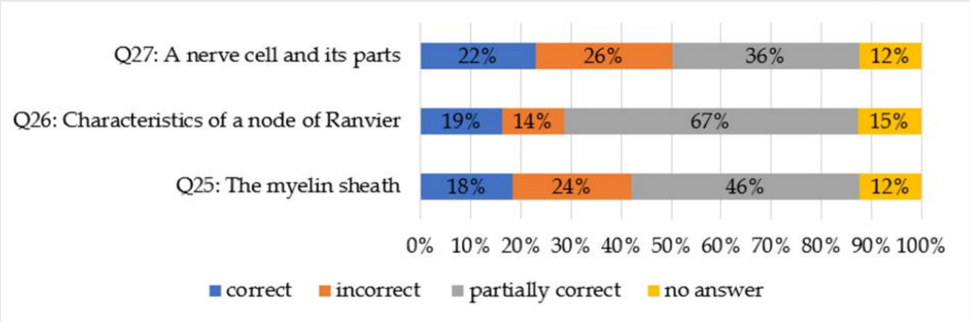


**Figure 6.** Student answers: Nervous tissue characteristics (Source: Authors' own elaboration)

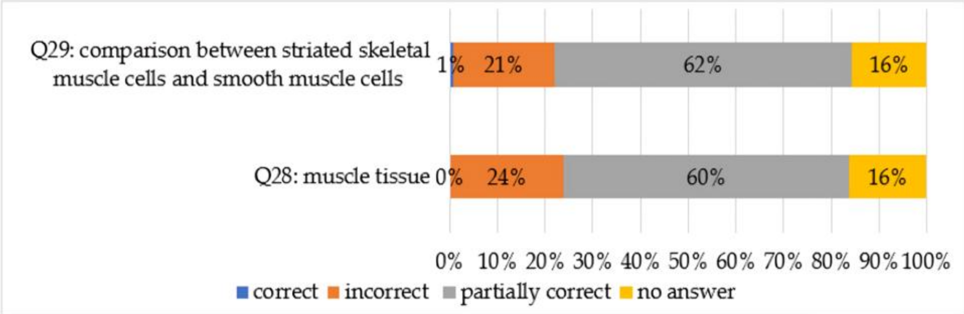


**Figure 7.** Student answers: Muscle tissue characteristics (Source: Authors' own elaboration)

### *Nervous tissue*

**Figure 6** shows that nervous tissue is a moderate area of knowledge, with only 20% of answers correct overall. The main gaps include 22% recognition of neuron anatomy (dendrites, perikaryon, and nodes of Ranvier) versus 45% who confuse all extensions with axons or incorrectly place growth cones in dendritic areas. This indicates partial descriptive competence but a systematic lack of understanding of the connections between neural structures.

### *Muscle tissue*

**Figure 7** indicates that muscle tissue is the second weakest area, with 62% of failures in general organization and 24% in understanding the ultrastructure of striated muscle (multinucleated cells, mitochondria/glycogen, composition of I/A bands). The comparison between striated and smooth muscle cells reveals gaps, indicating systematic deficiencies in descriptive and comparative knowledge about muscles.

## Misconceptions and Alternative Conceptions Identified Among Students

**Table 2** and **Table 3** reveal persistent misconceptions for all tissue types, with epithelial tissue showing the highest error rates (50 to 74%; Q2-Q3-Q6-Q9) due to confusion regarding the extracellular matrix, followed by connective tissue deficits (71 to 94%; Q10-Q11-Q16-Q19-Q22), and muscle comparison errors (71-74%; Q28-Q29). The average prevalence of misconceptions is 18.43% for specific alternative conceptions (**Table 2**), rising to over 50% of incomplete responses on 15 questions (**Table 3**). This indicates systematic gaps in descriptive and relational knowledge rather than isolated errors.

**Table 2.** Misconceptions identified among students about tissues types

| Incorrect proposals | PP | Questions |
|---|---|---|
| All types of tissues are represented at the level of each organ | 28% | Q1. About the main families of tissues |
| The surface epithelium is distinguished by the chemical composition of its extracellular matrix. | 22% | Q2. the surface epithelium is distinguished by |
| Acinar glands are the types of glandular epithelium not found in the human body. | 20% | Q7. What type of glandular epithelium is not found in the human body |
| Immunocompetent cells (macrophages, lymphocytes, etc.) alone defend the connective tissue. | 17% | Q12. Functions of connective tissue |
| The ground substance of connective tissue is homogeneous. | 15% | Q13. The composition of the matrix and ground substance of connective tissue |
| Reticulin fibers have no supporting function. | 13% | Q16. Reticulin fibers |
| Connective cells are plasma cells, mast cells | 14% | Q17. connective cells |

Note. PP: Partial percentage

**Table 3.** Percentage of incorrect answers (partially or totally incorrect) about tissues types

| Questions | P (%) |
|---|---|
| Q2. Characteristic of lining epithelium | 67 |
| Q3. Composition of lining epithelium | 74 |
| Q6. Characteristics of glandular epithelium | 61 |
| Q9. Structure of endocrine glands | 56 |
| Q10. Composition of connective tissue? | 71 |
| Q11. Structure and function of connective tissue | 51 |
| Q16. Reticulin fibers | 82 |
| Q19. Loose connective tissue | 87 |
| Q20. Characteristics of bone tissue | 60 |
| Q21. About osteoblasts | 50 |
| Q22. Formation of hydroxyapatite crystals | 94 |
| Q23. Hematopoiesis | 55 |
| Q25. The myelin sheath | 52 |
| Q26. Characteristics of a node of Ranvier | 79 |
| Q28. Muscle tissue | 71 |
| Q29. Comparison between striated skeletal muscle cells and smooth muscle cells | 74 |

Note. P: Percentage (%)

# DISCUSSION

Contrary to expectations from reinforced high school biology curricula emphasizing basic tissue characteristics and comprehensive first-year histology programs across Moroccan universities, students demonstrated only partial mastery of fundamental tissue identification competencies essential for accurate family classification, revealing systemic deficiencies spanning all four major tissue families—epithelium, connective tissue, muscle, and nervous tissue—despite these foundational concepts requiring minimal cognitive effort beyond basic memorization typically reinforced through both secondary and university-level instruction (Rinaldi et al., 2017; Vemu et al., 2019). This unexpected performance gap challenges assumptions about knowledge transfer from secondary education and highlights potential disconnects between curriculum design and assessment formats. Longitudinal tracking from high school biology through first-year university reveals attrition in foundational competencies presumed stable across educational transitions.

The most pervasive error pattern manifests as systematic substitution of epithelial classification criteria (cell shape, layer number, specialization, function) by connective tissue attributes (extracellular matrix composition, and macromolecules), with students accurately memorizing unique epithelial cellular composition yet systematically failing standard classification protocols despite repeated curriculum exposure, reproducing internationally documented tendencies toward recognition-biased rather than analytical tissue differentiation (Mansouri et al., 2020; Rinaldi et al., 2017; Sant'Anna et al., 2022). Cognitive overload from competing classificatory frameworks privileges visually dominant matrix features over epithelial stratification subtlety. compromising higher-order discriminatory capacity. This cross-contamination reveals fundamental gaps in tissue taxonomy instruction sequencing that fail to scaffold progressive conceptual differentiation from descriptive recall toward relational integration essential for clinical reasoning.

Specific misconceptions include persistent exocrine/endocrine gland confusion—particularly thyroid morphological criteria—and hydroxyapatite bone localization errors despite robust connective tissue ubiquity recognition, revealing domain-specific knowledge fragmentation where students compartmentalize tissue characteristics rather than developing integrated classificatory frameworks essential for clinical and laboratory applications (García et al., 2019; Gribbin et al., 2023). Mastering glandular functional morphology demands higher-order synthesis transcending isolated cellular identification toward systems-level integration. Mineralization misconceptions signal deficient clinic-pathological correlations within basic science curricula, compromising diagnostic readiness for future healthcare professionals.

Nervous tissue misconceptions persist through dendrite/axon conflation and growth cone misplacement, compounded by blood cell identification failures that privilege visual field memorization over morpho-functional analysis, alongside pervasive inability among over half of the students to comprehend muscle tissue architectural organization and comparative cellular morphology—perpetuating cross-tissue structural misconceptions that intensify across escalating cellular complexity gradients (Dikmenli, 2010; Helle et al., 2010). Performance decrements correlate directly with increasing cellular differentiation complexity spanning tissue types, from relatively homogeneous muscle fibers to heterogeneous neuronal networks. Visual memorization strategies collapse at higher-order organizational integration levels requiring spatial-relational reasoning beyond isolated feature recognition. These findings underscore the limitations of traditional lecture-based approaches for developing integrated tissue recognition competencies essential for clinical histopathology (Campos-Sánchez et al., 2014; Cheng et al.,2021; Hortsch & Mangrulkar, 2015).

The result analysis related to **RQ1** confirms clear performance hierarchy with connective tissues achieving 78-100% success rates substantially outperforming epithelium (moderate performance), muscle tissues (Sesli & Kara, 2012), and nervous tissues (20% success rates, **Figure 6**) (Chimmalgi & Hortsch, 2022), directly reflecting morphological simplicity gradients: abundant, easily identifiable connective matrix versus escalating structural complexity of epithelial stratification, muscle fiber organization, and neuronal architecture, while validating cognitive predominance of matrix-based reasoning paradigms

(Brenner, 2022; Hortsch, 2023). Performance inversely correlates with feature density and organizational complexity per microscopic field (Yilmaz & Batdi, 2021). Matrix dominance reflects evolutionary primacy in tissue recognition hierarchies (Vali-Betts et al., 2021).

These identification difficulties align with international literature demonstrating superior effectiveness of virtual microscopy (Francis et al., 2023) combined with active learning strategies (Pesesse et al., 2023) versus traditional methods, operating within Moroccan structural constraints of limited practical laboratory opportunities, deficient illustrated pedagogical resources, and specialized histological terminology (Bolatlı & Taş, 2023) that collectively undermine student motivation and tissue identification competency acquisition—underscoring the imperative for localized multi-modal teaching reform (Bloodgood, 2012; Joaquim et al., 2022; Smirle et al., 2012; Teshome, 2022; Then et al., 2023). Hybrid digital-active models optimize existing infrastructure while scaling pedagogical innovation (Rajprasath et al., 2018; Syaidah et al., 2020).

## CONCLUSIONS

Students prove low knowledge levels of tissue structures related to organ organization and persistent difficulties distinguishing tissue types, despite minimal cognitive effort required for basic memorization of these concepts essential for laboratory exercises across biological disciplines. The questionnaire targeting first three levels (knowledge, comprehension, and application) of the Bloom's taxonomy reveals that many students fail to develop targeted basic histology skills, exhibiting gaps in understanding tissue classification criteria–particularly epithelium–and maintaining misconceptions about composition, location, and function. As histology constitutes a foundational longitudinal discipline, these deficiencies risk obstructing learning in related biological and medical fields, underscoring the critical need to transition students from rote memorization to meaningful learning through versatile, student-centered active teaching methods that address prior misconceptions and integrate digital tools alongside traditional approaches to strengthen motivation and align university program objectives with effective pedagogical practices.

### Limitations of the Study

The single-institution SVI/STU sample (first- and second-year biology/geology students) precludes national generalizability across all Moroccan universities and excludes master's cycle students, potentially underestimating variations in teaching approaches and student demographics across the country's more than fifteen institutions.

Exclusive reliance on questionnaire (MCQ) data collection favors recognition over descriptive skills, while the single annual assessment overlooks histology's longitudinal progression foundational to biological/medical disciplines, necessitating multi-modal, multi-site validation for comprehensive learning outcomes reliability.

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