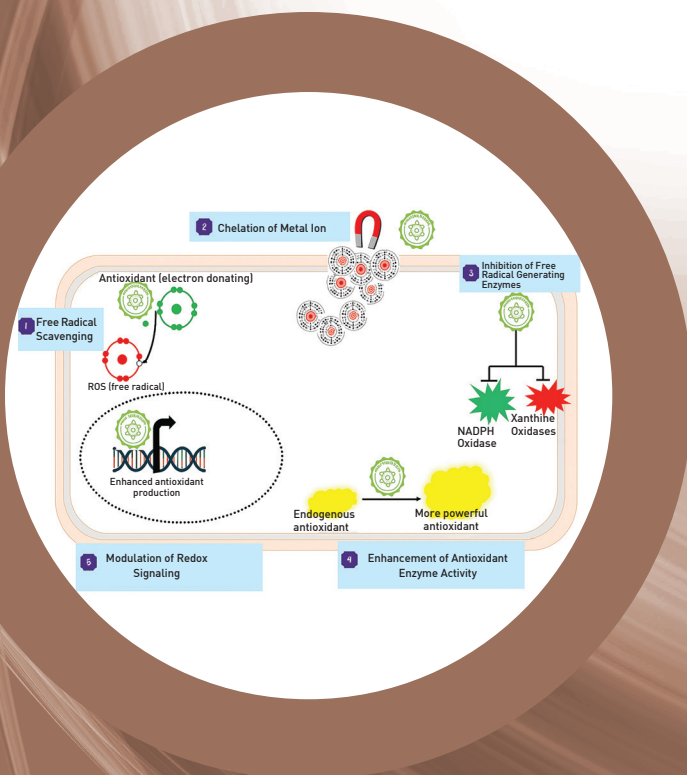


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I, Amitabh Kumar, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Publisher

EDITORIAL

In this last issue of 2024, we celebrate the spirit of inquiry by sparking discussions on evolutionary literacy and Ayurveda, along with three other insightful articles spanning diverse areas of interest.

The first article, 'Unravelling the Tree of Life: A Study on the Evolutionary Literacy of Undergraduate Pre-service Teachers', explores the role of biology teachers in disseminating accurate scientific knowledge where the authors highlight the necessity of addressing misconceptions in biological evolution to ensure that the future educators possess the requisite knowledge and understanding to guide upcoming learners effectively and strongly emphasise integrating evolution into educational frameworks.

Building on, the article 'Science, Skepticism, and the Pseudoscience Debate Around Ayurveda—Implications in Science Education', discusses the historical importance and core principles of Ayurveda, and the reasons behind its frequent criticism. It advocates to foster scientific temper among students through education so that they are able to strike a balance between preserving our rich medical heritage and ensuring that healthcare remains rooted in evidence, ethics, and public well-being.

The next article, 'Oxygen: The Mischievous Master of Reactions', talks about the most fascinating element for the existence of life on earth and discusses about the dual nature of oxygen—its essential role in biological systems, its reactive

involvement in combustion, and its frequently overlooked impact in causing oxidative stress that damages cells, proteins, and DNA, contributing to the development and progression of various diseases. The article emphasises how oxygen is vital for sustaining life, yet has the potential to inflict harm through generation of Reactive Oxygen Species (ROS).

Shifting focus toward experiential learning, 'Modification and Upgradation of Biology Laboratory into Biotechnology Laboratory at Secondary Stage Phase II for the Enhancement of Skill-based Education', highlights the urgent need for modification and upgradation of biology laboratory into biotechnology laboratory at higher secondary stages in schools for providing effective learning in biotechnology. It emphasises on how laboratories play an integral role in attaining the objectives specified by the curriculum and aid in skill-based learning, a pre-requisite to develop experiential learning.

Building on the theme of inclusive education, the study titled 'The Effect of Differentiated Curriculum Design on Academic Outcomes for Students with Multiple Disabilities at Primary Level', investigates the impact of differentiated curriculum design on the academic performance of students with multiple disabilities and how simplifying lesson content, incorporating visual and tactile aids, implementing hands-on learning activities, and providing individualised instruction can improve learning outcomes.

In addition to the articles, this issue also contains breakthrough research findings in different fields of science all compiled from *Science Daily*.

We sincerely hope that readers will find the articles interesting and informative. As an

institution committed to improving the quality of our resources and materials, your valuable suggestions, observations and comments are always welcome to bring further improvement in the quality of the journal.

Happy reading and happy learning!

UNRAVELLING THE TREE OF LIFE: A STUDY ON THE EVOLUTIONARY LITERACY OF UNDERGRADUATE PRE-SERVICE TEACHERS

***Sujata B. Hanchinalkar¹, Shania Kariappa² and Subashini V.³**

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Evolution stands as the cornerstone of modern biology, yet misconceptions surrounding this fundamental concept persist among students, potentially carried from high school into their undergraduate studies. Recognising the pivotal role of biology teachers in disseminating accurate scientific knowledge, this study delves into identifying and analysing misconceptions in biological evolution among 60 undergraduate pre-service teachers. Employing the Biological Evolution Literacy (BEL) Survey, participants' misconceptions were scrutinised across 23 statements grouped into five categories. Results unveil a prevalent presence of misconceptions among these prospective teachers (with the major chunk of the sample falling in the 'average' category), with varying degrees of intensity across different aspects of evolution.

Remarkably, no significant disparity in misconception prevalence was observed between groups, despite one having been exposed to undergraduate-level knowledge. This underscores the persistent nature of misconceptions and emphasises the urgency of addressing them comprehensively. The implications of these findings resonate deeply within science education. They advocate for the introduction of evolutionary concepts at the secondary school level, followed by rigorous exploration at the university level. Equipping future teachers with accurate conceptions and pedagogical skills becomes imperative to foster a generation of scientifically literate learners, thereby mitigating the perpetuation of misconceptions. In essence, this research underscores the critical need to confront misconceptions in biological evolution head-on, ensuring that the next generation of educators possess the requisite knowledge and understanding to guide future learners effectively. Hence, this study was taken up considering pre-service student teachers as participants.

Keywords: Evolution, Misconception, Pre-service Teachers

Introduction

A child learns science as part of their growth, regardless of formal science schooling. Human nature considers comprehending every natural phenomenon to be an essential aspect of its existence. The study of science requires research and discovery of its surroundings. It is based on the fundamental human nature of understanding the universe. Science education refers to the process of understanding the natural world. Biology

is a science that helps us comprehend the living world and how its numerous species (including humans) function, evolve, and interact. Biology not only teaches us about our biological functioning, but also about the environment and ecosystems. Evolution is one of the important unifying concepts in the study of biology. Evolutionary biology allows us to understand not just how and why species evolved, but also what mechanisms are currently modifying or changing them. Astronomy, physics,

biochemistry, geochronology, geology, biology, anthropology, and other sciences all provide rich and consistent evidence for evolution. Evolution is significant because it explains how life originated on Earth and how various species are related. The evolutionary links contribute to the resolution of biological issues as well as the diversity of life. Many people hold persistent beliefs about evolution. Some are simply misunderstandings— notions that arise while learning about evolution, potentially as a result of educational experiences and/or media exposure. Other myths may result from deliberate attempts to misrepresent evolution. Misconceptions, within the context of science education, refer to erroneous or inaccurate beliefs held by individuals that contradict established scientific knowledge or principles that might arise as a result of a lack of clarity in this scientific field. If teachers have such misconceptions, the younger generations will as well, which may have an impact on their understanding of the world. Thus, this study is an attempt to determine the extent to which undergraduate student teachers have misconceptions about biological evolution.

Theoretical Framework

Concepts are pivotal in human cognition, aiding in the categorisation and understanding of stimuli. Rosch (1978) introduced prototype theory, suggesting that people form concepts through mental prototypes, aiding object classification and information generalisation (Rosch and Mervis, 1975). Conceptions, beyond categorisation, shape interpretation and response to information. Cognitive psychology research, including studies by Johnson-Laird (1983)

and Rumelhart (1980), highlights the role of mental models and schema theory in problem-solving. Concept formation is crucial in science education, building on students' prior knowledge and experiences. Ausubel's theory of meaningful learning (Ausubel, 1968) emphasises integrating new knowledge into existing cognitive structures. The malleability of concepts is a key area of study, with researchers like Posner and Strike (1976) exploring how prior conceptions may clash with scientific principles, leading to misconceptions.

Misconceptions in science education refer to incorrect beliefs that clash with established scientific principles. They encompass various ideas diverging from scientific norms, categorised into preconceived notions, non-scientific beliefs, conceptual, vernacular, and factual misconceptions. Research by Soyibo (2008), Kumandaş (2015), and Verma and Choudhuri (2022) identify the multiple sources of misconceptions, including interactions with the physical world, textbooks, oversimplifications, teacher influence, language, culture, and media exposure. These misconceptions often persist despite exposure to correct information, hindering students' understanding and application of scientific knowledge.

Exploring evolution reveals its central role in unifying biological knowledge, crucial for a comprehensive understanding of the subject. Evolution, as described by Wiles (2010), entails the diversity of life arising from common ancestry, focusing on descent with modification. Smith (2010) clarifies evolution as not faith-based, nor explaining life's origin, but rather an emergent, ongoing process. Yates and Marek (2011) have administered

the BEL survey to different groups of participants, like school children, university graduates, teachers, etc., concluding that misconceptions existed, to some extent, in all these participants. Misconceptions about evolution often stem from misunderstanding natural selection, perpetuating beliefs like evolution being just a theory or organisms evolving within a single generation. These misconceptions, often rooted in cultural or religious beliefs, underscore the importance of accurate education in promoting scientific literacy. Understanding the nature and prevalence of misconceptions in biology, particularly evolution, is vital for effective science education and the cultivation of a scientifically literate society. It is also found that research is scarce in this area of study in India. This study would thus contribute to the field of science education.

Research Questions

1. What is the extent of misconceptions in Biological Evolution, prevailing among the undergraduate pre-service student teachers?
2. In which themes of Biological Evolution lie the most misconceptions, among the undergraduate pre-service student teachers?

Research Objectives

1. To analyse the extent of misconceptions in Biological Evolution, prevailing among the undergraduate pre-service student teachers.
2. To test the significant difference between the means of literacy in

biological evolution among 3rd-year and 4th-year undergraduate pre-service student teachers.

3. To identify the extent of misconceptions for each item within the themes of Biological Evolution.

Hypothesis

There is no significant difference between the means of literacy in biological evolution among 3rd-year and 4th-year undergraduate pre-service student teachers.

Methodology

This study's participants were pre-service student teachers in their third and fourth years of B.Sc.B.Ed. (CBZ) programme of RIE, Mysuru. The sample included a total of 60 students, 30 from each group. These are the students who have already completed their internship (fourth year) and aspire to become biology teachers in schools, or are about to begin their internship (third year) and imbibe the role of pre-service student teachers. These two groups were included in this study with the assumption that they were exposed to the concept of evolution in Class XII. Fourth-year students have also studied this concept in their undergraduate course. The BEL Survey was administered to these students.

Instrumentation

The study was conducted using the BEL Survey tool (Yates and Marek, 2011).

Description of the Tool

The survey is a six-point rating scale with 23 items about the concept of evolution. The scale ranges from strongly agreeing, somewhat agreeing, never heard of it, somewhat disagreeing, strongly disagreeing, or having no opinion on 23 statements about biological evolution misconceptions. Among 23 statements in the BEL survey, two statements (11 and 16) were directly from Cunningham and Wescott's survey, while eight (1, 6, 7, 9, 15, 17, 20 and 22) were adapted from it. The remaining 13 statements (2, 3, 4, 5, 8, 10, 12, 13, 14, 18, 19, 21 and 23) were developed based on an extensive review of the literature on misconceptions about biological evolution. With permission, the BEL survey was adapted from Cunningham and Wescott's 2009 survey, which was itself adapted from Almquist and Cronin (1988), incorporating additions from Wilson (2001), and Bishop and Anderson (1990). Almquist and Cronin's (1988) survey aimed to assess university and college students' perspectives on religion and science and their basic understanding of evolutionary processes. Cunningham and Wescott's 2009 survey focused on identifying common misconceptions regarding biological evolution and the reasons behind them.

In the study conducted by Yates and Marek (2011), Cunningham and Wescott's four category classification was revised into

five categories of biological evolution-related misconceptions commonly cited in the literature (Alters and Alters, 2001; Bishop and Anderson, 1990; Greene, 1990; Gregory, 2009; Jensen and Finley, 1996; Wandersee, Mintzes and Novak, 1994; Wescott and Cunningham, 2005; Wilson, 2001). These categories include:

1. Science, Scientific Methodology, and Terminology (SSMT)—addressing misconceptions related to scientific concepts and methods.
2. Intentionality of Evolution (IE)—encompassing misconceptions that attribute conscious will or direction to evolutionary mechanisms.
3. Nature of Evolution (NE)—covering misunderstandings about factors influencing biological evolution, such as the role of the environment, chance, and the distinction between individual and population-level changes.
4. Mechanisms of Evolution (ME)—focusing on misconceptions regarding evolutionary processes, including natural selection and mutations.
5. Evidence Supporting Evolution (ESE)—dealing with misunderstandings about the empirical support for evolutionary theory.

Table 1: Rationale for Choosing the Statements

S. No.	Category	Statements	Rationale
1	SSMT	A scientific theory that explains a natural phenomenon can be classified as a “best guess” or “hunch”.	This assesses the common misconception that scientific theories are mere guesses rather than well-substantiated explanations. Many students misunderstand the nature of scientific theories.
2	SSMT	The scientific methods used to determine the age of fossils and the Earth are reliable.	This statement evaluates students’ understanding of radiometric dating and other scientific methods used to determine geological and fossil ages, which are fundamental to evolutionary studies.
3	SSMT	According to the second law of thermodynamics, complex life forms cannot evolve from simpler life forms.	This addresses a common misuse of thermodynamics in arguments against evolution. The second law applies to closed systems, whereas Earth is an open system with continuous energy input from the Sun.
4	SSMT	The Earth is old enough for evolution to have occurred.	Evolution requires vast time scales, and this statement tests whether students recognise the Earth’s age (~4.5 billion years) as sufficient for evolutionary processes.
5	SSMT	Evolution cannot be considered a reliable explanation because evolution is only a theory.	This challenges the misconceptions about the meaning of “theory” in scientific contexts and reinforces that evolution is a well-supported framework, not mere speculation.
6	IE	Evolution always results in improvement.	Many students assume evolution has a direction toward progress. This statement corrects that evolution produces change, not necessarily improvement.
7	IE	Members of a species evolve because of an inner need to evolve.	This addresses Lamarckian misconceptions that evolution is driven by necessity rather than natural selection acting on genetic variation.
8	IE	Traits acquired during the lifetime of an organism—such as large muscles produced by bodybuilding—will not be passed along to offspring.	This counters the misconception that acquired traits can be inherited, reinforcing that only genetic changes are inheritable.

9	IE	If webbed feet are being selected for, all individuals in the next generation will have more webbing on their feet than do individuals in their parents' generation.	This addresses a misunderstanding of natural selection, clarifying that variation persists and gradual changes occur over multiple generations, not instantaneously.
10	IE	Evolution cannot cause an organism's traits to change within its lifetime.	Evolution acts at the population level over generations, not within an individual's lifetime. This statement ensures students distinguish between adaptation and evolution.
11	NE	New traits within a population appear at random.	This tests students' understanding that genetic mutations, which introduce new traits, occur randomly rather than being directed.
12	NE	Individual organisms adapt to their environments.	Many students mistakenly equate physiological adaptation with evolutionary change. This statement highlights the distinction between individual responses and genetic evolution.
13	NE	Evolution is a totally random process.	While mutations are random, natural selection is non-random. This statement assesses understanding of evolution's dual components: random variation and non-random selection.
14	NE	The environment determines which traits are best suited for survival.	Reinforces the principle that natural selection favours traits that confer survival and reproductive advantages in a given environment.
15	ME	Variation among individuals within a species is important for evolution to occur.	Genetic variation is essential for natural selection to act upon. This statement checks for recognition of its role in evolutionary processes.
16	ME	"Survival of the fittest" means basically that "only the strong survive".	This addresses a widespread misunderstanding of "fitness", which actually refers to reproductive success rather than physical strength.
17	ME	The size of the population does not affect the evolution of a species.	Population size influences genetic drift and selection. This statement tests awareness of evolutionary dynamics in small versus large populations.

18	ME	Complex structures such as the eye could have been formed by evolution.	Many argue that complex structures are "too perfect" to have evolved. This statement checks whether students understand gradual evolutionary processes.
19	ME	Only beneficial traits are passed on from parent to offspring.	While selection favours beneficial traits, neutral and even harmful traits can persist due to genetic drift. This assesses knowledge of inheritance mechanisms.
20	ESE	There exists a large amount of evidence supporting the theory of evolution.	A direct measure of whether students recognise the extensive fossil, genetic, and biochemical evidence supporting evolution.
21	ESE	According to the theory of evolution, humans evolved from monkeys, gorillas, or apes.	A common misconception—humans share a common ancestor with modern primates rather than evolving directly from them.
22	ESE	Scientific evidence indicates that dinosaurs and humans lived at the same time in the past.	This statement identifies students who hold misconceptions stemming from pseudoscience or popular culture, as dinosaurs became extinct ~65 million years before humans appeared.
23	ESE	The majority of scientists favour evolution over other explanations for life.	This evaluates awareness of the overwhelming scientific consensus supporting evolution as the best explanation for biological diversity.

The selection of these 23 statements was guided by their ability to comprehensively assess well-documented misconceptions about biological evolution among undergraduate life science students while ensuring conceptual clarity, reliability, and relevance. These items align with persistent misunderstandings identified in previous research (Gregory, 2009; Nehm and Schonfeld, 2008) and focus on five key themes—scientific methodology, intentionality of evolution, the nature and mechanisms of evolution, and supporting evidence. The statements were chosen to balance coverage without redundancy, preventing cognitive overload while maintaining diagnostic

accuracy. They also reflect common gaps in education where misconceptions persist due to inadequate prior instruction (Bishop and Anderson, 1990). Furthermore, the tool ensures a mix of correct and incorrect statements to avoid response bias, and its length remains optimal for engagement without compromising reliability. By targeting widely accepted misconceptions rather than advanced topics, the instrument remains accessible and effective for evaluating students' conceptual understanding. These considerations contribute to the robustness and validity of the tool in identifying and addressing misconceptions in evolutionary biology education.

Scoring

During the quantitative data analysis, responses were scored using two methods:

- (a) At first, responses like “strongly agree” and “somewhat agree” will be unified to represent participant agreement with the statement. Similarly, the responses “strongly disagree” and “somewhat disagree” will be combined to represent participant disagreement with the statement.
- (b) Using Likert scaling, a scoring index for biological evolution misconceptions will be created. Statements indicating low acceptance of evolution (or high acceptance of the associated misconception) will receive low scores, while statements indicating high acceptance of evolution (or non-acceptance of the associated misconception) will receive higher scores.

BEL Survey index scores can range from 0 to 115, with 115 [23 items multiplied by

5 score] representing the highest level of understanding combined with a lack of associated misconceptions, and lower indices representing lower levels of understanding combined with higher levels of biological evolution-related misconceptions. Additionally, the count of the number of misconceptions revealed by responses to the statements is made.

Reliability and Validity

Cronbach's alpha for the BEL Survey was 0.848, indicating that the items were internally consistent. When any one item was deleted, the reliability coefficient did not decrease by more than 0.014; thus, the survey's internal reliability was maintained (Yates and Marek, 2014). After analysing the items in this tool, the researchers determined that they were valid in relation to the study's content.

Results and Discussion

The data collected were analysed at various levels, catering to the objectives of this study.

Table 2: Scoring Index for Non-acceptance of Biological Evolution Misconceptions (Statements 2, 4, 8, 10, 11, 14, 15, 18, 20, 23)

Strongly Agree	Somewhat Agree	Undecided	Somewhat Disagree	Strongly Disagree	No Opinion
5	4	3	2	1	0

Table 3: Scoring Index for High acceptance of Biological Evolution Misconceptions (Statements 1, 3, 5, 6, 7, 9, 12, 13, 16, 17, 19, 21, 22)

Strongly Agree	Somewhat Agree	Undecided	Somewhat Disagree	Strongly Disagree	No Opinion
1	2	3	4	5	0

Third-year undergraduate pre-service student teachers are referred to as Group A, and fourth-year undergraduate pre-service student teachers are referred to as Group B.

The column graphs presented in Figs. 1 and 2 display the item-wise response of the students of both Groups A and B, indicating the extent to which the students have displayed acceptance or non-acceptance of the evolutionary statements.

In the case of certain items answered by Group A (e.g., 1, 5, 6, 10, 16, 22) and Group B (e.g., 1, 9, 10, 11, 13, 17, 19), there has been extremely minimal difference in the scores obtained. The probable reasons that could be attributed to this trend are, firstly, the partial understanding of the concepts, where students in both groups may possess incomplete knowledge, leading to nearly equal numbers of correct and incorrect responses, which is probably a result of rote memorisation rather than conceptual clarity. Secondly, the guessing behaviour of students,

where statements with a binary response format can lead to guessing, particularly among less confident respondents.

However, in certain other items answered by Group A (e.g., 2, 4, 12, 13, 14, 15, 19, 20, 21, 23) and Group B (e.g., 2, 4, 8, 12, 14, 15, 20, 21, 23), there is a huge margin of differences between both the extremities of responses. In this scenario, the attributing reasons for this occurrence could be firstly, the clarity of concepts—which emphasises that the statements addressed are well-taught and straightforward, that resulted in significant differences in correct responses, especially in Group B. Secondly, the knowledge gaps—where large margins indicate a stark absence of understanding among the Group A for certain advanced or nuanced aspects of evolution. Lastly, the role of polarising beliefs—that the statements touching on topics perceived as controversial might elicit strong, divergent responses depending on prior exposure or cultural influences. Both can be seen in Figs. 1 and 2.

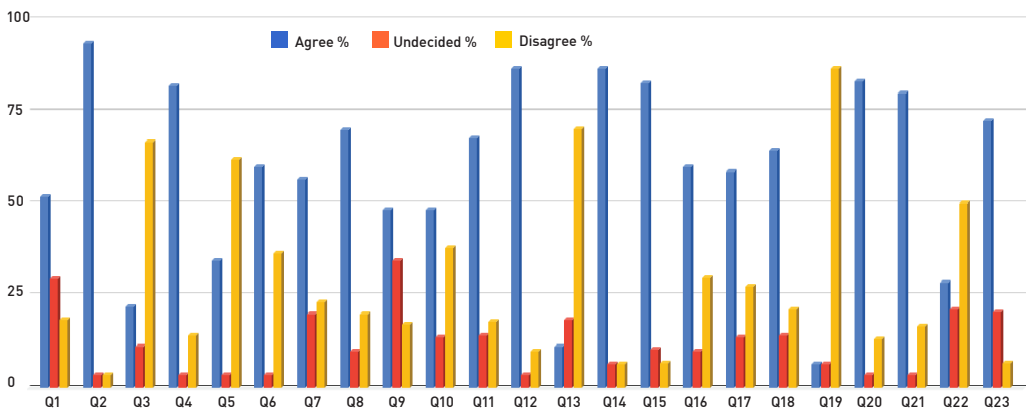


Fig. 1. Item-wise percentage analysis of Group A

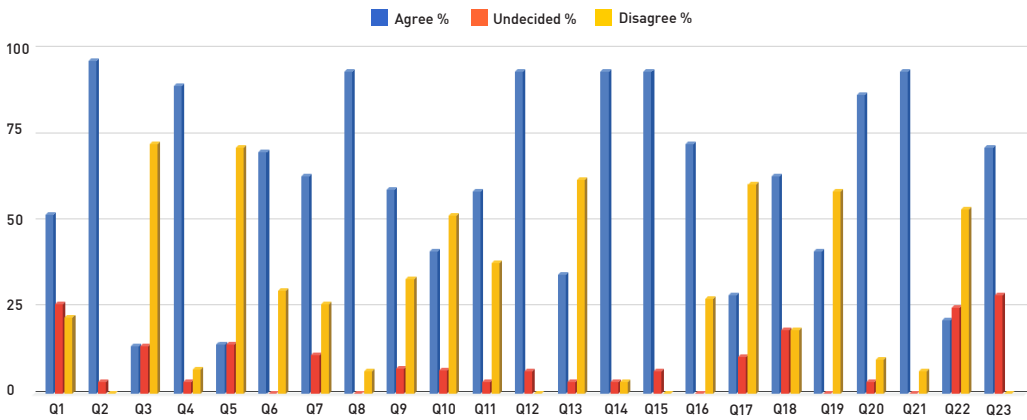


Fig. 2. Item-wise percentage analysis of Group B

Table 4 provides a bird’s eye view of the item-wise percentage of misconceptions of biological evolution, depicting the extent of acceptance or non-acceptance of the associated misconceptions among the B.Sc. B. Ed. (CBZ) student of the 3rd and the 4th year pre-service student teachers. The highlighted boxes are the scale components

depicting high acceptance of biological acceptance, i.e. low acceptance of the misconception. Therefore, if the mentioned boxes have higher percentage of responses, it depicts that the students lack misconception for those items and the vice versa indicates higher degree of misconceptions among them.

Table 4: BEL Survey Year-wise Student Response in Percentage

S. No.	Category	Statements	Group A			Group B		
			A*	U**	D***	A	U	D
1	SSMT	A scientific theory that explains a natural phenomenon can be classified as a “best guess” or “hunch”.	51.8	29.6	18.5	51.8	25.9	22.2
2	SSMT	The scientific methods used to determine the age of fossils and the Earth are reliable.	93.3	3.3	3.3	96.6	3.3	0
3	SSMT	According to the second law of thermodynamics, complex life forms cannot evolve from simpler life forms.	22.2	11.1	66.6	13.8	13.8	72.4
4	SSMT	The Earth is old enough for evolution to have occurred.	82.1	3.6	14.3	89.3	3.6	7.1

5	SSMT	Evolution cannot be considered a reliable explanation because evolution is only a theory.	34.5	3.4	62.1	14.3	14.3	71.4
6	IE	Evolution always results in improvement.	60	3.3	36.7	70	0	30
7	IE	Members of a species evolve because of an inner need to evolve.	56.7	20	23.3	62.9	11.1	25.9
8	IE	Traits acquired during the lifetime of an organism—such as large muscles produced by bodybuilding—will not be passed along to offspring.	70	10	20	93.3	0	6.7
9	IE	If webbed feet are being selected for, all individuals in the next generation will have more webbing on their feet than do individuals in their parents' generation.	48.3	34.5	17.2	59.2	7.4	33.3
10	IE	Evolution cannot cause an organism's traits to change within its lifetime.	48.3	13.8	37.9	41.4	6.9	51.7
11	NE	New traits within a population appear at random.	67.8	14.3	17.8	58.6	3.4	37.9
12	NE	Individual organisms adapt to their environments.	86.7	3.3	10	93.3	6.6	0
13	NE	Evolution is a totally random process.	11.1	18.5	70.4	34.5	3.4	62.1
14	NE	The environment determines which traits are best suited for survival.	86.7	6.7	6.7	93.3	3.3	3.3
15	ME	Variation among individuals within a species is important for evolution to occur.	82.7	10.3	6.9	93.3	6.7	0
16	ME	"Survival of the fittest" means basically that "only the strong survive".	60	10	30	72.4	0	27.6
17	ME	The size of the population does not affect the evolution of a species.	58.6	13.8	27.6	28.6	10.7	60.7
18	ME	Complex structures such as the eye could have been formed by evolution.	64.3	14.3	21.4	62.9	18.5	18.5
19	ME	Only beneficial traits are passed on from parent to offspring.	6.7	6.7	86.7	41.4	0	58.6

20	ESE	There exists a large amount of evidence supporting the theory of evolution.	83.3	3.3	13.3	86.7	3.3	10
21	ESE	According to the theory of evolution, humans evolved from monkeys, gorillas or apes.	80	3.3	16.7	93.3	0	6.7
22	ESE	Scientific evidence indicates that dinosaurs and humans lived at the same time in the past.	28.6	21.4	50	21.4	25	53.6
23	ESE	The majority of scientists favour evolution over other explanations for life.	72.4	20.7	6.9	71.4	28.6	0

*A - agree; **U - Undecided; ***D - Disagree.

Note: Data collected by the authors (2024)

Table 5: Categorisation of Sample based on Survey Scores

Group	Sample Size	Category		
		Above Average	Average	Below Average
A	30	5	25	-
B	30	4	26	-

In Table 5, it has been observed that in Group A the number of students in the Above Average category is 5, and in the Average category is 25, with no students in the Below Average category. Whereas in Group B, the number of students in the Above Average category is 4, and in the Average category is 26, with no students in the Below Average category.

The performance distribution can be attributed to a broad but superficial understanding among the majority, stemming from uniform curriculum exposure and persistence of common misconceptions about evolution. The above-average performers likely excelled

due to stronger cognitive skills, deeper interest, or engagement with supplementary learning resources. Variations in prior knowledge, confidence, and receptivity to learning also played a role, highlighting the need for teaching strategies that encourage critical thinking and address misconceptions to help more students achieve higher understanding.

From Table 6, the critical t-value obtained at $\alpha = 0.05$ is 1.671, whereas the obtained t-value is 0.37, which renders the hypothesis accepted, implying that there is no significant difference in the biological evolution literacy level of Groups A and B. Both groups have nearly identical mean scores (75.9 and 75.6),

Table 6: Significant Difference between the Means of Groups A and B

Group	Mean	Standard Deviation	Sample Size	Significance Level	t-value
A	75.9	10.31	30	0.05	0.37
B	75.6	9.92	30		

with standard deviations of 10.31 and 9.92, respectively, indicating similar performance and variability. The sample size for each group is 30 and the t-value of 0.37, at a significance level of 0.05; it suggests no statistically significant difference between the groups. These findings imply that the level of prior exposure to evolution (in the case of Group B) may not significantly impact the overall performance, highlighting potential gaps in conceptual understanding or the survey's ability to differentiate knowledge levels.

Science, Scientific Method and Terminology

Figures 3 and 4 provide an overview of the percentage analysis of the student responses belonging to this theme of

Biological Evolution. Of the 5 statements belonging to this theme, Statements 2, 3, 4 and 5 have been answered correctly by the majority of the students.

In case of Statement 1 (A scientific theory that explains a natural phenomenon can be classified as a "best guess" or "hunch") which is an incorrect notion, majority of the students of Group A (n = 14) and B (n = 14) have agreed that it is a correct statement, thus showing a great extent of misconception inferring that a scientific theory that explains a naturally occurring phenomenon in the nature is equivalent to a hunch or guess work.

The Statements 2 (the scientific methods used to determine the age of fossils and the Earth are reliable) and 4 (the Earth is old enough

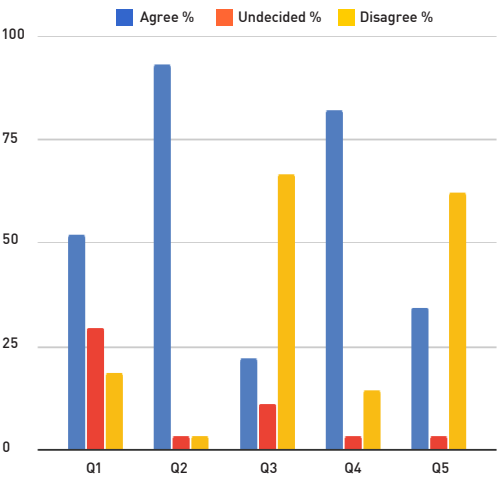


Fig. 3. Group A - % Response to Science, Scientific Method and Terminology

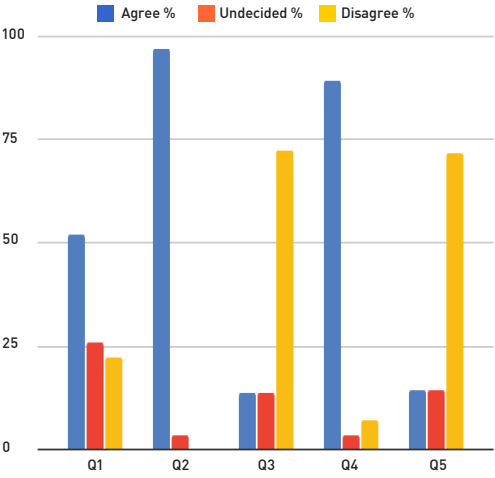


Fig. 4. Group B - % Response to Science, Scientific Method and Terminology

for evolution to have occurred) being the correct statements, majority of the students in Group A ($n = 28$; $n = 23$) and B ($n = 29$; $n = 25$) have agreed that they are indeed true; whereas, the Statements 3 (according to the second law of thermodynamics, complex life forms cannot evolve from simpler life forms) and 5 (evolution cannot be considered a reliable explanation because evolution is only a theory) being the incorrect statements, majority of the students in Group A ($n = 18$; $n = 18$) and B ($n = 21$; $n = 20$) have displayed their understanding towards the statements being false.

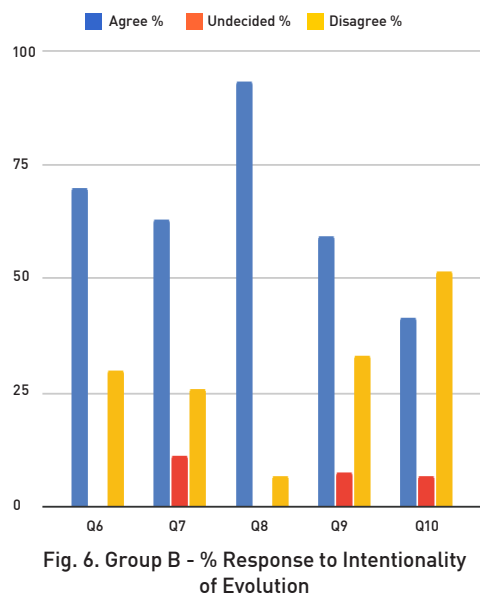
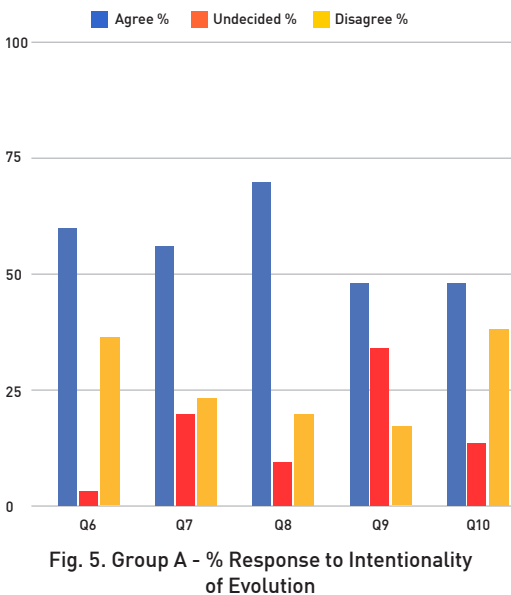
The similar responses across both groups may reflect common knowledge of basic scientific terms like "natural selection" and "adaptation", often recalled without deeper contextual understanding. Opposite responses can stem from differences in exposure to the scientific method, where the formally educated group better grasps

processes like hypothesis testing, while the unexposed group may rely on pseudoscientific ideas. Close margins between correct and incorrect answers might arise from confusion over scientific terminology, such as the misinterpretation of "theory" as speculation. In contrast, large margins likely indicate clarity in fundamental principles well-covered in formal education, such as understanding that science seeks natural explanations.

Intentionality of Evolution

Figures 5 and 6 provide an overview of the percentage analysis of the student responses belonging to this theme of Biological Evolution of the 5 statements belonging to this theme, only the Statements 8 and 10 have been answered correctly by the majority of students.

In the case of Statement 6 (evolution always results in improvement), the majority of the students in Group A ($n = 18$) and



B ($n = 21$) have exhibited a misconception, where it has been perceived that to evolve means to improve or to become a better version of oneself. Similarly, for Statement 7 (Members of a species evolve because of an inner need to evolve).

The majority of the students in Group A ($n = 17$) and B ($n = 17$) display a misconception that it is the individual organism's inner need or requirement, which enables the organisms to undergo evolution.

In case of Statement 8 (traits acquired during the lifetime of an organism—such as large muscles produced by bodybuilding—will not be passed along to offspring), the majority of the students in Group A ($n = 21$) and B ($n = 28$) display a better understanding of the notion within this theme of Intentionality of Evolution, w.r.t inheritance of traits; whereas for Statement 10 (evolution cannot cause an organism's traits to change within its lifetime), the majority of the students in Group A ($n = 14$) display a better understanding of the notion of the duration of undergoing evolution of a species, and Group B ($n = 12$) displays a lower level of understanding of the same concept, agreeing that the organisms can evolve within their lifetime. Therefore, here we see a mismatch in the trend of student responses between the groups of students.

Lastly, Statement 9 (if webbed feet are being selected for, all individuals in the next generation will have more webbing on their feet than do individuals in their parents' generation) being an incorrect notion, the majority of the students in Group A ($n = 14$) and B ($n = 16$) have displayed misconceptions, ascertaining with the conception that the offsprings exhibit an increased degree of a trait than its parents.

Similar responses across both groups are often rooted in shared misconceptions, such as perceiving evolution as a purposeful process driven by need. Divergent responses highlight the role of education in correcting these misconceptions, with the educated group better understanding evolution as non-intentional, while the unexposed group adheres to teleological explanations. Close margins reflect confusion over counterintuitive concepts, like the lack of a goal in evolution. However, statements emphasising non-intentionality, if explicitly taught, could yield large margins of correct responses among educated students.

Nature of Evolution

Figures 7 and 8 provide an overview of the percentage analysis of the student responses belonging to this theme of Biological Evolution. Of the 4 statements belonging to this theme, the Statements 11, 13 and 14 have been answered correctly by the students.

In case of Statements 11 (new traits within a population appear at random),

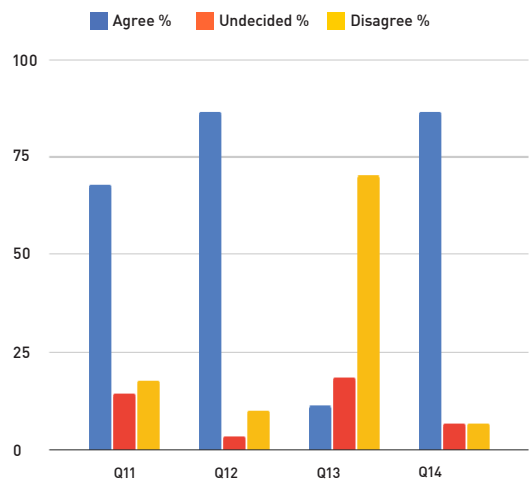


Fig. 7. Group A - % Response to Nature of Evolution

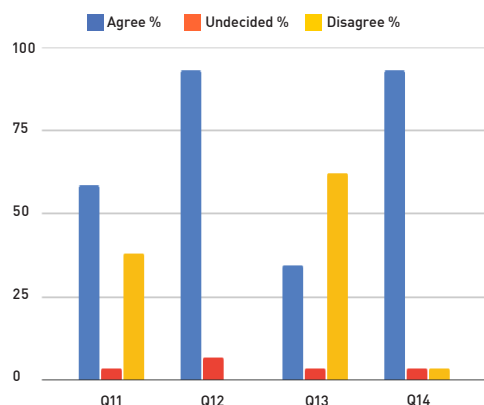


Fig. 8. Group B - % Response to Nature of Evolution

13 (evolution is a totally random process) and 14 (the environment determines which traits are best suited for survival), the majority of students in Group A (n = 19; n = 19; n = 26) and B (n = 17; n = 18; n = 28) have displayed minimal misconceptions regarding the appearance of traits, the evolution process and the role of environment in evolution, respectively. Whereas for Statement 12, an enormous majority of the students in Group A (n = 26) and B (n = 28) have displayed

misconceptions, thereby agreeing that the organisms adapt to their environment individually.

Similar responses may arise from general awareness of broad facts, like the gradual nature of evolution over time. Divergent responses reflect differences in understanding more complex ideas, such as punctuated equilibrium or population level changes. Close margins can be attributed to misinterpretations of evolutionary processes, such as the variability in rates of change. Large margins occur when fundamental ideas, like the distinction between individual and population-level evolution, are explicitly emphasised in education.

Mechanisms of Evolution

Figures 9 and 10 provide an overview of the percentage analysis of the student responses belonging to this theme of Biological Evolution. Of the 5 Statements belonging to this theme, Statements 15, 18 and 19 have been answered correctly by the students.

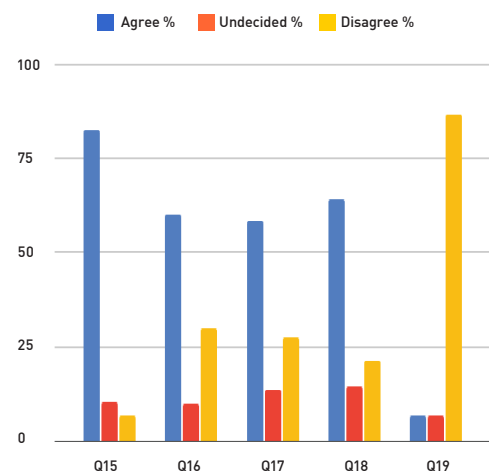


Fig. 9. Group A - % Response to Mechanisms of Evolution

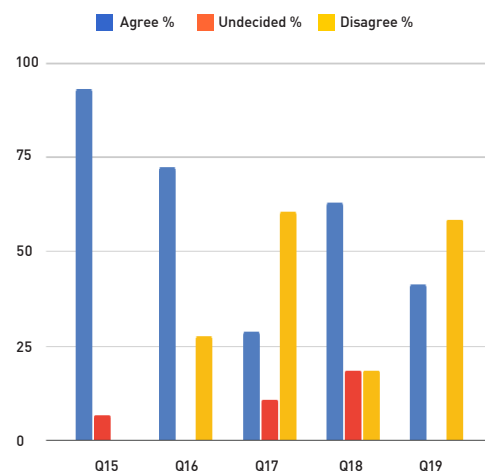


Fig. 10. Group B - % Response to Mechanisms of Evolution

With respect to Statements 15 (variation among individuals within a species is important for evolution to occur), 18 (complex structures such as the eye could have been formed by evolution) and 19 (only beneficial traits are passed on from parent to offspring), majority of the students in Group A ($n = 24$; $n = 18$; $n = 26$) and B ($n = 28$, $n = 17$, $n = 17$) have displayed the correct conception of this theme in the light of variation among species, evolution of complex structures and the inheritance of traits, respectively. Although in the case of Statements 16 and 17, students seem to have certain underlying misconceptions in regard with the meaning of the phrase “survival of the fittest” and the impact of population size on the process of evolution. For Statement 16 (“Survival of the fittest” means basically that “only the strong survive”), Group A ($n = 18$) and B ($n = 21$) students have displayed acceptance of this incorrect notion as a result of the oversimplification of concepts, thereby ascertaining that the mentioned phrases are synonymous with each other. Whereas, for Statement 17, the majority of the students in Group A ($n = 17$) have displayed a misconception that there is no role played by the size of the

population in the process of evolution; while Group B ($n = 17$) students have disagreed with this statement, thus portraying a better understanding of the concept.

Similar responses likely indicate shared recognition of well-known mechanisms like natural selection, even if a nuanced understanding is lacking. Opposite responses may reflect the depth of education, with the formally educated group correctly identifying less familiar mechanisms, such as genetic drift or gene flow, while the unexposed group relies solely on natural selection. Close margins could result from limited emphasis in teaching on mechanisms beyond natural selection. Large margins, however, are seen where formal education covers mechanisms like mutation and sexual selection in greater depth.

Evidence Supporting Evolution

Figures 11 and 12 show the percentage analysis of the student responses belonging to this theme of Biological Evolution. Of the four statements belonging to this theme, Statements 20, 22 and 23 have been answered accurately by the students.

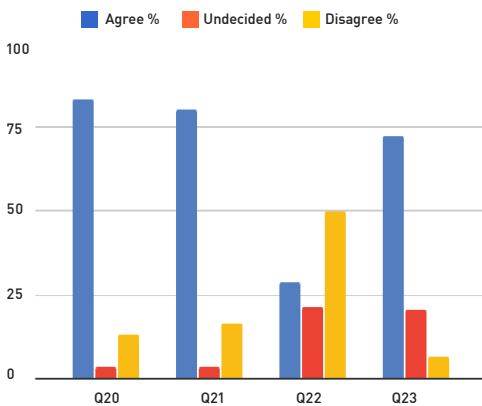


Fig. 11. Group A - % Response to Evidence Supporting Evolution

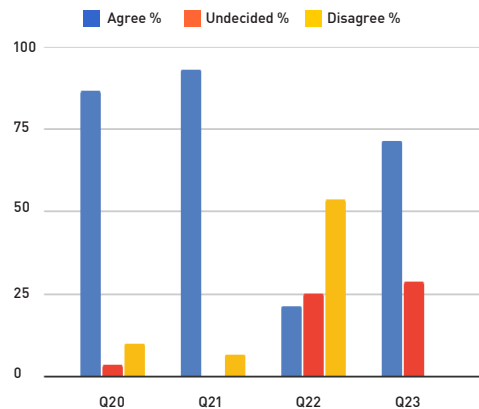


Fig. 12. Group B - % Response to Evidence Supporting Evolution

In case of Statement 20 (there exists a large amount of evidence supporting the theory of evolution.)

For the Statement 22 (scientific evidence indicates that dinosaurs and humans lived at the same time in the past) and 23 (the majority of scientists favour evolution over other explanations for life), the students in Group A (n = 25; n = 14; n = 21) and Group B (n = 26; n = 15; n = 20) have shown consensus with the correct notion of these concepts in terms of the number of evidence, the Jurassic period and the reliability of evolutionary theory as a “theory”. On the contrary, for Statement 21 (according to the theory of evolution, humans evolved from monkeys, gorillas, or apes), due to a misjudgement in the oversimplification of the concept, the majority of the students in Group A (n = 24) and Group B (n = 28) have agreed to the incorrect statement, therefore exhibiting their misconception in the undergraduate level of education.

Similar responses are often linked to widely recognised evidence, such as fossils or antibiotic resistance, known to both groups. Opposite responses highlight the educated group’s better grasp of diverse evidence types, like molecular biology or comparative anatomy, compared to the unexposed group’s potential scepticism. Close margins may stem from misinterpretation or overgeneralisation of evidence, while large margins are evident when robust empirical data, such as DNA sequence homologies, are well-integrated into formal education.

Conclusion

This research underscores the pervasive nature of misconceptions within the realm of

biological evolution across different themes. Despite variations in exposure to scientific concepts, no significant disparity was found in the biological evolution literacy levels between Groups A and B. The study highlights particular areas where misconceptions are prevalent, notably concerning the intentionality, nature, and mechanisms of evolution, as well as the origin of humans. Addressing these misconceptions is crucial for fostering a more accurate understanding of evolutionary concepts. Educators and policymakers should focus on targeted interventions to rectify these misconceptions and promote scientific literacy among learners. By enhancing public understanding of biological evolution, we can cultivate a more informed society capable of engaging critically with scientific advancements and addressing contemporary challenges effectively.

Implications

The implications drawn from this research on misconceptions in biological evolution are profound and necessitate immediate action to rectify the prevailing issues. Firstly, the findings underscore the urgency of integrating evolutionary concepts into secondary school curricula. By introducing evolution at this early stage, students can develop a foundational understanding of this central theme in biology, laying the groundwork for more advanced study later on. Furthermore, it is imperative to delve into evolutionary principles with depth and rigour at the university level. This ensures that future biology teachers, as well as students pursuing scientific disciplines, possess accurate conceptions and are equipped to address misconceptions effectively.

The critical role of teachers cannot be overstated. Educators must themselves hold correct conceptions of evolution and be adept at facilitating student learning through both theoretical instruction and practical exposure. By nurturing a generation of scientifically literate individuals, teachers can help stem the propagation of misconceptions among future learners. It is concerning that despite multiple exposures to evolutionary concepts throughout their academic journey, students continue to harbour misconceptions. This highlights a systemic issue that demands attention. With the removal of evolution from NCERT textbooks, there is a risk that future cohorts of students may lack formal opportunities to correct their misconceptions.

This underscores the necessity for educational policymakers to ensure that Curricula and textbooks comprehensively address the concept of evolution, emphasising both theoretical understanding and practical applications.

Failure to address these challenges could have far-reaching consequences, as students who graduate with misconceptions may inadvertently perpetuate them among the next generation of learners. Therefore, concerted efforts are needed to integrate evolution into educational frameworks effectively, providing students with a robust understanding of the reality of evolutionary processes on Earth.

REFERENCES

- ALMQUIST, A.J. AND J.E. CRONIN. 1988. Fact, Fancy, and Myth on Human Evolution. *Current Anthropology*. Vol. 29, No. 3. pp. 520–522. <http://www.jstor.org/stable/2743476>
- ALTERS, B. J. AND S. M. ALTERS. 2001. Defending Evolution in the Classroom: A Guide to the Creation/ Evolution Controversy. Sudbury, MA: Jones and Bartlett.
- AUSUBEL, D. P. 1968. *Educational Psychology: A Cognitive View*. Holt, Rinehart and Winston.
- BISHOP, B.A. AND C.W. ANDERSON. 1990. Student Conceptions of Natural Selection and Its Role in Evolution. *Journal of Research in Science Teaching*. Vol. 27, No. 5. pp. 415–427.
- CUNNINGHAM, D. L. AND D. J. WESCOTT. 2009. Still More “Fancy” and “Myth” than “Fact” in Students’ Conceptions of Evolution. *Evolution Education and Outreach*. Vol. 2. pp. 505–517. 10.1007/s12052-009-0123-6
- GREENE, E.D., JR. 1990. The Logic of University Students’ Misunderstanding of Natural Selection. *Journal of Research in Science Teaching*. Vol. 27. pp. 875–885.
- GREGORY, T.R. 2009. Understanding Natural Selection: Essential Concepts and Common Misconceptions. *Evolution: Education and Outreach*. Vol. 2, No. 2. pp. 156–175.
- JENSEN, M.S. AND F.N. FINLEY. 1996. Changes in Students’ Understanding of Evolution Resulting from Different Curricular and Instructional Strategies. *Journal of Research in Science Teaching*. Vol. 33. pp. 878–900.
- JOHNSON-LAIRD, P.N. 1983. *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*. Harvard University Press.
- KUMANDAS, B. 2015. *Misconceptions in Biology Education: A Review of Relevant Research* (Master’s Thesis). Bilkent University Institutional Repository.

- NEHM, R. H. AND I. S. SCHONFELD. 2008. Measuring Knowledge of Natural Selection: A Comparison of the CINS, an Open-response Instrument, and an Oral Interview. *Journal of Research in Science Teaching*. Vol. 45, No. 10. pp. 1131–1160.
- POSNER, G. J., K. A. STRIKE, P. W. HEWSON AND W. A. GERTZOG. 1982. Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. *Science Education*. Vol. 66, No. 2. pp. 211–227. <https://doi.org/10.1002/sce.3730660207>
- ROSCH, E. 1978. Principles of Categorisation. In Rosch, E. and B. B. Lloyd (Eds.). *Cognition and Categorisation*. Lawrence Erlbaum Associates. pp. 27–48.
- ROSCH, E. AND C. B. MERVIS. 1975. Family Resemblances: Studies in the Internal Structure of Categories. *Cognitive Psychology*. Vol. 7, No. 4. pp. 573–605.
- RUMELHART, D. E. 1980. Schemata: The Building Blocks of Cognition. In Spiro, R. J., B. C. Bruce and W. F. Brewer (Eds.), *Theoretical Issues in Reading Comprehension*. Lawrence Erlbaum Associates. pp. 33–58.
- SMITH, M. U. 2010. Current Status of Research in Teaching and Learning Evolution: I. Philosophical/Epistemological Issues. *Science and Education*. Vol. 19, No. 6–8. pp. 523–538.
- SOYIBO, K. 2008. An Exploration of Junior High School Students' Misconceptions Concerning Simple Electric Circuits. *Research in Science and Technological Education*. Vol. 26, No. 1. pp. 5–21.
- VERMA, P. AND R. CHOUDHURI. 2022. Investigating the Magnitude and Sources of Students' Misconceptions in Biology: A Case Study of Higher Secondary Level Students. *International Journal of Science Education*. Vol. 44, No. 1. pp. 57–72.
- WANDERSEE, J. H., J. J. MINTZES AND J. D. NOVAK. 1994. Research in Alternative Conceptions in Science: Part II Learning. In Gabel, D. L. (Ed.), *Handbook of Research on Science Teaching and Learning*. pp. 177–210. Macmillan, New York.
- WESCOTT, D. J. AND D. L. CUNNINGHAM. 2005. Recognising Student Misconception about Science and Evolution. *MountainRise*. Vol. 2. pp. 1–8.
- WILES, J. R. 2010. Overwhelming Scientific Confidence in Evolution and Its Centrality in Science Education—and the Public Disconnect. *Science Education Review*. Vol. 9, No. 1. pp. 18–27. <https://files.eric.ed.gov/fulltext/EJ896065.pdf>
- WILSON, J. A. 2001. Pseudoscientific Beliefs among College Students. *Reports of the National Centre for Science Education*. Vol. 21. pp. 9–13.
- YATES, T. B. AND E. A. MAREK. 2011. A Regional Study of the Types and Prevalence of Biological Evolution-related Misconceptions held by Oklahoma Public High School Prebiology Students. *Creative Education*. Vol. 2, No. 3. pp. 263–272.
- YATES, T. B. AND E. A. MAREK. 2014. Teachers Teaching Misconceptions: A Study of Factors Contributing to High School Biology Students' Acquisition of Biological Evolution-related Misconceptions. *Evolution: Education and Outreach*. Vol. 7, No. 7. <https://doi.org/10.1186/s12052-014-0007-2>
- YATES, TONY AND EDMUND MAREK. 2015. A Study Identifying Biological Evolution-related Misconceptions Held by Prebiology High School Students. *Creative Education*. Vol. 6. pp. 811–834. 10.4236/ce.2015.68085

SCIENCE, SKEPTICISM, AND THE PSEUDOSCIENCE DEBATE AROUND AYURVEDA — IMPLICATIONS IN SCIENCE EDUCATION

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Ayurveda is a traditional Indian system of medicine and lifestyle that has been in practice since ancient Vedic times, emphasising holistic well-being and harmonious living. While it has played a significant role in India's healthcare history, the advent of modern evidence-based medicine has shifted Ayurveda into a complementary or alternative role. This article explores the historical significance and foundational principles of Ayurveda, critically examines its claims through the lens of modern scientific understanding, and discusses why Ayurveda is often under scrutiny. Additionally, it addresses the challenges posed by the misrepresentation of Ayurveda, its potential risks to public health, and its implications for scientific temper and education in India.

Keywords: Healthcare, Ayurveda, Evidence-based Medicine, Pseudoscience, Scientific Temper

Introduction

Healthcare in India has a rich history that dates back to almost 5,000 years, with Ayurveda standing as one of the oldest systems of medicine. The benefits of Ayurveda in its ideal form are numerous—provides holistic (physical, mental and emotional health) and personalised healthcare; prevention-focused, emphasising on diet and nutrition for healing, and uses herbs, minerals and natural substances in the process with fewer side-effects. Along with other traditional practices like Siddha and Unani, Ayurveda was the primary form of medical treatment for centuries in the country. However, the rapid advancements in modern medicine led to a gradual shift in the healthcare landscape. In current times, Ayurveda is often considered an alternative or complementary form of medicine with modern evidence-based medicine having become the principal mode of treatment.

Modern medicine is a discipline that applies scientific knowledge, technology, and evidence-based practices to diagnose, treat, and prevent diseases, covering diverse fields such as surgery, radiology, and genetics. Many mistakenly equate allopathy with modern medicine. The term was originally used to describe crude medical practices of medieval times. Today, it is considered obsolete.

Following India's post-independence development, the healthcare sector saw significant progress. The advent of modern medicine, coupled with technological advancements in the West, provided new methods for treatment and management of diseases. Government initiatives such as national programmes targeting polio, malaria, leprosy, and maternal, child health services and many others, further strengthened the role of modern medicine. As a result traditional medical systems including Ayurveda took a backseat in the mainstream

healthcare system. However, in recent years, there has been a resurgence of interest in the field of Ayurveda. The Indian government established the Ministry of AYUSH with the goal of reviving and promoting traditional systems of medicine (Mahesh, 2019). As a result of patronage and support from the government, there has been a significant rise in the popularity of Ayurveda with increase in access to Ayurvedic treatments and products (Badiyani and Kotadia, 2023). This is also reflected in the market value of the Ayurvedic sector which was estimated to be three billion USD in 2016 in India, with its current market value continuing to grow (Mukherjee et al., 2017; Karousatos et al., 2021). This surge in popularity has also been fueled by widespread claims made on electronic media and social platforms. Many supporters and advocates of Ayurveda claim that Ayurvedic drugs available in the market today offer numerous benefits, often endorsing it as a "side-effect free" alternative to modern pharmaceutical medicine. However, such claims have been met with growing skepticism from the scientific community which points out the lack of empirical evidence supporting many of these (Patwardhan, 2016).

Despite its widespread use, Ayurveda remains a subject of debate, with critics labeling it a pseudoscientific practice due to its dearth of rigorous clinical testing (Bausell, 2007; Philips et al., 2019), unregulated practices (Patwardhan, 2016) and lack of scientific soundness in the theoretical foundations (Beall, Kaufman and Kaufman, 2018). While Ayurveda has stood the test of time with its use continuing for centuries, with the advent of modern technologies such as scientific testing tools and techniques, many of the once unverifiable aspects of Ayurveda can

be verified today. For example, the accurate quantities of phytochemicals present in the preparation of Ayurveda medicines can be measured today which was not possible till a few decades ago. Moreover, several ways of scientific clinical trials for its efficacy can also be employed today. By applying such knowledge, the possible fallacious production, manufacturing and preparation of Ayurvedic medicines, which are prevalent today, could be avoided to a large extent.

The discussions around Ayurveda also need to be looked at under the purview of science education so that students appreciate the approaches of healthcare in Ayurveda and modern medicines which are principally different from each other. Understanding this is also crucial for students so that they are able to deal with and handle misinformation and disinformation surrounding the two healthcare systems.

In view of the above discussions, this study was undertaken with the objectives discussed herewith.

Objectives

This paper attempts to address the following objectives:

1. To analyse the foundational principles of Ayurveda and critically examine the reasons why Ayurveda is often under scrutiny
2. To discuss the challenges posed by the misrepresentation of Ayurveda and its potential risks to public health
3. To identify the implications of Ayurvedic practices in terms of science education

Methodology

This study is a narrative review that examines the scientific validity of Ayurveda by analysing existing literature from various sources. Databases such as Google Scholar and PubMed were used for the literature search. The literature search was conducted using keywords such as “Ayurvedic medicine and clinical evidence”, “Ayurveda and pseudoscience”, and “Ayurveda basic principles”. The search included research articles, systematic reviews, clinical trials, observational studies, case reports, and newspaper reports that were directly relevant to and situated within the context of the Indian subcontinent, without any limitations on the sources, including publications or journals. The selected studies were analysed for scientific evidence, critical perspectives, and historical context regarding Ayurveda. Key themes such as theoretical principles, clinical efficacy, safety concerns, and public health implications were identified and synthesised.

Limitation: A limitation of this review is the potential bias in available literature. However, the study aims to provide a balanced and critical perspective by incorporating a wide range of academic sources.

Delimitation: The focus of the paper is on Ayurveda, and hence the paper does not delve into detail about modern medicine nor makes any attempt to elaborately compare Ayurveda with modern medicine. References to modern medicine have been made only to set a context.

Ayurveda: Historical Significance and Basic Principles

Ayurveda is an alternative medicine system with historical roots in the Indian subcontinent. Ayurveda is not just limited to treatment and cure of diseases, rather it is considered to be a way of living a healthy life (Narayanaswamy, 1981). It evolved in India and has survived as a distinct discipline from ancient times to the present day (Narayanaswamy, 1981). Ayurveda's historical roots date back to over 5,000 years. Originally transmitted orally, Ayurveda's earliest concepts were first recorded during Vedic period. Documented history available today from the Indian subcontinent dates 3,500 years and those references suggest that the oral tradition of Ayurveda is much older (Narayanaswamy, 1981). Foundational texts like the *Charaka Samhita* and *Sushruta Samhita* guide its practices (Mukherjee et al., 2017).

According to Ayurveda, the five elements or *Panchamahabhutas*—*Vayu* (air), *Teja* (fire), *Aap* (water), *Prithvi* (earth) and *Akasha* (aether) are believed to have build up the living beings and the external universe (Parasuraman, Thing and Dhanaraj, 2014). The *Panchamahabhutas* (five elements) combine in pairs to form one of the the *Tridosha*, or the three fundamental humors namely—*Vata*, *Pitta*, and *Kapha*. *Vata* regulates body movement, *Pitta* regulates chemical processes such as metabolism and temperature, and *Kapha* is responsible for growth, protection, lubrication, and overall sustenance. Together, these three *doshas* define an individual's constitution, known as *Prakriti*, which influences both physical and

mental characteristics (Parasuraman, Thing and Dhanaraj, 2014).

The *Tridosha* represent distinct psychobiological constitutional types that influence all aspects of human traits, functions, and health patterns. According to Ayurveda, well-being is maintained when these *doshas* are in harmony, while any imbalance among them leads to disease. Thus, Ayurveda determines an individual's *Prakriti* based on the interplay of the *Panchamahabhutas* and *Tridosha*, allowing for a distinctive treatment approach tailored to their unique constitution (Eatmon, 2020). The same is represented in Fig. 1. While prevention of disease is promoted through modifications in lifestyle, medicinal herbs form a fundamental part of Ayurveda.

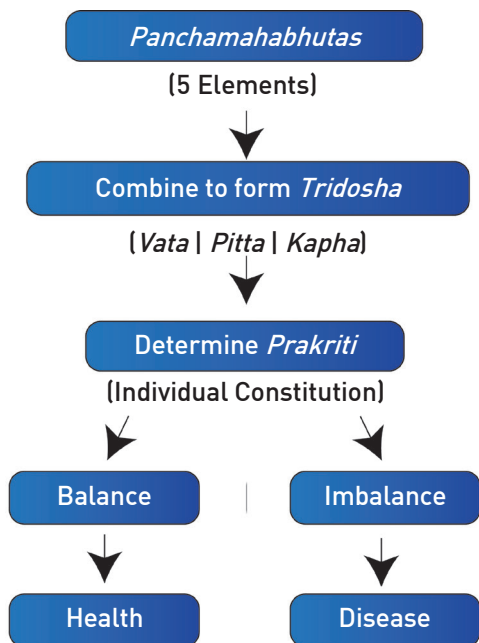


Fig. 1. Ayurvedic concept of health

In the next section we will understand why Ayurveda's principles are regarded as unscientific in today's evidence-based medical landscape.

Why Does Ayurveda Face Scrutiny?

Modern medicines have a strict globally accepted mechanism of clinical trials before they are made available in the market for public. The whole process is scientific, transparent and open for scrutiny by any party, though like any system, it is not infallible. However, in the case of Ayurveda, by virtue of it being not quantifiable in many aspects, and also because of the lack of transparency and lack of rigorous clinical trials, the authenticity of Ayurveda is often challenged.

Ayurveda is often regarded by scientific experts as pseudoscientific in its principle (Manohar, 2013; Bausell, 2007; Beall, Kaufman and Kaufman, 2018). The Oxford dictionary defines pseudoscience as "A pretended or spurious science; a collection of related beliefs about the world mistakenly regarded as being based on scientific method or as having the status that scientific truths now have." Pseudoscience can thus be said as something that looks like science but in fact is false, misleading or unproven. The goal of pseudoscience is to operate alongside the scientific system, either by imitating it or attempting to replace it (Blancke, Boudry and Pigliucci, 2017). This parallel framework makes it considerably difficult for the general public to distinguish between both forms of knowledge (Ortega, 2025). This parallel structure significantly complicates the general public's ability to distinguish

between the two domains of knowledge—science and pseudoscience.

Coming up with a simple criterion that enables us to differentiate pseudoscience from genuine science is a far more complex issue. According to Hansson (2013), something can be considered pseudoscientific if only it fulfills all of the given criteria:

1. It pertains to an issue within the domains of science in a broad sense (the criterion of scientific domain),
2. It suffers from such a severe lack of reliability that it cannot be trusted, and at all (the criterion of unreliability), and
3. It is part of a doctrine whose major proponents try to create the impression that it represents the most reliable knowledge on its subject matter (the criterion of deviant doctrine).

In the case of Ayurveda, several key criticisms appear to align with the criteria of pseudoscience.

Let us discuss some of these in detail.

Lack of Empirical Evidence

The Science philosopher Karl Popper argued that “good science is falsifiable, in that it makes precise claims which can be tested and then discarded (falsified) if they don't hold up” (Arnet, 2021). Science is based on evidence that is testable, reproducible and falsifiable. Ayurveda on the other hand, is based upon unfalsifiable principles, with no scientific way to prove or disprove them through empirical evidence (Dominic, n.d.). Ayurvedic concepts such as *tridosha* and *prakriti* are non-quantifiable concepts that cannot be tested or measured which turns

them into metaphysical rather than physical concepts (Dominic, n.d.).

In modern medicine, evidence comes from well-designed studies to guide clinical practice (Murad et al., 2016). Evidence in such case refers to reliable data generated through clinical trials, systematic reviews and meta-analyses (Murad et al., 2016). These form the strongest form of evidence because they minimise bias and allow independent verification.

In Ayurveda, on the other hand text from classical Samhitas, the experiential knowledge of practitioners, and patient-reported outcomes also count as evidence (Patwardhan, 2014). While such observations provide cultural and historical insights, they lack the methodological rigour of scientific evidence.

Although Ayurveda is considered a complete medical system by its practitioners, it lacks the rigorous scientific methodology necessary for accurate detection of diseases and their treatment. This is reflected in the limited availability of well-designed, high-quality controlled trials in the current literature centering around practice of Ayurveda (Philips et al., 2020). Many Ayurvedic treatments have not undergone the meticulous clinical testing required for as in case of modern medicines.

In clinical testing, double-blind, Randomised Controlled Trials (RCT) are considered as the standard. Such trials involve randomisation and blinding, that is, the patients as well as the administrators of treatment or the evaluator of result do not know which group they are in. This process helps in minimising potential biases. But, RCT alone is not

sufficient as strong evidence for a claim. In a scientific valid study, there needs to be diligent definitions for quality inclusion, unbiased methodology, accuracy in analysis and drawing conclusions (Philips et al., 2019). The sample size for a study must be determined through power analysis, which estimates the number of participants needed to detect a meaningful difference. Also, the findings from the study should be published in reputable journals following CONSORT (Consolidated Standards of Reporting Trials) guidelines for transparency (Suresh and Chandrashekara, 2012).

Much of the research in Ayurveda is limited to preclinical studies, such as those involving cells, tissues, and small animal models, with fewer rigorous clinical trials demonstrating clinically relevant benefits in humans (Kale et al., 2024). Therefore, it is crucial to examine all available evidence and assess each study based on its methodological quality and potential signs of data manipulation. This is achieved through systematic reviews and meta-analyses. If research publications tend to favour studies with positive results, it can lead to publication bias, which must be addressed to ensure a balanced and accurate scientific record.

Ayurveda claims to take a holistic approach to health and disease treatment, emphasising the healing of the body, mind, senses, and spirit. Practitioners often argue that Ayurvedic treatments are assessed for efficacy using methods that contradict its holistic principles (Patwardhan, 2011). A common defense is that because modern science cannot explain certain phenomena, long-standing beliefs that have endured for thousands of years should remain unquestioned. Since concepts such as *Panchamahabhuta* and *Tridosha* have

remained unchanged for millennia and they are therefore assumed to be inherently valid.

However, such arguments overlook a fundamental principle of scientific inquiry that unquestioned acceptance prevents rigorous validation. Without critical examination, the validity of these concepts remains unverified and unproven. For Ayurveda to be considered as a valid system of medicine for disease treatment, its ancient wisdom must be scrutinised, tested, and substantiated with empirical evidence.

Quantitative methods in medical research such as randomised control trials are considered as the standard for validating medical claims. In the case of Ayurveda, there is a large body of qualitative observations based on patient narratives and practitioner experiences. While these observations can be valuable for understanding the cultural, social and psychological dimensions of Ayurvedic practice, they can complement, but not replace, empirical evidence.

Lack of Transparency

Another reason Ayurveda receives criticism is the lack of transparency in methodologies. Ayurvedic herbal medicines are generally categorised into classical non-proprietary and patent and proprietary (P&P) drugs (Philips et al., 2020). Classical medicines are produced following the principles and guidelines outlined in the Ayurvedic texts such as the *Charaka Samhita* and *Sushruta Samhita*. In contrast, proprietary medicines are formulated by private manufacturers, who determine their ingredients, composition, and preparation methods (Philips et al., 2020).

Practitioners often create herbal concoctions without revealing their ingredients, making

scientific validation impossible (Dominic, n.d.; Bhalerao et al., 2010). While this approach aligns with traditional perspectives on medicine, it directly contradicts the scientific community's emphasis on peer-reviewed transparency (Dominic, n.d.). Authentic knowledge should be open and verifiable, rather than concealed behind secrecy or mysticism. Such evidences of lack of transparency and honesty is one of the reasons why Ayurveda is under scrutiny.

Challenges in Re-evaluating Ayurveda

Ayurveda is often regarded with deep respect due to its historical and cultural significance, which also carries the risk of it escaping critical scrutiny. In medical science, the authority of tradition must be weighed against scientific scrutiny. Ayurveda's basic concepts were not re-examined in the light of the greater understanding of the human body and disease. For instance, we know through rigorous scientific research that no amount of heavy metals such as lead is deemed safe for the human body (Vorvolakos et al., 2016), but these heavy metals are still commonly found in Ayurvedic formulations (Fernández et al., 2015; Saper et al., 2004; Centers for Disease Control and Prevention, 2012; The Times of India, 2017).

Many contemporary practitioners of Ayurveda are reluctant to critically examine the teachings of classical Samhitas, which contradicts the approach of ancient Indian sages. These sages emphasised direct observation (*Pratyaksha*), inference (*Anumana*), and logical reasoning (*Yukti*) over unquestioned reliance on textual authority (*Shabda Pramana*) (Lakhotia, 2023). Their unquestioning belief in the *Panchamahabhuta*

principle often leads to biased studies. For example, in the studies by Sharma (2018) and Jayasundar (2013), the authors attempt to relate the five mahabutas with the five spins of quantum physics. Such studies are designed to validate pre-existing beliefs rather than objectively test them (Lakhotia, 2023). Such flawed theoretical or experimental approaches, aimed at reaching predetermined conclusions, are characteristic of pseudoscience (Lakhotia, 2010). Also, the methods of treatment of Ayurveda underwent hardly any change for centuries with little to no addition to its literature for a long time (Lakhotia, 2023).

Unregulated Practices

The widespread word-of-mouth promotion and social media popularity, driven by the perceived but unquestioned 'assured' and 'safer' profile of these practices, have led to a significant increase in their usage by the general people as well as patients with both acute and chronic diseases (Philips et al., 2019). A lot of Ayurvedic drugs are also easily available without prescription from a licensed practitioner.

As mentioned earlier, before a modern medicine drug is launched in the market, it undergoes extensive pre-clinical and phased clinical trials. However, Ayurveda drugs do not face such compulsions before they are launched for marketing and use. Since many Ayurvedic drugs are of plant origin, they can be registered as phytopharmaceuticals (plant-derived drugs). Phytopharmaceutical drugs undergo a stringent regulatory approval process under the supervision of the Drugs Controller General of India. But when the

same plant-origin drugs are registered as Ayurvedic patent and proprietary (P&P) they do not have to undergo this regulatory process, giving such drugs an advantage of being launched into the market without prerequisite approvals that other modern medicine go through (Patwardhan, 2016).

The National Policy 2002 on Indian Systems of Medicine explicitly emphasises the need for strong evidence supporting Ayurveda (P&P) products, yet this recommendation remains unimplemented (Patwardhan, 2016). Currently P&P Ayurveda drugs can be put in the market without any scientific or clinical data as evidence (Patwardhan, 2016). One such example is of Coronil, a drug launched during the pandemic with empty claims to treat COVID-19. Increasing number of reports and publications are questioning the safety of Ayurveda drugs with current scientometrics

suggesting a rise in cases that show adverse reactions with such products increase in case reports showing adverse events with such products (Patwardhan, 2016).

Drawing from the above discussions, Table 1 summarises the key reasons why Ayurveda remains under scrutiny in contrast to modern science which is based on various scientific research criteria.

Ayurveda Through the Lens of Non-linear Dynamic Systems (NDS)

In order to rationalise its complexity in terms of quantifiability, NDS is considered a viable lens for Ayurveda. NDS is a scientific framework that helps explain phenomena in complex systems that do not respond linearly to external influences. NDS theory comes from the mathematical study and understanding of complexity and chaos such

Table 1: Ayurveda and Modern Science in terms of Scientific Research

Scientific Research Criteria	Standard in Modern Science	Status in Ayurveda
Falsifiability	Scientific claims must be testable and open to criticism through empirical evidence	Ayurvedic concepts like <i>Tridosha</i> , <i>Prakriti</i> , and <i>Panchamahabhuta</i> are metaphysical and cannot be empirically tested
Empirical Evidence	Relies on reproducible results from well-designed clinical trials, systematic reviews, and meta-analyses	Mostly depends on Samhitas, practitioner experience, and anecdotal reports
Transparency and Replicability	Methods, ingredients, and data are publicly documented for scrutiny and replication	Proprietary or not fully disclosed formulations, undocumented methods
Regulations	Drugs must undergo preclinical and clinical trials under strict regulatory supervision	Many Ayurvedic drugs are marketed without adequate clinical data or satisfactory regulatory clearance

as how a system changes over time and the complex interaction of systems that happens over time [Knight, 2023]. This framework has been borrowed in Ayurveda because it matches the holistic, balance-oriented view of Ayurveda better than reductionist biomedical paradigms [Rioux, 2012].

Ayurveda sees health as an emergent property of many interacting factors such as diet, lifestyle, environment, constitution, etc. It treats people as multi-level, interacting systems whose health is a dynamic balance, and NDS offers concepts and methods that map well onto that view. Thus, Ayurveda aligns more naturally with systems thinking and non-linear feedback loops than with single-variable RCTs. Ayurveda advocates often state that Ayurveda cannot be assessed with conventional scientific methods and present NDS as a “bridge paradigm”. This makes NDS a useful lens for designing new kinds of studies that examine health as a system-level property. It can be seen as an effort to modernise and develop appropriate research methods for complex, whole-system practices.

However, NDS is a methodological and conceptual tool. While it may appear to be a promising approach for Ayurveda, it will still require empirical evidence. Moreover, NDS does not seem to justify Ayurvedic practices by itself, nevertheless it provides a potential framework for developing new ways to study them. At the same time, NDS risks being misused as a defensive shield, implying that Ayurveda is “too complex” to be tested by science—which undermines falsifiability. Whether Ayurveda is scientific and evidence-based will still depend on whether its interventions produce reproducible, measurable health outcomes under rigorous testing.

Misrepresentation of Ayurveda

One of the main reasons for the general Indian population's reluctance toward modern medicine is the concern over perceived potential side effects, which, in fact, exists, and hence cannot be denied. In contrast, Ayurvedic medicines, being herb-based and often marketed as free of side effects, present a popular alternative [Kafle et al, 2018]. The claims of being “natural and toxin-free” further mislead people into thinking that they can administer such drugs on long term and without authorisation of an expert. Utilising this opportunity, a number of misleading advertisements about such drugs started to appear in electronic, print and social media during the past decade. Many prominent public figures and celebrities, acting as brand ambassadors, are endorsing products with unrealistic claims [Patwardhan, 2016]. Additionally, numerous television channels are airing deceptive advertisements, making exaggerated promises to lure desperate patients [Patwardhan, 2016].

As quoted by Patwardhan (2016), Ms Shailaja Chandra, former Secretary, Department of AYUSH says, “In a video clip on the internet several senior members of a Government funded research council can be viewed providing information and promoting the use of an Ayurvedic drug which is being sold commercially. The use of the product is being advised for treating a serious condition—diabetes. Such advocacy can be perilous and lead to self-treatment which is fraught with needless risks. It invites a conflict of interest charge and brings the entire science of

Ayurveda and the research work done for long into disrepute.”

A number of scientists from national organisations such as the Council of Scientific and Industrial Research (CSIR) have expressed deep skepticism toward market-driven and populist narratives, as they undermine the reliability of the research done in eminent research institutes of the country (Patwardhan, 2016). A review of publicly available data suggests that the evidence supporting these products is not robust or scientifically rigorous (Patwardhan, 2016). The promotion of commercially-driven products by government agencies, doctors, and scientists, despite lacking strong scientific backing, raises serious concerns.

In response to such misleading claims, the Supreme Court of India took action in February 2024, prohibiting a well-known Ayurvedic brand from advertising treatments for serious conditions such as high blood pressure, diabetes, epilepsy, and lupus (Mohanty, 2024). Currently, many Ayurvedic drugs are marketed for diseases for which the cure is not readily available and non-communicable diseases (NCDs), which account for a significant portion of morbidity and mortality in India. These include cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes. Notably, these diseases are listed under the Drugs and Magic Remedies (Objectionable Advertisements) Act, 1954, which prohibits claims regarding the diagnosis, cure, mitigation, treatment, or prevention of any of the 56 diseases specified in its Schedule, including Diabetes, Cancer, AIDS, Asthma, and Obesity. In an effort to strengthen this

law, the Ministry of Health proposed an amendment to the Act on 3 February 2020, specifically targeting advertisements that claim to have “magic” cures. This amendment was meant to apply to all categories of drugs, including Ayurvedic, Siddha, Unani, and Homeopathic medicines (Bajeli-Datt, 2023).

However, despite the government publishing a draft bill and seeking stakeholder feedback, an RTI response dated 7 November 2024, revealed that no progress had been made in implementing the proposed amendment (Bajeli-Datt, 2024). For the past two years, there has been no movement of files on the matter, raising concerns about the effectiveness and enforcement of the existing law.

Safety and Efficacy Concerns—A Case of Blood Growth Regulator-34

To understand the real-world implications of such misleading claims, let us consider the case of BGR-34, an antidiabetic drug developed by two Indian government-owned laboratories—NBRI (National Botanical Research Institute) and CIMAP (Central Institute of Medicinal and Aromatic Plants).

BGR-34 was launched for commercial use in 2016, its constituent ingredients being derived from six plants: fenugreek (*Trigonella foenum-graecum*), Giloy (*Tinospora cordifolia*), Daruharidra (*Berberis aristata*), Vijaysar (*Pterocarpus marsupium*), Gudmar (*Gymnema sylvestre*) and Manjeestha (*Rubia cordifolia*). Fenugreek is known to interact with other drugs, and it has natural blood thinners, increasing risks for bleeding which can prove dangerous, especially for diabetic patients (Eldin, Abdalmutalab and Bikir, 2013). And there are several studies that document

liver toxic effects of *Giloy* [Kulkarni et al., 2022] and *Gudmar* [Shiyovich, Nesher and Sztarkier, 2010].

A placebo-controlled clinical trial of BGR-34 at a CSIR Ayurvedic hospital was registered with Clinical Trials Registry of India (CTRI) and published in *European Journal of Pharmaceutical and Medical Research*—a predatory journal (Predatory Journals List, n.d.). The summary did not show any statistical analysis but minimally asserted that the trial “show(ed) promising results” promoting wider use (CTRI). These findings were later presented at an OMICS conference and republished in the *Journal of Traditional and Complementary Medicine* (Yadav, 2018), again without credible peer review.

The same trial was then published in *Journal of Traditional and Complementary Medicine*, where BGR-34 was described as efficient in reducing fasting blood glucose, postprandial glucose and glycosylated haemoglobin [Gupta et al., 2018]. No peer-reviewed publications were found on scientific research addressing contraindications, toxicology, or other related issues. Many physicians noted concerns about the safety of the drug (Shaikh, 2017). Multiple side-effects were reported and it was widely described as inefficient [Chandna, 2018]. The drug has faced significant criticism, and without further clinical trials, its efficacy remains unclear, raising concerns about its safety (Shaikh, 2017). This herbal supplement is a classical example of how public health is put at risk and promotes traditional untested formulations to endanger the public while refusing to accept the absence of evidence.

How Misinformation Impacts Public Health?

The use of Ayurvedic herbal medication is popular not only among the people of the Indian subcontinent but its use is increasing in the west. Despite being viewed as a safer alternative option, emerging cases of adverse effects of Ayurvedic drugs have raised concerns about their safety (Rammanohar, 2019). Especially, drugs containing substances like mercury, arsenic, and other minerals have raised concerns and are being examined for toxicity.

Recent high-quality observational studies have confirmed the hepatotoxic potential of Ayurvedic drugs. Commonly used and widely available over-the-counter Ayurveda medications containing herbs or their extracts such as Turmeric (*haldi*), Aloe Vera, *Ashwagandha*, *Gudmar*, *Guggul*, Puncture Vine, *Gotu-kola* (centella), Tamarind, *Senna*, *Bakuchi*, *Noni* and *Malabar*—have been linked to different forms of liver injury, including both acute and chronic liver failure (Karousatos et al., 2021).

Drug-induced liver injury due to Ayurvedic medication is thus on the rise, with clinical presentations including asymptomatic liver test abnormalities, acute hepatitis with or without jaundice, acute liver failure and severe hepatitis (Philips, 2019). Toxicity arises either from direct effects or indirect mechanisms, such as herbal metabolites, unknown herb-herb and herb-drug interactions, adulteration of Ayurvedic drugs with prescription medications, and contamination resulting from substandard manufacturing practices (Philips, 2019).

Ashwagandha (*Withania somnifera*), one of the most popularly used herbs in Ayurveda, is prescribed for a wide range of health

and disease conditions (Singh et al., 2011). However, Björnsson et al. (2020) reported multiple cases of Ashwagandha-induced liver damage from Iceland and the US Drug-Induced Liver Injury Network (DILIN) (Philips and Theruvath, 2024). In 2020, the Technical University of Denmark stated that establishing a standardised safe lower limit for Ashwagandha in supplements was not feasible. Denmark subsequently banned Ashwagandha due to its potential adverse impact on hormones, its hepatotoxicity and its ability to induce abortion (McKeown, n.d.). Following this, health regulatory agencies in Germany and Sweden reportedly supported Denmark's risk assessment, raising the chances of other European Union member states to also prohibit Ashwagandha-based supplements in the future (Knight, n.d.). Overall, while Ashwagandha-related herb-induced liver injury (HILI) was once considered rare, reports of such cases are increasing worldwide (Philips and Theruvath, 2024).

Inorganic forms of mercury is another common ingredient used in Ayurveda. These ions tend to build up in kidneys which establishes its association with membranous nephropathy. According to Ayurvedic practitioners, Mercury undergoes multiple "purification" processes, claimed to render it safe for use in treatment (Devaraju et al., 2024). However, in a study by Devaraju et al. (2024), chemical analysis of such Ayurvedic drugs was found to be 1,000-times greater than the allowed limits, questioning the safety of such drugs.

In India, the leading cause of drug-induced liver injury in individuals with a healthy liver is anti-tuberculosis combination therapy (Devarbhavi et al., 2021). However, in this

case, the benefits of treatment far outweigh the risks, as it effectively cures a disease that was once among the deadliest for humans. In contrast, alternative medicines such as Ayurvedic herbal supplements lack clinically proven benefits yet have well-documented toxicities and adverse effects. The risks associated with their use far surpass their anecdotal or negligible benefits. As a result, these herbal drugs have become the second most common cause of drug-induced liver injury in otherwise healthy individuals in India (Devarbhavi et al., 2021).

Regardless, such Ayurvedic drugs continue to be produced and prescribed to millions of people across India (Rammanohar, 2019). This poses risk to public health not only due to unregulated products and practices in this field but it also delays the initiation of the right treatment.

Educational Implications

The implications of the discussions around Ayurveda could be many in terms of education. While it highlights India's cultural and historical identity, it also runs the risk of encouraging students giving in to pseudoscience in the absence of adequate and appropriate explanations without any bias regarding Ayurveda as a form of valid healthcare system. Some of the implications are discussed below.

Scientific Temper

Scientific temper is enshrined in the Indian Constitution (Article 51A(h)) as a fundamental duty of every Indian citizen. It emphasises a rational, inquiry-based approach to knowledge and encourages citizens to critically analyse claims, seek empirical

evidence, and reject dogma. The National Education Policy (NEP) 2020 identifies the development of scientific temper as a key purpose of education. Similarly, the National Curriculum Framework for School Education (NCF-SE) 2023, which guides curriculum development across different stages of schooling in India, emphasises the importance of scientific temper, evidence-based reasoning, and critical thinking as essential components of students' holistic development.

In the context of Ayurveda, the debate over its scientific validity such as metaphysical principles, lack of empirical evidence, insufficient clinical trials to support its claims, raise critical questions about the state of scientific temper in India and its role in shaping public perception, policy, and education.

The Challenge of Balancing Tradition with Scientific Inquiry

Ayurveda is deeply intertwined with India's cultural and historical identity. While it offers valuable insights into holistic health, its lack of rigorous clinical validation and the prevalence of misleading claims pose a challenge to scientific discourse. The over-commercialisation of Ayurveda, especially with products like BGR-34, raise concerns about the weakening of evidence-based reasoning in the public health domain.

The qualitative observations based on patient narratives and practitioner experiences in Ayurveda will allow students to appreciate how traditional knowledge systems are embedded in culture. However, rigorous empirical research combined with such qualitative observations will provide a more

balanced approach to evaluating Ayurveda, acknowledging its cultural significance and at the same time not exempting it from scrutiny.

The increasing institutional endorsement of Ayurveda without scientific scrutiny including its integration into mainstream medical education risks undermining the principles of scientific inquiry. For instance, the equivalence of Ayurveda with modern medicine in certain educational and professional contexts may create false parity between empirically tested treatments and those lacking clinical validation.

Need for Rational Discourse in Science Education

To foster a scientific temper, India's education system must emphasise critical thinking, research-based learning, and skepticism towards unverified claims. A few key steps include:

- **Integrating Scientific Temper in Curricula:** Science education at school and university levels should include discussions on how to evaluate traditional knowledge through modern scientific methods. Ayurveda and other traditional practices should be studied critically, acknowledging their cultural significance while also examining their claims through peer-reviewed research and clinical trials. Practitioners should be trained in scientific reasoning rather than unquestioning adherence to traditional texts.
- **Teaching the Importance of Evidence-based Medicine:** Medical and science curricula should clearly differentiate between evidence-based medicine and

traditional practices, ensuring that future healthcare professionals understand the role of rigorous testing and peer-reviewed research. Introducing courses on medical skepticism, regulatory science, and public health ethics can help students navigate the complexities of traditional and modern medicine.

- **Addressing Misinformation through Science Communication:** The proliferation of misleading health claims about Ayurveda on social media underscores the need for scientific literacy among the public. While promoting the benefits of alternative and complementary medicine systems, educational institutions, policymakers, and media houses also need to work together to promote fact-checking initiatives and public awareness campaigns that dispel myths surrounding them.
- **Encouraging Research-driven Policy Making:** While promoting Ayurveda, policymakers should prioritise evidence-based validation rather than cultural or other vested motives. Research funding should be directed toward rigorous clinical trials that can either substantiate, or even debunk, invalid Ayurvedic claims, if any. Educational institutions, particularly in the fields of medicine and pharmacology, should encourage interdisciplinary research that brings at least the testable aspects of Ayurveda under the lens of modern science.

As emphasised in the NEP 2020 and NCF-SE 2023 about the development of scientific temper, evidence-based reasoning,

and critical thinking as key to education, the school curriculum needs to provide space wherever appropriate and relevant to discuss Ayurveda under such lens. Such approach will not only reinforce students' understanding about Ayurveda, but will also help them deal with the misinformation and disinformation associated with it.

Conclusion

While modern medicine has its own shortcomings in terms of its possible side-effects or market manipulations, the mechanism of its clinical trials, efficacy testing, transparency, etc., is quite robust. However, evidences of such crucial aspects are inadequate in the case of Ayurveda as discussed in the article. The Ayurveda debate in modern India is also not just about medicine. It is about the broader battle between scientific temper and cultural sentiments. Traditional areas of medicine such as Ayurveda deserve to be fully explored. In recent years, there has been a growing movement to position Ayurveda as either equivalent to or a viable alternative to modern medicine. However, for it to be recognised as such, it must withstand rigorous empirical scrutiny.

An analysis of existing literature highlights several reasons why Ayurveda faces scrutiny—the lack of rigorous, reproducible clinical trials; reliance on vague, non-quantifiable concepts like *doshas* and *prakriti*; lack of transparency; and unregulated practices. Unlike modern medicines, Ayurvedic drugs do not undergo the same stringent testing processes, leading to criticism from the scientific community.

Furthermore, the popularisation of Ayurveda, without adequate regulation, poses public health risks, as seen in multiple case reports of adverse events linked to these drugs.

Education plays a crucial role in shaping how society perceives science, medicine,

and rational inquiry. Thus, fostering scientific temper through education is the need of the hour as it can help us strike a balance between preserving our rich medical heritage and ensuring that healthcare remains rooted in evidence, ethics, and public well-being.

REFERENCES

- ARNET, EVAN. 2021. What Does It Mean for Science to be Falsifiable? SciU Conversations in Science at Indiana University. Retrieved on 20 February 2025 from <https://blogs.iu.edu/sciu/2021/07/31/what-does-it-mean-for-science-to-be-falsifiable>
- BADIYANI, J.M. AND H. KOTADIA. 2023. Recent Developments and Initiatives taken by Government to Ayurveda under Ministry of AYUSH. *Journal of Management Research and Analysis*. Vol. 10, No. 3. pp. 147–150.
- BAJELI-DUTT, K. 2023. Proposal to Amend Law Against Misleading Ads Put on Back Burner. *The New Indian Express*. <https://www.newindianexpress.com/thesundaystandard/2023/Oct/08/proposal-to-amend-law-against-misleading-ads-put-on-back-burner-2621822.html>. Accessed on 8 October 2023.
- . 2024. Four Years on, Government Keeps Draft Amendment to Drugs Ad Law in Cold Storage. *The New Indian Express*. <https://www.newindianexpress.com/nation/2024/Nov/11/four-years-on-government-keeps-draft-amendment-to-drugs-ad-law-in-cold-storage>. Accessed on 11 November 2024.
- BAUSELL, R.B. 2007. *Snake Oil Science: The Truth about Complementary and Alternative Medicine*. Oxford University Press.
- BEALL, J. 2018. Predatory Journals Exploit Structural Weaknesses in Scholarly Publishing. *4open*. Vol. 1. pp. 1–3.
- BHALERAO, S., R. MUNSHI, P. TILVE AND D. KUMBHAR. 2010. A Survey of the Labeling Information Provided for Ayurvedic Drugs Marketed in India. *International Journal of Ayurveda Research*. Vol. 1, No. 4. pp. 220–222.
- BJÖRNSSON, H.K., E.S. BJÖRNSSON, B. AVULA, I.A. KHAN, J.G. JONASSON, M. GHABRIL AND V. NAVARRO. 2020. Ashwagandha-induced Liver Injury: A Case Series from Iceland and the US Drug-induced Liver Injury Network. *Liver International*. Vol. 40, No. 4. pp. 825–829.
- BLANCKE, S., M. BOUDRY AND M. PIGLIUCCI. 2017. Why Do Irrational Beliefs Mimic Science? The Cultural Evolution of Pseudoscience. *Theoria*. Vol. 83, No. 1. pp. 78–97.

- CENTERS FOR DISEASE CONTROL AND PREVENTION. 2012. Lead Poisoning in Pregnant Women Who Used Ayurvedic Medications from India-New York City, 2011-2012. *MMWR: Morbidity & Mortality Weekly Report*. Vol. 61, No. 33.
- CHANDNA, H. 2018. Modi Govt's Love for Ayurveda May Be Undermining Ancient Medicinal System. *The Print*. Retrieved on 12 March 2025, from <https://theprint.in/india/governance/modi-govts-love-for-ayurveda-may-be-undermining-ancient-medicinal-system/163354>
- DEVARBHAVI, H., T. JOSEPH, N.S. KUMAR, C. RATHI, V. THOMAS, S. P. SINGH, ... AND P. RAO. 2021. The Indian Network of Drug-induced Liver Injury: Etiology, Clinical Features, Outcome and Prognostic Markers in 1288 Patients. *Journal of Clinical and Experimental Hepatology*. Vol. 11, No. 3. pp. 288–298.
- DEVARAJU, P. K., J. SESHADRI, C. M. BALASUBRAMANIAN, A. A. KURIEN, G. SENTHILKUMARAN, V. D. RAJARATHINAM, ... AND N. GOPALAKRISHNAN. 2024. Complementary and Alternative Medicine Use and Glomerular Disease: A Contemporary Case Series. *Kidney Medicine*. Vol. 6, No. 6. pp. 1–6. 100827.
- DOMINIC, S.K. n.d. Ayurveda: Ancient Tradition or Pseudoscientific Practice? A Philosophical Inquiry. Retrieved on 7 March 2025 from <https://philarchive.org/archive/DOMAAAT>
- EATMON, M. 2020. Ancient Wisdom and Future Medicine: A Defense of the Science of Ayurveda. Masters of Liberal Studies Theses. 91.
- ELDIN, I. M. T., M. M. ABDALMUTALAB AND H. E. BIKIR. 2013. An In Vitro Anticoagulant Effect of Fenugreek (*Trigonella foenum-graecum*) in Blood Samples of Normal Sudanese Individuals. *Sudanese Journal of Paediatrics*. Vol. 13, No. 2. pp. 52–56.
- FERNÁNDEZ, S., G. A. POLLIO, V. DOMÍNGUEZ, S. NOGUÉ, M. TORRA AND F. CARDELLACH. 2015. Outbreak of Lead Poisoning Associated with Ayurvedic Medicine. *Medicina Clínica* (English Edition). Vol. 144, No. 4. pp. 166–169.
- GUPTA, B. P., I. SHARMA, N. KOHLI, S. SHARMA, A. RATHI AND A. K. SHARMA. 2018. Preliminary Clinical Assessment and Non-toxicity Evaluation of an Ayurvedic Formulation BGR-34 in NIDDM. *Journal of Traditional and Complementary Medicine*. Vol. 8, No. 4. pp. 506–514.
- HANSSON, S. O. 2013. Defining Pseudoscience and Science. In *Philosophy of Pseudoscience: Reconsidering the Demarcation Problem*. pp. 61–77. The University of Chicago Press. <https://press.uchicago.edu/ucp/books/book/chicago/P/bo15996988.html>
- JAYASUNDAR, R. 2013. Quantum Logic in Ayurveda. In *An Integrated View of Health and Well-being: Bridging Indian and Western Knowledge*. pp. 115–139. Dordrecht: Springer Netherlands.
- JOHN, P. 2017. Deadly Metals in Ayurvedic Pills. *The Times of India*. <https://timesofindia.indiatimes.com/city/ahmedabad/deadly-metals-in-ayurvedic-pills/articleshow/58017380.cms>. Accessed on 5 April 2017.
- KALE, S. R., T. R. KEDAR, S. S. SAPKAL AND N. K. GANDHI. 2024. A Review on Problems Associated with Clinical Trials of Ayurvedic Medicine. *International Journal of Novel Research and Development*. Vol. 9, No. 11.

- KAFLE, G., I. BHATTARAI, A.K. SHRESTHA AND M. SIWAKOTI. 2018. Why Do Patients Choose to Consume Ayurvedic Medicines in Nepal? An Exploratory Study. *International Journal of Ayurvedic Medicine*. Vol. 9, No. 4. pp. 250–7.
- KAROUSATOS, C. M., J. K. LEE, D. R. BRAXTON AND T. L. FONG. 2021. Case Series and Review of Ayurvedic Medication Induced Liver Injury. *BMC Complementary Medicine and Therapies*. Vol. 21. pp. 1–11.
- KNIGHT, K. N.D. EU REGULATORY UPDATE ON ASHWAGANDHA. *Vitafoods Insights*. Retrieved on 10 March 2025 from <https://www.vitafoodsinsights.com/regulation/eu-regulatory-update-ashwagandha>
- KNIGHT, R. 2024. Introduction to the Section: Nonlinear Dynamic Systems Theory. *The Psychoanalytic Study of the Child*. Vol. 77, No. 1. pp. 82–87. <https://doi.org/10.1080/00797308.2023.2242230>
- KULKARNI, A.V., P. HANCHANALE, V. PRAKASH, C. KALAL, M. SHARMA, K. KUMAR AND LIVER RESEARCH CLUB INDIA. 2022. Tinospora Cordifolia (Giloy)–Induced Liver Injury During the COVID-19 Pandemic—Multicenter Nationwide Study from India. *Hepatology Communications*. Vol. 6, No. 6. pp. 1289–1300.
- LAKHOTIA, S. C. 2010. Validation of Ayurvedic Formulations in Animal Models Requires Stringent Scientific Rigor. *Journal of Ayurveda and Integrative Medicine*. Vol. 1, No. 3. p. 171–172.
- LAKHOTIA, S. C. 2023. “Confessions of an Ayurveda Professor”—A Wake up Call. *Indian Journal of Medical Ethics*. Vol. 8, No. 2. pp. 143–145.
- MANOHAR, P. R. 2013. Uniform Standards and Quality Control of Research Publications in the Field of Ayurveda. *Ancient Science of Life*. Vol. 32, No. 4. pp. 185–186.
- MAHESH, T.S. 2019. Education System of India and Ayurveda—A Critical Analysis. *Language, Discourse and Society*. Vol. 7, No. 1. pp. 143–151.
- McKEOWN M. N.D. Why did Denmark ban Ashwagandha? *Office for Science and Society*. McGill University. Retrieved on 10 March 2025 from <https://www.mcgill.ca/oss/article/critical-thinking-health-and-nutrition/why-did-denmark-ban-ashwagandha>
- MOHANTY, S.K. 2024. SC Stays Ayush Ministry’s Notification Allowing Unapproved Ads of Ayurvedic, Siddha, and Unani Drugs. *The New Indian Express*. <https://www.newindianexpress.com/nation/2024/Aug/27/sc-stays-ayush-ministrys-notification-allowing-unapproved-ads-of-ayurvedic-siddha-and-unani-drugs>. Accessed on 27 August 2024.
- MUKHERJEE, P.K., R.K. HARWANSH, S. BAHADUR, S. BANERJEE, A. KAR, J. CHANDA, ... AND C.K. KATIYAR. 2017. Development of Ayurveda—Tradition to Trend. *Journal of Ethnopharmacology*. Vol. 197. pp. 10–24.
- MURDAR, M.H., N. ASI, M. ALSAWAS AND F. ALAHBAD. 2016. New Evidence Pyramid. *BMI Evidence-based Medicine*. Vol. 21, No. 4. pp. 125–127.
- NARAYANASWAMY, V. 1981. Origin and Development of Ayurveda: (A Brief History). *Ancient Science of Life*. Vol. 1, No. 1. pp. 1–7.
- ORTEGA, J.L. 2025. How Does Pseudoscience Differ from Science? A Pair-wise Bibliometric Analysis. *Scientometrics*. Vol. 130, No. 10. pp. 5849–5870.

- PARASURAMAN, S., G. S. THING AND S. A. DHANARAJ. 2014. Polyherbal Formulation: Concept of Ayurveda. *Pharmacognosy Reviews*. Vol. 8, No. 16. pp. 73–80.
- PATWARDHAN, B. 2011. Ayurveda GCP Guidelines: Need for Freedom from RCT Ascendancy in Favor of Whole System Approach. *Journal of Ayurveda and Integrative Medicine*. Vol. 2, No. 1. pp. 1–4.
- . 2014. Bridging Ayurveda with Evidence-based Scientific Approaches in Medicine. *The EPMA Journal*. Vol. 5, No. 1. pp. 19.
- . 2016. Ayurvedic Drugs in Case: Claims, Evidence, Regulations and Ethics. *Journal of Ayurveda and Integrative Medicine*. Vol. 7, No. 3. p. 135–137.
- PHILIPS, C. A., S. RAJESH, S. K. JOHN, G. C. VALIATHAN AND P. AUGUSTINE. 2019. Traditional Herbal Medicine for Liver Cancer: “Let’s Pretend I Like Cooking and You Pretend It Tastes Nice”. *Cancer*. Vol. 125, No. 9. pp. 1568–1569.
- PHILIPS, C. A., R. AHAMED, S. RAJESH, T. GEORGE, M. MOHANAN AND P. AUGUSTINE. 2020. Comprehensive Review of Hepatotoxicity Associated with Traditional Indian Ayurvedic Herbs. *World Journal of Hepatology*. Vol. 12, No. 9. p. 574–595.
- PHILIPS, C. A. AND A. H. THERUVATH. 2024. A Comprehensive Review on the Hepatotoxicity of Herbs Used in the Indian (Ayush) Systems of Alternative Medicine. *Medicine*. Vol. 103, No. 16. e37903.
- PREDATORY JOURNALS LIST. N.D. OPEN ACCESS JOURNAL. Retrieved on 11 March 2025 from https://www.openaccessjournal.com/blog/predatory-journals-list/#E-_predatory_journals
- RAMMANOHAR, P. 2019. Toxicity of Ayurvedic Medicines and Safety Concerns: Ancient and Modern Perspectives. In *Toxicology in Antiquity*. pp. 441–458. Academic Press.
- RIoux, J. 2012. A Complex, Non-linear Dynamic Systems Perspective on Ayurveda and Ayurvedic Research. *The Journal of Alternative and Complementary Medicine: Paradigm, Practice and Policy Advancing Integrative Health*. Vol. 18. No. 7. pp. 709–718.
- SAPER, R. B., S. N. KALES, J. PAQUIN, M. J. BURNS, D. M. EISENBERG, R. B. DAVIS AND R. S. PHILIPS. 2004. Heavy Metal Content of Ayurvedic Herbal Medicine Products. *JAMA*. Vol. 292, No. 23. pp. 2868–2873.
- SHARMA, H. 2018. Correlation of Physiological Principles of Ayurveda with Spin Types of Quantum Physics. *Annals of Ayurvedic Medicine*. Vol. 7, No. 3–4. pp. 72–74.
- SHAIKH, S. 2017. Are AYUSH-supported BGR-34 and IME-9 Drugs Safe and Effective for Diabetes? *Alt News*. Retrieved on 13 August 2017 from <https://www.altnews.in/bgr-34-ime-9-drugs-safe-effective-diabetes/>
- SHIYOVICH, A., L. NESHER AND I. SZTARKIER. 2010. Toxic Hepatitis Induced by *Gymnema Sylvestre*, A Natural Remedy for Type 2 Diabetes Mellitus. *The American Journal of the Medical Sciences*. Vol. 340, No. 6. pp. 514–517.

- SINGH, N., M. BHALLA, P. DE JAGER AND M. GILCA. 2011. An Overview on Ashwagandha: A Rasayana (Rejuvenator) of Ayurveda. *African Journal of Traditional, Complementary, and Alternative Medicines*. Vol. 8, No. 5 Suppl. pp. 208–213. <https://doi.org/10.4314/ajtcam.v8i5S.9>
- SURESH, K. P. AND S. CHANDRASHEKARA. 2012. Sample Size Estimation and Power Analysis for Clinical Research Studies. *Journal of Human Reproductive Sciences*. Vol. 5, No. 1. pp. 7–13.
- VORVOLAKOS, T., S. ARSENIU AND M. SAMAKOURI. 2016. There is No Safe Threshold for Lead Exposure: A Literature Review. *Psychiatriki*. Vol. 27, No. 3. pp. 204–214.
- YADAV, S. 2018. Inside India's Fake Research Paper Shops: Pay, Publish, Profit. *The Indian Express*. Retrieved on 12 March 2025 from <https://indianexpress.com/article/india/inside-indias-fake-research-paper-shops-pay-publish-profit-5265402/>

OXYGEN: THE MISCHIEVOUS MASTER OF REACTIONS

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Oxygen, the breath of life, is also a master of mayhem, fueling reactions that create vitals for life and also capable of destruction. This enigmatic element drives combustion, respiration, and corrosion with equal vigour, earning its reputation as both creator and destroyer. This article explores the dual nature of oxygen — its essential presence in biological systems, its volatile role in combustion, and its often overlooked contribution to oxidative stress.

Keywords: Carboniferous, Superoxide Radical Anion, Reactive Oxygen Species, Oxidative Stress, Antioxidant

Introduction

Oxygen, the invisible celebrity of the periodic table — you cannot see it, smell it, or taste it, yet you would die in about three minutes without it. From fueling fire to turning our blood red, from giant insects to the stunning Northern Lights or the *Aurora Borealis*, caused due to the charged electron interaction of the Sun and the Earth's atmospheric oxygen along the Earth's magnetic field lines (Ramos-Lara et al., 2021), it is the most fascinating element for the existence of life on Earth. But oxygen has not always been around in abundance. If you took a time machine to 2.5 billion years ago, you would find yourself almost devoid of oxygen in the territory of the anaerobic bacteria that ruled then. That all changed by the appearance of the tiny cyanobacteria that could produce oxygen by the process of photosynthesis. This increasing population of oxygen-producing organisms slowly and eventually led to the Great Oxygenation Event disaster that wiped out the anaerobic life that could not handle the sudden influx of this new gas.

During the Carboniferous period, roughly 300 million years ago, oxygen levels soared to around 35 per cent of the atmosphere (Chen et al., 2022). This surplus enabled insects to reach terrifyingly large sizes, giving rise to the legendary giant insects. Imagine dragonflies with wingspans of nearly three feet buzzing around like miniature drones on steroids. Thankfully, we were non-existent during that era. However, oxygen's impact extends far beyond ancient arthropods. It is also responsible for the breathtaking spectacle of the Northern Lights (*Aurora borealis*). When charged particles from the Sun collide with the Earth's atmosphere, they excite oxygen atoms, causing them to emit the iconic green glow. Without oxygen, the aurora would have been far less vibrant. While oxygen is essential for life, it is also a bit of a troublemaker. Its high reactivity means that it readily combines with other elements, sometimes with explosive consequences. This propensity for reaction is why iron rusts, apples turn brown and fires spread. Thus, oxygen plays a dual role, serving as both a life-giver and a destroyer.

Evolution of Oxygen

The formation of the first traces of oxygen takes us back to approximately 2.4 to 2.1 billion years ago. There occurred two major oxygenation events, like the Great Oxidation Event (GOE) and the Neoproterozoic Oxygenation Event (NOE) [Chen et al., 2022]. The oxygen we see around us is a result of the complex interplay between the geosphere, atmosphere and biosphere (Fig. 1).

The GOE was driven by the evolution of tiny cyanobacteria that produced oxygen by photosynthesis, which shifted the predominantly anoxic (oxygen-poor) environment to an oxygen-rich environment. Increased atmospheric oxygen led to the oxidation of iron, forming the continental red beds in the marine ocean. It formed the banded iron formations (BIFs) that were a key geographical event [Olejarz et al., 2021].

The Earth witnessed a shift from the methane-rich atmosphere to an oxygen-rich atmosphere that reduced the greenhouse gas levels and led to the first mass extinction event, where the anaerobic organisms got wiped out and what remained were the organisms that evolved the aerobic respiration metabolic pathways.

The second oxidation event was the NOE that led to the increase in the oxygen levels of the present day around 800–540 million years ago. Unlike the GOE, it was characterised by the carbonate precipitation in oceans. There occurred more stable atmospheric conditions, and the oxygen levels became sufficient to support the large, multicellular eukaryotic life, leading to the Cambrian explosion [Canfield et al., 2013]. Thus, these two major evolutionary events led to the oxygen formation and the evolution of the early animals with a more efficient aerobic metabolism.

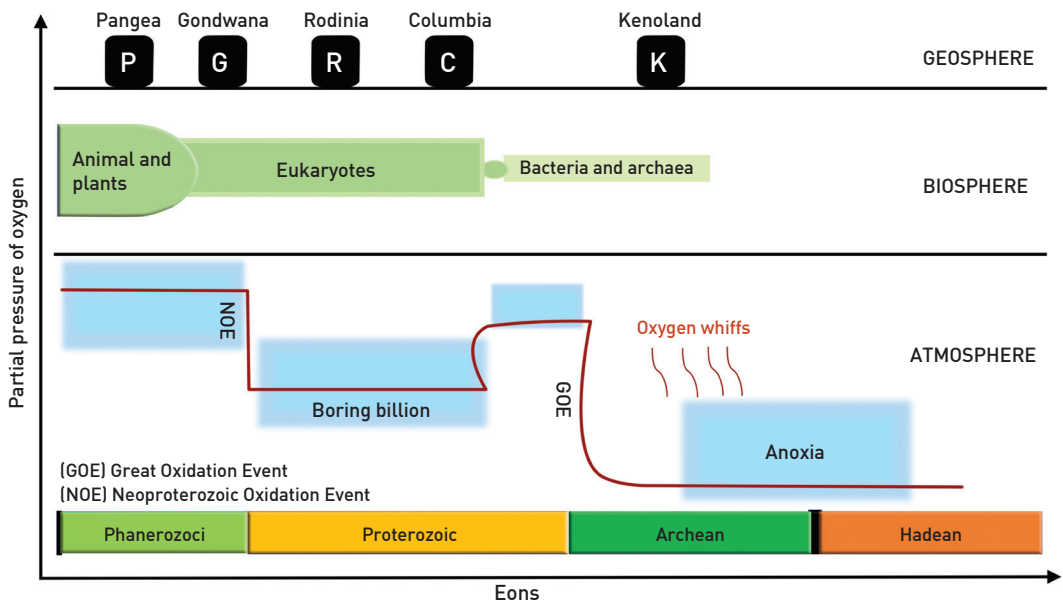


Fig. 1. Evolution of oxygen in early Earth [Chen et al., 2022]

Discovery of Oxygen

The Polish alchemist Michael Sendivogius wrote as far back as 1604 that “Man was created of the Earth and lives by virtue of the air; for there is in the air a secret food of life...” It was well before the formal discovery of oxygen that Sendivogius predicted it. The latter half of the 18th century produced scientists like Joseph Priestley, Carl Wilhelm Scheele and Antoine Lavoisier who are credited to have discovered oxygen by their independent experimental set-ups (Trayhurn, 2019). In 1774, Joseph Priestley, placed some samples of mercuric oxide (HgO) in a glass container on which he focused the sunlight using a magnifying glass (Fig. 2). This experiment caused the decomposition of mercuric oxide into mercury (Hg) and a gas that allowed

the brighter burning of the candle placed inside and thus in turn helped the mice to survive longer than the rest. He termed it ‘dephlogisticated air’, a purer form of air which we now know as oxygen. Prior to Priestley’s publication, between 1771 and 1772, Carl Wilhelm Scheele, heated several substances like potassium nitrate (KNO_3), magnesium oxide (MnO_2) and mercuric oxide (HgO) that led to enhanced combustion and respiration which he termed as the ‘fire air’. Though he conducted his experiments in 1771–1772, his experiment wasn’t published until 1774. And subsequently then in the year 1775–77, Antoine Lavoisier repeated Priestley’s experiment but with a more controlled approach and was the first to coin the term *oxygène*, meaning ‘acid former’ in Greek (*oxys*—sharp or sour and *genes*—producer) (Trayhurn, 2019).

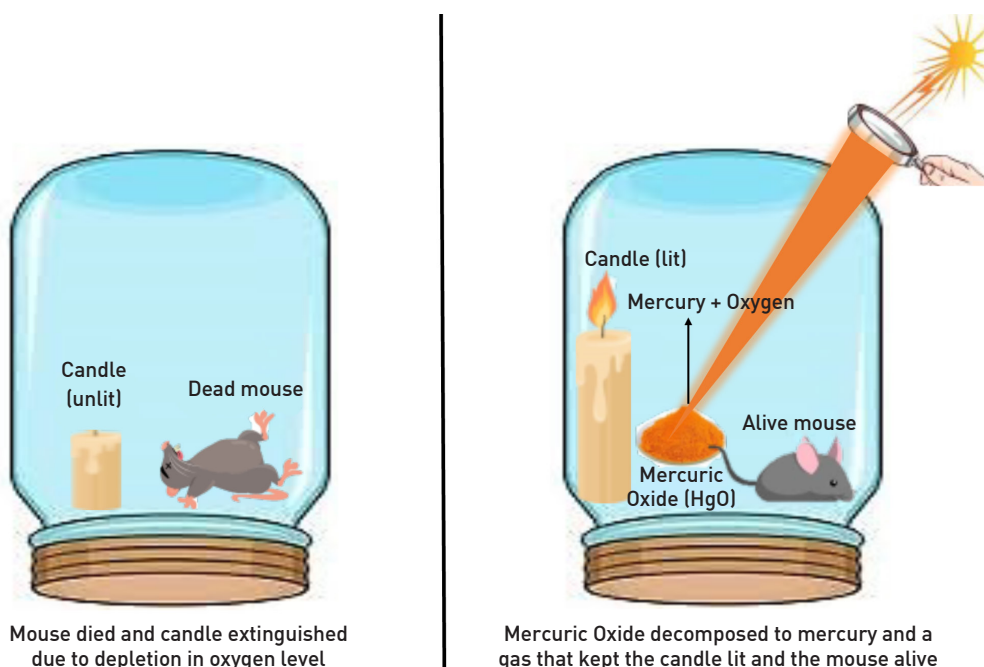


Fig. 2. Discovery of oxygen by Priestley

Oxygen: The Necessity of Life

Oxygen is one of the unsung heroes of our cosmos that infused life on earth, shaping the very fabric of our existence. From the first gasp of air at birth to illuminating our cosmic journey, oxygen pulses through every capillary of this planet. It is a recognised nutrient and is the protagonist in the mitochondrial process of formation of ATP, the quintessential molecule of energy produced by the process of oxidative phosphorylation where oxygen acts as the final electron acceptor. Its strong presence is felt in all the metabolic processes,

including the TCA cycle, gluconeogenesis, lipolysis, and numerous other pathways (Trayhurn, 2019). It maintains the delicate balance of oxygen in air and efficiently replenishes it as needed alongside playing a supporting role in the carbon cycle too by helping regulate the greenhouse levels of the atmosphere. Apart from the normal biological functions, it plays a crucial role in the welding, steel manufacturing, and chemical industries. In the medical field, oxygen therapy is used to treat patients with respiratory disorders by providing adequate level of oxygen for survival (Fig. 3).

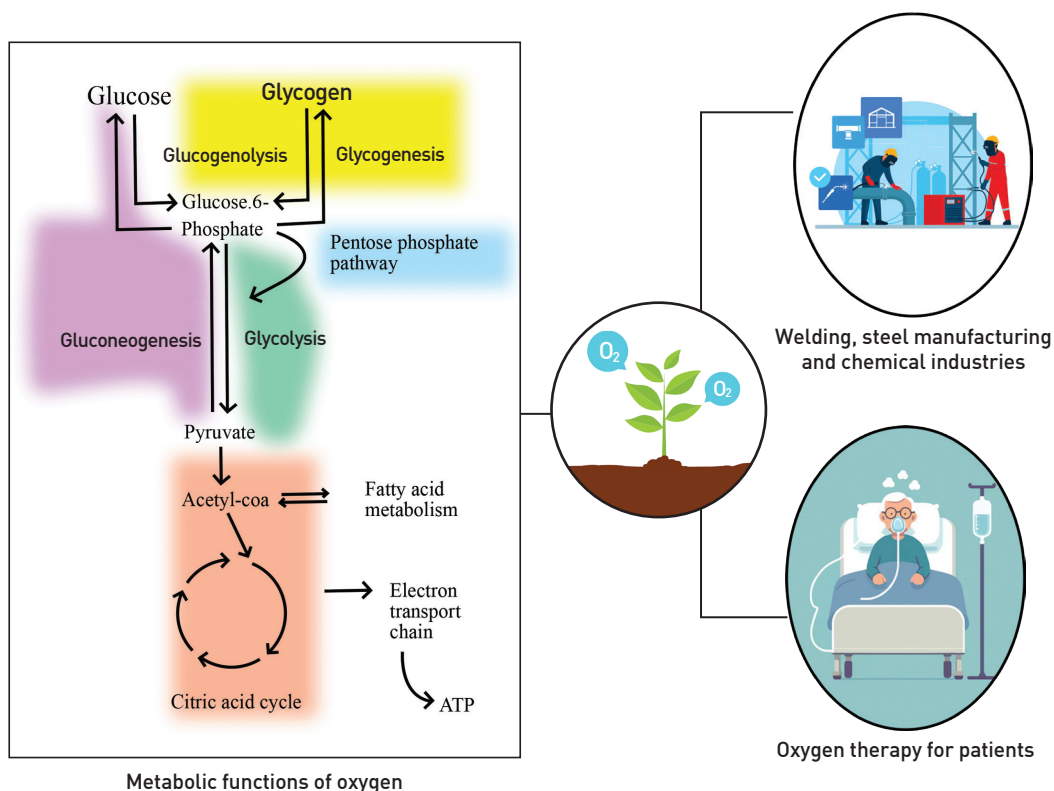


Fig. 3. Importance of oxygen in our daily life

Oxygen: The Evil

Although oxygen is a saviour, it can prove to be fatal on several occasions. Molecular oxygen has two unpaired electrons with parallel spin in their antibonding orbital in their ground state that restricts their ability to interact with other molecules. Due to several chemical phenomena, adulterated forms of the oxygen are generated, which are highly reactive due to the presence of unpaired electrons that can combine with other species, initiating a cascade of reactions.

Addition of a single electron to molecular oxygen results in the formation of the superoxide radical anion ($O_2^{\cdot-}$), while the addition of two electrons yields peroxide (O_2^{2-}). These highly reactive entities, collectively known as the Reactive Oxygen Species (ROS), can induce oxidative stress and damage

proteins, lipids, and DNA in organisms. In the redox realm of bodily pathophysiology, two distinct conditions emerge. 'Oxidative eustress', characterised by low-level oxidative stress, is surprisingly beneficial, facilitating cell growth, redox signaling, and apoptosis (Jomova et al., 2023) (Fig. 4). In contrast, 'oxidative distress' arises when the body is overwhelmed by high concentrations of oxidants and depleted of antioxidants, leading to various debilitating diseases, including cancer, cardiovascular disorders, and neurodegenerative conditions (Fig. 4).

Sources of ROS

There are two major pathways of ROS production. The endogenous pathway involves the sites in the cell that are mainly involved in respiration and photosynthesis, which are governed by oxidation.

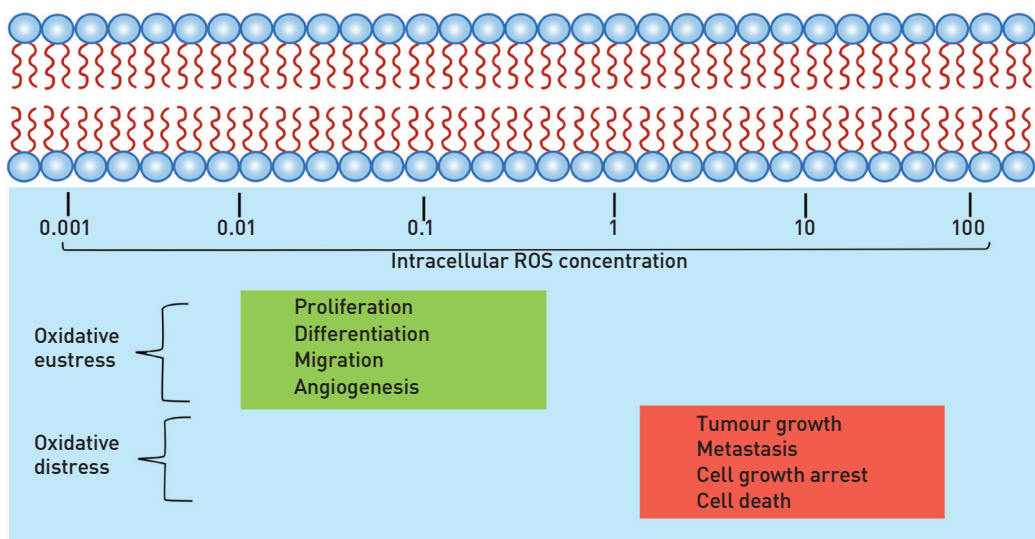


Fig. 4. Cellular responses during oxidative eustress and oxidative distress in relation to intracellular ROS species concentration (Sies and Jones, 2020)

The oxidative phosphorylation in mitochondria, the membrane-bound NADPH oxidases (NOXs), peroxisomes, chloroplasts, and cytochrome P450 during the process of photosynthesis and respiration produce the ROS particles. According to a few new studies, the ribosome is also said to produce ROS due to any imbalance in the ROS homeostasis. On the other hand, smoking, drug consumption, chemotherapies, alcohol consumption, smoked meat, metal-containing drugs, etc., trigger the production of ROS species by increasing the

lipid peroxidation and reducing the levels of the antioxidants (Fig. 5). The latter is the exogenous source of ROS (Jomova et al., 2023).

Types of ROS

There are various types of ROS generated in the body due to the misbalance in the homeostasis, which can cause severe detrimental effects to the body. A few examples are as mentioned in Table 1 (Jomova et al., 2023).

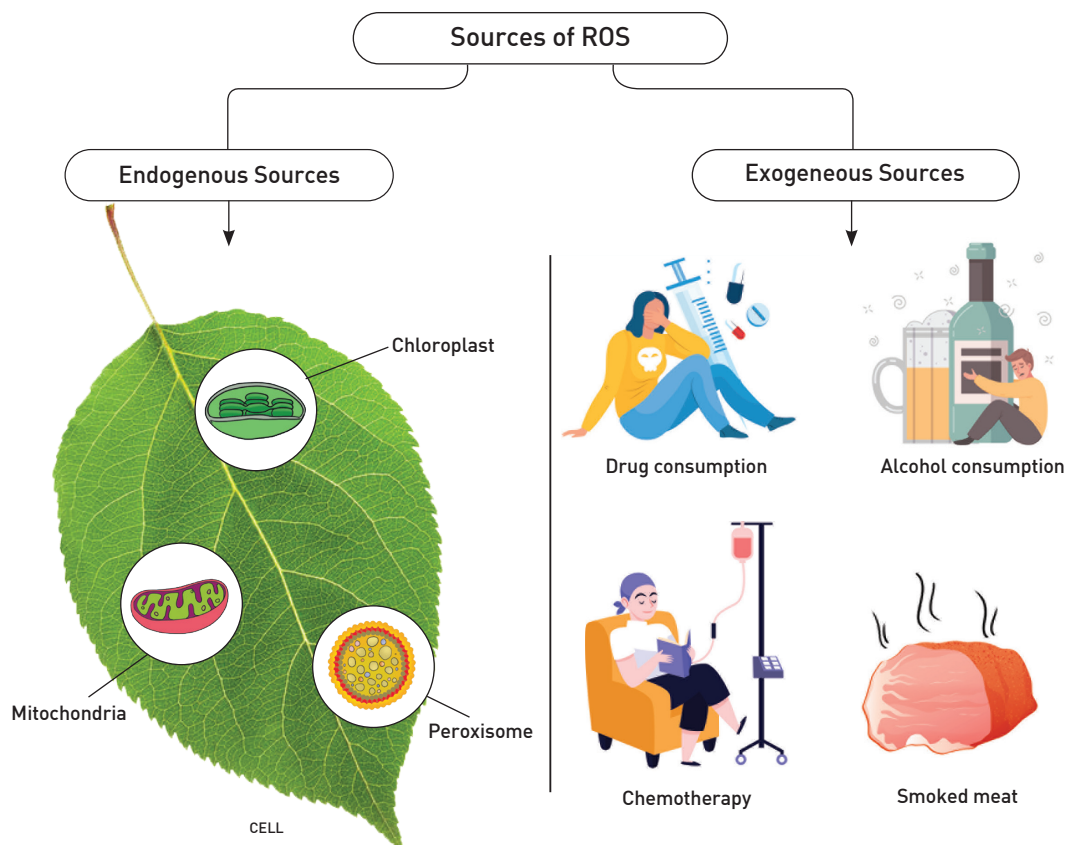


Fig. 5. Various sources of Reactive Oxygen Species (ROS)

Table 1: Various ROS Radicals, their Mechanism of Generation, and the Cellular Damage Caused by Them

Name of the Radical	Mechanism of Generation inside the Body	Cellular Damage Caused
Superoxide Radical ($O_2^{\cdot-}$)	Produced in mitochondria during electron leakage in oxidative phosphorylation. Also formed by activated phagocytes.	Precursor to other ROS, causes oxidative stress, and contributes to DNA, protein, and lipid damage.
Hydroperoxyl Radical ($HOO\bullet$)	Formed in equilibrium with superoxide radical ($O_2^{\cdot-}$) in physiological conditions.	Can damage biomolecules but exists in low concentration.
Hydroxyl Radical ($OH\bullet$)	Generated via Fenton reaction ($H_2O_2 + Fe^{2+} \rightarrow OH\bullet + OH^- + Fe^{3+}$). Also formed by water radiolysis or redox metal reactions.	Highly reactive, causes severe DNA, protein, and membrane lipid damage, leading to cell dysfunction and death.
Singlet Oxygen ($^1O_2$)	Produced by energy transfer to molecular oxygen, often in photodynamic therapy (PDT).	Oxidises biomolecules, causing lipid peroxidation, protein oxidation, and DNA damage.
Peroxyl Radicals ($ROO\bullet$)	Formed when molecular oxygen reacts with radicals ($R\bullet$), or by lipid peroxidation.	Leads to oxidative degradation of lipids, impacting membrane integrity.
Thiyl Radicals ($RS\bullet$)	Formed by thiol-mediated radical repair processes.	Involved in oxidative stress and can alter protein function.
Carbonate Radical ($CO_3^{\cdot-}$)	Formed in the presence of bicarbonate during Fenton-like reactions.	Causes oxidation and damage to DNA bases, proteins, and lipids.
Peroxynitrite ($ONOO^-$)	Formed by the reaction of superoxide radical ($O_2^{\cdot-}$) and nitric oxide ($NO\bullet$).	Damages proteins, DNA, and lipids via nitration and oxidation, contributing to inflammation and neurodegenerative diseases.
Ozone (O_3)	Formed from the reaction between dioxygen (O_2 , the normal oxygen molecule) and singlet oxygen (O , oxygen atom) in the presence of a third body molecule able to absorb the heat of the reaction.	Causes asthma, emphysema, and chronic bronchitis, chronic obstructive pulmonary disease (COPD), adverse respiratory effects, and premature death in newborn babies.

*NOTE: R• stands for Radical

Oxidative Stress, Diseases, and Damage

The oxidative stress in the body results in the progressive development of various diseases that may be life-threatening in severe cases. It includes cardiovascular diseases like

atherosclerosis, hypertension, and heart failure, while the neurological diseases caused imply Alzheimer's, Parkinson's, and multiple sclerosis. It also results in cancer, diabetes, kidney failure, cataracts, and ageing (Pizzino et al., 2017) (Table 2). Thus, these ROS are highly dangerous to the body and must be prevented at any cost.

Table 2: Different ROS Species Involved in Various Diseases

Disease	Specific ROS Involved	Symptoms
Atherosclerosis	Superoxide (O_2^-), Hydrogen peroxide (H_2O_2), Hydroxyl radical ($\bullet OH$)	ROS oxidise LDL cholesterol, promoting foam cell formation and plaque build-up in arteries. Symptoms: chest pain (angina), risk of stroke or heart attack
Hypertension	Superoxide (O_2^-), Peroxynitrite ($ONOO^-$)	ROS impair nitric oxide signaling, reducing vasodilation, and increasing blood pressure. Symptoms: headache, fatigue, and heart strain
Heart Failure	Superoxide (O_2^-), H_2O_2 , $ONOO^-$	Oxidative damage to heart muscle cells contributes to cardiac remodeling. Symptoms: breathlessness, fatigue, fluid retention, reduced exercise tolerance
Alzheimer's Disease	H_2O_2 , $\bullet OH$, O_2^- , O_3	ROS damage neurons and promote beta-amyloid aggregation. Symptoms: memory loss, confusion, impaired cognition
Parkinson's Disease	Superoxide (O_2^-), H_2O_2 , $\bullet OH$, O_3	ROS damage dopaminergic neurons in the substantia nigra. Symptoms: tremor, muscle rigidity, bradykinesia
Multiple Sclerosis	O_2^- , $\bullet OH$, NO, $ONOO^-$	ROS contribute to demyelination and neuroinflammation. Symptoms: muscle weakness, vision issues, coordination problems
Cancer	O_2^- , H_2O_2 , $\bullet OH$, O_3	ROS induce DNA mutations, promoting carcinogenesis. Symptoms: vary by type; may include lumps, fatigue, unexplained weight loss

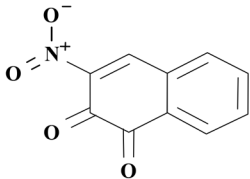
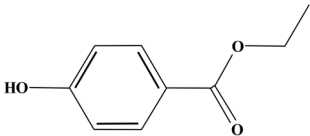
Diabetes Mellitus	$O_2^-, H_2O_2, \bullet OH^-$	ROS impair insulin secretion and cause β -cell dysfunction. Symptoms: increased thirst, urination, blurred vision, fatigue
Kidney Failure	$H_2O_2, ONOO^-$	ROS contribute to glomerular injury and tubular cell apoptosis. Symptoms: swelling, fatigue, nausea, and fluid/electrolyte imbalance
Cataract	$H_2O_2, \bullet OH^-$	ROS damages lens proteins, leading to opacity. Symptoms: blurred vision, faded colours, glare sensitivity
Aging	$O_2^-, H_2O_2, \bullet OH^-, O_3$	Accumulated oxidative damage to DNA, proteins, and lipids over time. Symptoms: reduced skin elasticity, cognitive decline, higher risk of chronic diseases

Antioxidant Systems and Their Mode of Action

The antioxidant system comprises the antioxidant enzymes, which are the metalloproteins that convert the highly reactive ROS particles into more stable

components. The delicate balance between the ROS and the antioxidants is quite essential for the proper functioning of the body (Poljsak, Šuput and Milisav, 2013). There are two major classes of antioxidants: Antioxidant enzymes and low molecular weight antioxidants (Tables 3 and 4).

Table 3: Structure and Function of Antioxidant Enzymes

Name of Antioxidant Enzymes	Structure of Antioxidant	Function
SOD		Converts superoxide anion (O_2^-) into hydrogen peroxide (H_2O_2) and oxygen (O_2). First line of defense against ROS.
Catalase		Breaks down hydrogen peroxide (H_2O_2) into water and oxygen, preventing the formation of hydroxyl radicals.

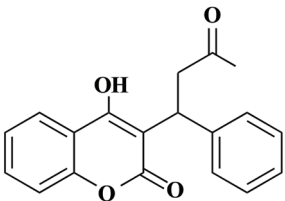
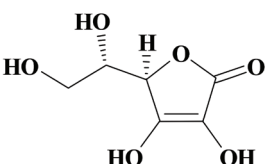
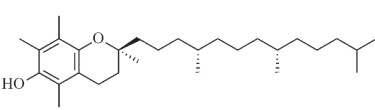
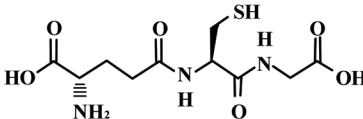
GPX (Glutathione Peroxidase)		Reduces hydrogen peroxide and lipid peroxides to water and corresponding alcohols using glutathione.
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Table 4 : Structure and Function of Low Molecular Weight Antioxidants

Name of Low Molecular Weight Antioxidants	Structure of Antioxidant	Function
Vitamin C Ascorbic Acid		Water-soluble antioxidant that neutralises a variety of ROS including superoxide and hydroxyl radicals; regenerates Vitamin E.
Vitamin E α -Tocopherol		Lipid-soluble antioxidant that protects cell membranes from lipid peroxidation by neutralising lipid radicals.
Glutathione Reduced Glutathione (GSH)		Acts as a cofactor for GPX; directly scavenges ROS and regenerates other antioxidants (like Vitamins C and E).

Antioxidant Therapy

Antioxidant therapy refers to the neutralisation of the excess ROS species formed during a particular process and maintain the ROS homeostasis. It thus helps to reduce the oxidative stress and reduces further cell damage (Fig. 6). Following are

the few major mechanisms that are involved in the antioxidant therapy:

- 1. Free radical scavenging:** The ROS species are the entities with an overall negative charge or incomplete oxidation state that makes them more reactive and thus form several harmful compounds while undergoing a

cascade of reactions. The antioxidants like Vitamin C and Vitamin E act by donating electrons to ROS and scavenging the free radicals and reducing the cell damage. This process is synonymously called as Hydrogen Atom Transfer (HAT) or Single Electron Transfer (SET).

2. **Chelation of metal ions:** There are several metal ions, like iron, copper, etc., that catalyse the formation of the several ROS species. Some of the antioxidants help chelate, or trap these metal ions that can no longer take part in the ROS formation.

3. **Inhibition of free radical generating enzymes:** Enzymes like NADPH oxidase and xanthine oxidase help in the ROS species generation. Yet another class of antioxidants help reduce the level of production of the enzymes generating the free radicals and protect the body from oxidative stress.

4. **Enhancement of antioxidant enzyme activity:** These antioxidants are the entities that can further accelerate the power of the endogenous class of antioxidants like SOD, catalase, GPX, etc.

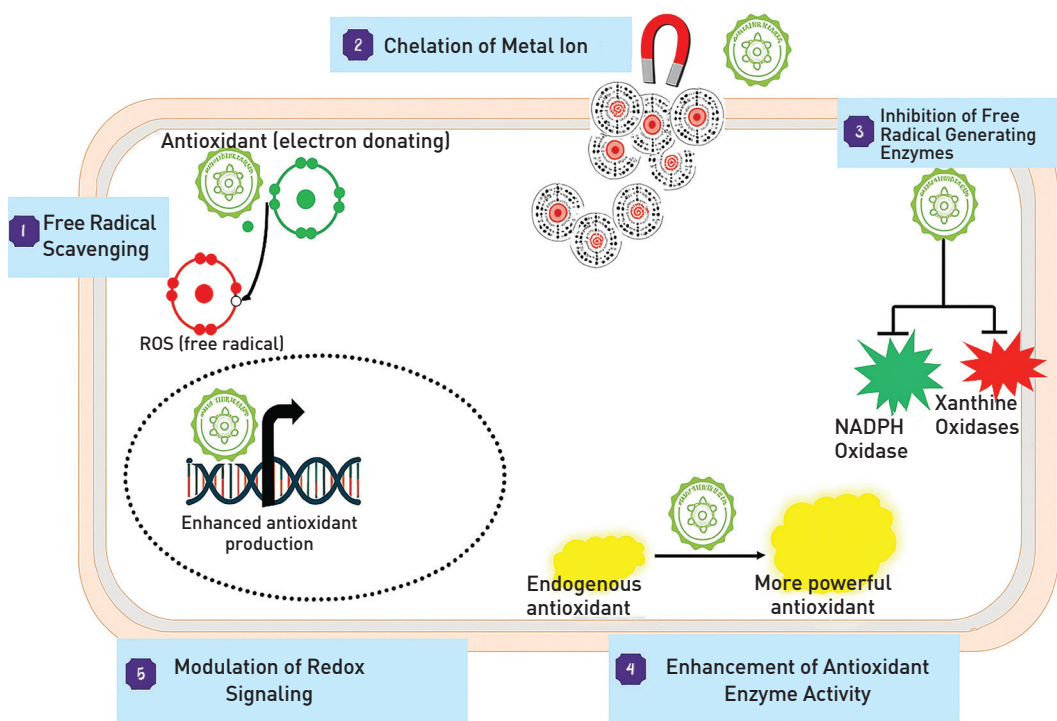


Fig. 6. Mechanisms of antioxidant therapy

- 5. Modulation of redox signaling:** Some antioxidants can influence the redox pathways and help reduce ROS at the cellular level.

Antioxidant Therapy in Treating Diseases

With the advancement in the medical field, some of the life-threatening diseases are being treated using the antioxidant therapy. Table 5 represents the specific diseases and their antioxidant therapy.

While oxygen is vital for sustaining life, its paradox lies in its potential to inflict harm

through the generation of ROS. These highly reactive molecules can lead to oxidative stress, damaging cells, proteins, and DNA, and contributing to the onset and progression of numerous diseases—from neurodegenerative disorders to cardiovascular and metabolic conditions.

Antioxidants, both endogenous and dietary, act as crucial defenders in neutralising ROS and maintaining cellular redox balance. Antioxidant therapy, therefore, represents a promising strategy in the prevention and management of oxidative stress-related diseases. However, it is essential to approach such therapy with precision—understanding

Table 5: Various Antioxidant Therapies in Treating Diseases

Diseases	Antioxidant Therapy	Mechanism
Cardiovascular Disease [CVD]	Vitamin E, Vitamin C, Coenzyme Q10, Polyphenols (for example, resveratrol)	Helps reduce oxidative stress in arteries, improves endothelial function
Alzheimer's Disease	Vitamin E, Alpha-lipoic acid, Curcumin, Coenzyme Q10	Antioxidants may slow cognitive decline
Parkinson's Disease	Coenzyme Q10, Vitamin E, Glutathione	Neuroprotective role through reducing free radical damage
Cancer	Selenium, Vitamin C, Flavonoids, Lycopene	Role in prevention; adjunct to chemotherapy (controversial in active disease)
Diabetes Mellitus	Alpha-lipoic acid, Vitamin C, Vitamin E	Reduces oxidative stress and improves insulin sensitivity
Chronic Kidney Disease [CKD]	N-acetylcysteine [NAC], Vitamin E, Vitamin C	Reduces oxidative damage in renal tissue
Liver Diseases (for example, NAFLD)	Vitamin E, Silymarin (milk thistle), Glutathione	Reduces liver inflammation and oxidative stress
Age-related Macular Degeneration [AMD]	Lutein, Zeaxanthin, Vitamin C, Vitamin E, Zinc	Slows progression of vision loss
Skin Aging/Photodamage	Vitamin C, Vitamin E, Polyphenols (for example, green tea extract), Glutathione	Used in creams and supplements to reduce damage from UV exposure

the right type, dose, and context—since indiscriminate use may disrupt normal redox signaling or even exert pro-oxidant effects (Liu et al., 2018).

Conclusion

In essence, oxygen is not inherently evil, but its darker side emerges when its balance is disturbed. While it sustains life, it also has the potential to cause harm when mismanaged.

This duality makes oxygen both fascinating and formidable — a true mischievous master of reactions. Therefore, the article concludes by emphasising the need for continued research and thoughtful application in clinical settings. Harnessing its power responsibly, developing strategies to counteract oxidative stress, and promoting awareness about its role in health and disease are crucial steps towards ensuring human welfare and advancing medical science.

REFERENCES

- CANFIELD, D.E., L. NGOMBI-PEMBA, E.U. HAMMARLUND, S. BENGTSON, M. CHAUSSIDON, F. GAUTHIER-LAFAYE ... AND A. EL ALBANI. 2013. Oxygen Dynamics in the Aftermath of the Great Oxidation of Earth's Atmosphere. *Proceedings of the National Academy of Sciences*. Vol. 110, No. 42. pp. 16736–16741.
- CHEN, G., Q. CHENG, T.W. LYONS, J. SHEN, F. AGTERBERG, N. HUANG AND M. ZHAO. 2022. Reconstructing Earth's Atmospheric Oxygenation History Using Machine Learning. *Nature Communications*. Vol. 13, No. 1. 5862. doi:10.1038/s41467-022-33388-5. PMID: 36195593; PMCID: PMC9532422.
- RAMOS-LARA, M. DE LA PAZ, H.J. DURAND-MANTEROLA AND S.A. CANALES-POZOS. 2021. The Low Latitude Aurora Borealis of 1789 from Mexico Records. *Advances in Space Research*. Vol. 68, No. 6. pp. 2320–2331.
- JOMOVA, K., R. RAPTOVA, S.Y. ALOMAR, S.H. ALWASEL, E. NEPOVIMOVA, K. KUCA AND M. VALKO. 2023. Reactive Oxygen Species, Toxicity, Oxidative Stress, and Antioxidants: Chronic Diseases and Aging. *Archives of Toxicology*. Vol. 97, No. 10. pp. 2499–2574. doi: 10.1007/s00204-023-03562-9. Epub 2023 Aug 19. PMID: 37597078; PMCID: PMC10475008.
- LIU, Z., Z. REN, J. ZHANG, C.C. CHUANG, E. KANDASWAMY, T. ZHOU AND L. ZUO. 2018. Role of ROS and Nutritional Antioxidants in Human Diseases. *Frontiers in Physiology*. Vol. 9. 360203.
- OLEJARZ, J., Y. IWASA, A.H. KNOLL AND M.A. NOWAK. 2021. The Great Oxygenation Event as a Consequence of Ecological Dynamics Modulated by Planetary Change. *Nature Communications*. Vol. 12, No. 1. pp. 3985.
- PIZZINO, G., N. IRRERA, M. CUCINOTTA, G. PALLIO, F. MANNINO, V. ARCORACI AND A. BITTO. 2017. Oxidative Stress: Harms and Benefits for Human Health. *Oxidative Medicine and Cellular Longevity*. 2017(1). 8416763.

- POLJSAK, B., D. ŠUPUT AND I. MILISAV. 2013. Achieving the Balance Between ROS and Antioxidants: When to Use the Synthetic Antioxidants. *Oxidative Medicine and Cellular Longevity*. 2013(1), 956792.
- SIES, H. AND D. P. JONES. 2020. Reactive Oxygen Species (ROS) as Pleiotropic Physiological Signalling Agents. *Nature Reviews Molecular Cell Biology*. Vol. 21, No. 7. pp. 363–383. doi: 10.1038/s41580-020-0230-3. Epub 2020 Mar 30. PMID: 32231263.
- TRAYHURN, P. 2019. Oxygen — A Critical, But Overlooked, Nutrient. *Frontiers in Nutrition*. Vol. 6. doi: 10.3389/fnut.2019.00010. PMID: 30809528; PMCID: PMC6379287.

MODIFICATION AND UPGRADATION OF BIOLOGY LABORATORY INTO BIOTECHNOLOGY LABORATORY AT SECONDARY STAGE PHASE II FOR THE ENHANCEMENT OF SKILL-BASED EDUCATION

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Education in science aims to develop an understanding of natural and physical phenomenon. It enables the student to establish scientific temperament, critical thinking, evidence-based learning and promotes research-based approaches.

Biotechnology is a part of Biology which is a crucial subject that plays an essential role in providing the medical and agricultural sustainability to the country. For learning and providing education in science, laboratories play a crucial role in experiential learning rather than rote learning. NEP 2020 and NCF-SE 2023 primarily focuses on reformation in education systems, which can provide experiential learning in schools to keep pace with increasing demand of skill and technology. This review paper aims to highlight the urgent need for modification and upgradation of biology laboratory into biotechnology laboratory at higher secondary stages in schools for providing effective learning in biotechnology.

Keywords: Modification and Upgradation, Laboratory, Biology, Biotechnology, Experiential Learning, Skill Enhancement

Introduction

Education plays a significant role in building a powerful nation as the future of the nation depends upon the educational status of younger minds. The education system has a long-term impact on the growth and development of the nation and its citizens.

Over the next decade, India will be having the highest population of younger people across the globe, and it is the nation's duty to provide high quality education and growth opportunities to them, which will determine the future of the country.

According to the National Curriculum Framework for School Education 2023, (NCF-SE 2023) learning in science helps us to acquire knowledge about the physical and natural world. Science education

includes systematic observation, questioning, formation and testing of hypothesis via designed set of experiments, result analysis, and the continuous revision of the knowledge. It promotes creativity, curiosity, evidence-based thinking and decision making which help in development of scientific temperament in a student.

Applied sciences such as physics, chemistry, mathematics and biology are the subjects which are required to utilise present scientific data to find different practical applications, inventions, and technology (Özyigit, 2020). Science education has a significant role in developing younger minds that can adapt to fast-growing and skill-seeking 21st century. For a nation to develop at its maximum, it should have better healthcare systems, pharmacy, agricultural sustainability, food industry, forestry, etc., (Bahaman et al., 2021)

and biology is an integral part of them. It is the science that deals with the events occurring in the body of the organisms, that is life processes, nutrition, and metabolism. It also includes interactions of an organism with its surrounding environment and effect on each other (Hamiet and Hatice, 2020). Biology has many branches namely zoology, botany, biotechnology, biochemistry, ecology, evolutionary biology, microbiology, genetics, molecular and structural biology, immunology, toxicology, virology, etc. (Aslan et al., 2020). Out of these, biotechnology is an emerging field which uses living organisms, such as plants, animals, microbes, or their parts to improve or develop various products in order to improve the quality of human life. Biotechnology has a diverse range of applications in day-to-day life such as fermentation of bread dough, production of curd and vinegar, production of leather, etc. (Samsulrizal et al., 2020). Recombinant DNA technology is a remarkable applied field of biotechnology which serves as a wider horizon in the sciences such as medicine, pharma industry, bio-pharma, agricultural sectors, thus providing an immense number of benefits to the society (Tomic et al., 2021).

Role of Biotechnology in Current Research Areas

With the outbreak of COVID-19 pandemic, biotechnology gained greater importance for its pivotal role in disease prevention and diagnostics. People are now aware about biotechnology with the development of vaccines for SARS-CoV-2. The field has helped in accelerated development and access of vaccines to the public for disease prevention. Awareness and promotion regarding biotechnology should be done at

the basic level i.e. at higher secondary stages for the development of science education in schools as biotechnology is not only limited to disease control and prevention, but it also plays a significant role in agricultural and pharmaceutical sectors as shown in Fig. 1 and discussed later in brief.

There are various applications of biotechnology such as formulation and development of new drugs, organs, and tissues, specific gene delivery vectors and gene therapy, edible vaccines, bioremediation and environmental cleaning tools, insect- and pest-resistant varieties of crops.

For the development of new varieties in plants and newer breeds in animals, the desired proteins which are not produced by the cell can be synthesised with the help of recombinant DNA technology or the specific gene encoding protein can also be incorporated into the cell with the help of vectors that are used in rDNA techniques. The genes of bacteria or any living organism

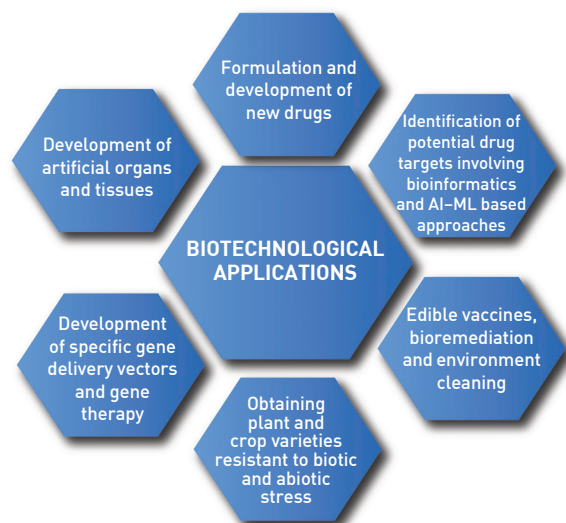


Fig. 1. Applications of biotechnology

can be manipulated in such a way that can help in increasing the fertility of soil, it can also serve as insecticide, biopharming and can even reduce pollution i.e. bioremediation. In recent years, in-silico approaches like identification of potential drug targets involving bioinformatics and AI-ML based approaches and their applications are making their way into research and development in the biotech and pharma sectors (Subramaniam et al., 2020).

Biotechnology is a growing field across the globe, as it has a wide range of applications in agriculture, medicine, environment, industry, engineering and it offers thousands of job prospects for young graduates. Biotechnology allows a student to learn better as it has practical and skill enhancement-based applications which would be beneficial for their career. NEP 2020 primarily focuses on the basic understanding of concepts via experiential learning and hands-on training methods rather than rote learning and learning for long subjective type exams. The younger generation is full of ideas and talents which can be utilised in research institutions and biotech industries.

The branches of biology being taught in schools and universities such as biology and life sciences, should be promoted at large scale, in terms of knowledge, skill development and finance. According to the data presented by the educational researchers (Tiwari et al., 2022), Fig. 2 depicts the market share of different sectors of biotechnology industries in India.

It shows that there are various job-related opportunities in the biology and biotechnology field like in Bio-informatics, Bio-industry, Bio-agricultural, Bio-pharmaceuticals and other related Bio-services which require a high skill-based expertise (Tiwari et al., 2022).

This study is a literature review which

discusses the urgent need for modification and upgradation of biology laboratories into biotechnology laboratories at higher secondary stages in schools for skill enhancement and to provide students a better and effective learning environment.

Introduction to Skill-based Education in the light of NEP 2020 and NCF-SE 2023

From the ancient period, India is well known for its Gurukul's and its disciplined way of imparting skill-based education to the students. The gurukul system placed a strong focus on practical skills and different subjects like science, medicine, mathematics and martial arts were taught. In the past decades post-independence, significant changes have been done in the Indian Education system. The first education policy was formed in 1968, then changes were made in 1986 and in 1992. The policies and patterns formed in 1992 have

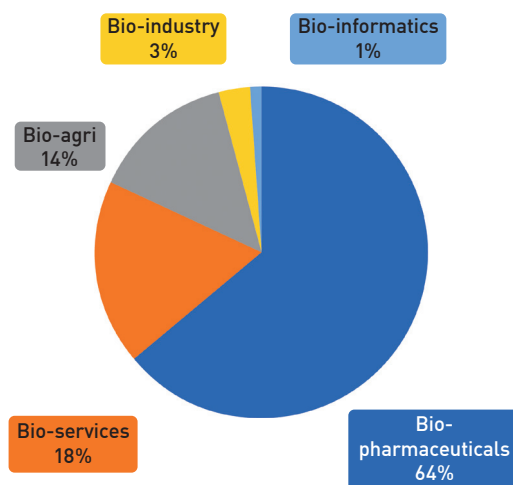


Fig. 2. Market share of different sectors of biotechnology industries

been followed by the educational institutions for the last 34 years till the formation of National Education Policy in 2020, also known as NEP 2020. It emphasises on the development of cognitive abilities such as critical thinking and problem solving leading to the holistic development of a student's mind. The students not only learn but they also understand how to learn. The fundamental principles of NEP 2020 include pedagogy, which is multidisciplinary, multilingualistic, flexible, holistic in nature, provides full equity and inclusion to all students, inculcates extensive use of technology and is learner-centric. It gives more emphasis on conceptual understanding and skill-based learning rather than rote learning. NEP 2020 has been formed with the efforts and suggestions of teachers, students, and other stakeholders from all over the country.

The Central Board of Secondary Education (CBSE) has designed the Skill Education Curriculum targeting students of Grades 9 and 10 with Life Sciences as a subject. According to CBSE, the life sciences sector is a key futuristic sector globally comprising of pharmaceutical, biotechnology and medical devices. The Indian life science sector has the world's 3rd largest hub for large MNCs and small companies which together comprise approximately 8,000 active companies and has shown a growth of 8 per cent over the last five years and this data will continue to have double digit growth projections for the next five years.

Fig. 3 highlights various opportunities in the life sciences sector listed by CBSE.

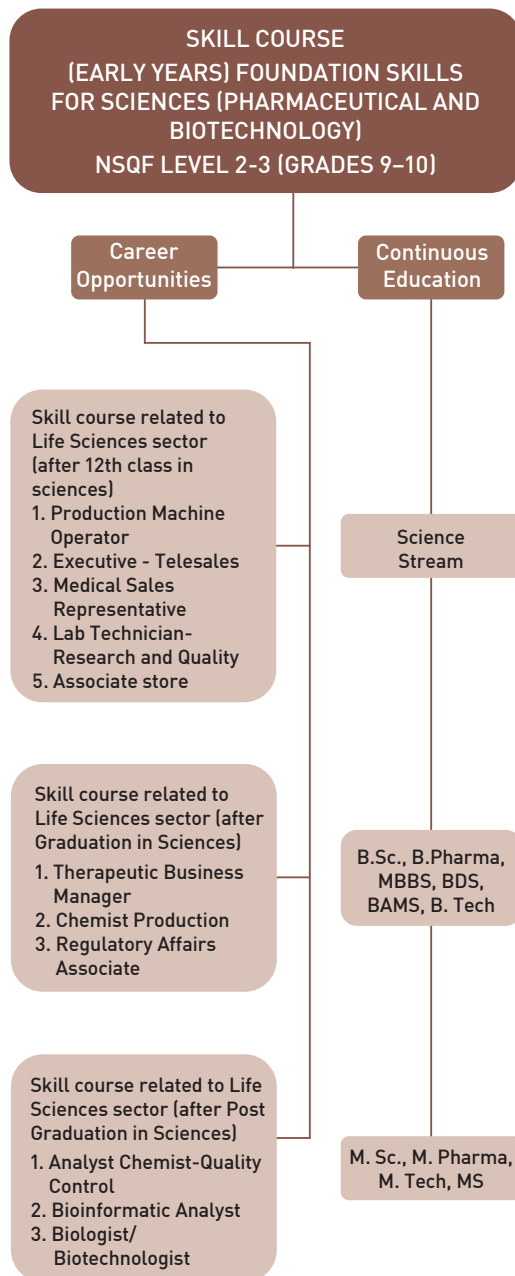


Fig. 3. Various opportunities in the life sciences sector listed by CBSE

Department of Skill Education Curriculum for Session 2023–24, CBSE

Foundation Skills for Sciences
(Pharmaceutical and Biotechnology)
(Subject Code-421) Grades 9 and 10

CBSE is playing a major role in generating awareness regarding career opportunities in the biology and related sectors. As this sector requires highly skilled employees, there is an urgent need for skill-based education right from the starting, i.e. at school level.

In addition, there is a current need to follow the NEP 2020 which majorly focuses on providing skill-based education, for better future of the nation.

Barriers to the Skill-based Education in Biology and Biotechnology

There are several barriers in providing skill-based education which are faced by students and teachers, as briefly discussed below.

- (i) **Lack of awareness and career guidance towards the field of research in science in the younger minds:** The students studying science in Grades 11 and 12 are only inclined towards medical and engineering fields, and not to the research field due to lack of career guidance. The students should be provided with proper career guidance sessions and opportunities to learn via skill-based laboratory techniques and applications. By learning via experimental and skill-based approaches the student get better exposure to research and skill-based career opportunities rather than opting only for medical and engineering-based career fields.

(ii) **Lack of exposure to scientific laboratory:**

HSC level students are less exposed to the laboratory due to the immense pressure and compulsion of subjective board examination. The students should be provided with better opportunities and time to learn various tools and techniques given in the books. This will not only help the students to grow basic laboratory skill, but also, they will get exposure to diverse career paths. They should be exposed to laboratory experiments, tools and techniques which are related to biotechnology for a better understanding of the concepts. Along with the experiment, the knowledge of practical application in industries and research should be provided to the students to increase the curiosity and scientific temperament among students.

- (iii) **Lack of funding and infrastructure:** For learning biotechnology at school level, the schools should have a well-equipped biology and biotechnology laboratory.

- (iv) **Lack of knowledge and expertise at higher secondary stages:** Proper guidance and training programmes for biotechnological experiments should be provided not only to the students but also to the biology teachers.

There is an urgent need to overcome all the barriers listed above in order to excel in the field of research.

Need for Modification and Upgradation of Biology Laboratory into Biotechnology Laboratory

Teaching biology as well as biotechnology, whether taking place in classroom or in

the laboratory, requires a multi-faceted environment for effective teaching which involves interaction and communication between teacher and students (Aslan et al., 2020). The necessary elements for creating an effective learning environment in the laboratory require well equipped instruments and tools. The use of various tools and techniques involved in learning experimental procedures and good laboratory practices is not only limited to the classroom, but it also gives a wider perspective to the learner or the student (Sayan and Mertoglu, 2020).

Laboratory plays an essential role in attaining the objectives designed by the curriculum and helps in the proper retention of these objectives for the students. Laboratories contribute to student's knowledge of science and enhance their skills in scientific thinking and teamwork, discussion, and hands-on experiential learning. Studies conducted for science education reveal that application in laboratory increases the achievements in science education, motivates students to pursue science and perform scientific experiments. To promote effective biology and biotechnology learning course materials, laboratories must be used in a smarter way.

Strategies to Overcome the Barriers

In the past decade the government has taken several initiatives for the promotion of learning of biology and biotechnology subjects like DBT Skill Vigyan Programme, DBT-Biotech Industrial Training Programme (BITP), Pradhan Mantri Kaushal Kendra (PMKK), Khorana Programmes for Scholars, DBT-TWAS Programme, etc. All these programmes are skill- and experimental-based programmes for higher educational

stages but not for school stages.

So, there is a need for introduction and exposure to well-equipped biotechnology laboratories at higher secondary stages. Students should be exposed to basic tools and techniques along with brief experimental procedures.

The basic tools and technologies that have been discussed in textbooks of Grades 11 and 12 are microscopy, centrifugation, electrophoresis, chromatography, spectroscopy, fluorescence in situ hybridisation (FISH), DNA sequencing, DNA microarray, enzyme linked Immunosorbent assay (ELISA), flow cytometry, etc. The topics such as genome engineering, gene cloning, bioprocessing, microbial, plant, animal, and organ culture, have been discussed briefly. The textbooks also comprise chapters on bioinformatics and structural biology which is again an emerging field of biology.

All tools and scientific equipment's cannot be introduced in biotechnology laboratories at higher secondary stages due to lack of funding and expertise, but a few can be equipped for an introductory level and basic understanding for school students. The basic scientific equipment's that can be kept in a biotechnology laboratory at higher secondary stages are pH meter device, water bath, microtome, incubator, oven, analytical balance, Light Microscope, hemocytometer, haemometer, weighing machine, centrifuge device, column chromatography apparatus, autoclave, laminar flow hood, Gel electrophoresis unit, gel visualiser, vortex mix, UV-Vis spectrophotometer, magnetic stirrer, water distillation unit, refrigerator to store chemicals, etc.

Some of the experiments or practical from the university level can be incorporated to school stages as well such as:

1. Genomic and Plasmid DNA isolation via gel electrophoresis.
2. Culturing bacteria on agar and LB media.
3. Isolation of chlorophyll and carotenoid pigments from spinach via column chromatography.
4. Microbiology: To carry out serial dilution, enumeration techniques for bacteria, handling cultures and isolating bacteria, gram staining, microscopy, good microbiology practices, etc.
5. Biochemistry: To study the effect of temperature and pH on enzyme activity, Protein quantification assays such as Bradford or Lowry method.
6. Hematology: Performing blood cell counts, measuring hematocrit and packed cell volume, determination of ABO and rhesus blood samples, etc.

The above listed experiments are the basic biology and biotechnology laboratory experiments that can be done even in the minimal availability of biology and biotechnology tools, equipment and reagents.

Basic knowledge related to another emerging field from biology is bioinformatics which can be learned through basic software and tools like BLAST, Clustal Omega, UniProt, etc. These are freely available on the internet and can be used by students for better understanding of in-silico approaches of the research field.

The knowledge of bioinformatics can be utilised for various purposes such as in gene therapy for rare diseases, in protein

structure prediction, genome and exome sequencing studies, evolutionary studies, drug discovery, agriculture and crop improvement technology. Basic study of bioinformatics at higher secondary stages should be given to the students to promote research-based approaches among students and can be easily taught by teachers as it does not require any well-equipped laboratory instruments and equipments. Students can also come up with their innovative ideas and can make an investigatory or research report for project submission.

Discussion

On proper exposure to the tools and techniques used in the field of biology and biotechnology, students will be able to understand basic scientific concepts and can acquire more scientific explanation to the phenomena occurring in nature—biochemical, anatomical, and morphological aspects of living organisms or when preserved as specimens. Hands-on training of these tools and techniques require little expertise but it will be beneficial for students in their undergraduate and postgraduate courses (Ministry of Education, 2020).

Incorporation of biotechnology at such a young stage will give a clear vision of this subject and its career scopes. Exceptionally bright students may also find any research problem and can come up with the ultimate solution to it, during their higher studies. The students can also take up certain research projects which can help them in entrepreneurship and novel innovation. Promotion of biotechnology and development and upgradation of biology and biotechnology laboratory combined with the subject knowledge at higher secondary stages will

help in creating awareness among the young minds towards the field of research and industrial applications.

Conclusion and Future Perspectives

It has been recommended that the classroom students value and understand the need for a scientific laboratory at schools through the gradual development of their ability to scientifically understand complex phenomenon tools and techniques, via hands-on training. Laboratories play an integral role in attaining the objectives specified by the curriculum and also help the students to develop their skills for critical thinking and behaviour, investigation, discussion and scientific research-based approach. Well-developed laboratory and laboratory experiments, tools, techniques,

and instruments are essential for the students to develop experiential learning. Developed laboratories can help the students to get minimal exposure of a biotech and pharma industries, and they can also learn the minimal skills for the same. Skill-based learning along with proper learning of application will also help the students to pursue higher studies. All these modifications are done in the curriculum according to the NEP 2020 and NCF-SE 2023 which highly support skill-based education, for better and effective learning. In the future, biology and biotechnology will play a frontline role in providing healthcare systems, agricultural sustainability and will generate several employment opportunities for the younger generation.

REFERENCES

- ASLAN, A., T.A. ENGIN, G. KURMANBEKOVA, F. KAYALAR, F. KAYALAR, Y. KARAGÖZ AND A. ENGIN. 2020. Standing of Biotechnology Subjects Found in Biology Courses of Higher Education and Profiling of Prospective Teachers for Their Interests on Biotechnology. *Frontiers in Life Sciences and Related Technologies*. Vol. 1, No. 2. pp. 51–57.
- BAHAMAN, A. H., R. A. WAHAB, A. A. ABDUL HAMID, K. B. ABD HALIM AND Y. KAYA. 2021. Molecular Docking and Molecular Dynamics Simulations Studies on β -glucosidase and xylanase *Trichoderma asperellum* to Predict Degradation Order of Cellulosic Components in Oil Palm Leaves for Nanocellulose Preparation. *Journal of Biomolecular Structure and Dynamics*. Vol. 39, No. 7. pp. 2628–2641.
- MINISTRY OF EDUCATION. 2020. *National Education Policy 2020*. Ministry of Human Resource Development, Government of India. https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf
- ÖZYIGIT, I. I. 2020. About Life Sciences and Related Technologies. *Frontiers in Life Sciences and Related Technologies*. Vol. 1, No. 1. pp. 1–11.
- SAMSULRIZAL, N. H., M. HAZUKI, N. S. A. AZMI, Z. S. M. SAID, N. A. WAHAB AND Z. RAMLI. 2020. Orthologous Revelation between *Elaeis Guineensis*, *Arabidopsis Thaliana* and *Solanum Lycopersicum*. *International Journal of Life Sciences and Biotechnology*. Vol. 3, No. 2. pp. 164–179.

- SAYAN, H. AND H. MERTOGLU. 2020. Equipment Use in Biology Teaching. *Journal of Educational Issues*. Vol. 6, No. 1. pp. 357–371.
- SAYAN, H. AND H. MERTOGLU. 2020. Investigation of the Opinions of Science Teachers About Homework. *Journal of Education and Learning*. Vol. 9, No. 2. 2020. DOI:10.5539/jel.v9n2p232.
- SUBRAMANIAM, Y., N. MAZLAN, H. HASSAN, J.N. JAAFAR, S.M. ANUA, T.T. YOUNG AND S.N.S. AL-HUMAIRI. 2020. Antimicrobial Activity of *Musa Acuminata Peel* Extract Against Gram-positive Bacteria. *International Journal of Life Sciences and Biotechnology*. Vol. 3, No. 2. pp. 191–196.
- TIWARI, K., G. SINGH, G. SINGH, S. K. SHARMA AND S. K. SINGH. 2022. Industrial Biotechnology: An Indian Perspective. *Journal of Applied Biology and Biotechnology*. Vol. 10, No. 5. pp. 22–33. DOI: 10.7324/JABB.2022.100503
- TOMIC, N., M. HADZIC, N. LOJO-KADRIC, J. RAMIC AND L. POJSKIC. 2021. Delphinidin, Luteolin and Halogenated Boroxine Modulate CAT Gene Expression in Cultured Lymphocytes. *International Journal of Life Sciences and Biotechnology*. Vol. 4, No. 1. pp. 25–32.

THE EFFECT OF DIFFERENTIATED CURRICULUM DESIGN ON ACADEMIC OUTCOMES FOR STUDENTS WITH MULTIPLE DISABILITIES AT PRIMARY LEVEL

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This study explains about the effect of differentiated curriculum design on academic performance of primary school students with multiple disabilities in government schools. Conducted over two months in two inclusive schools in Chennai, it involved ten students of Class 4 under the Samacheer Kalvi framework. Teacher trainees used strategies like simplifying content, using visual aids, hands-on activities, and personalised assessments to meet individual learning needs.

Data collection included pre- and post-assessments and classroom observations. The findings showed significant improvements in comprehension, retention, and participation. Qualitative data highlighted stronger teacher-student relationships and better peer collaboration. The study emphasises the effect of differentiated instruction in enhancing educational outcomes and the importance of training teachers in adaptive teaching methods.

Keywords: Differential Curriculum Design, Multiple Disabilities, Teaching Method, Universal Design for Learning

Introduction

Inclusive education advocates equal opportunities for all children including children with disabilities. It seeks to create ecological educational environment, accepts participation, engagement, and academic growth for every learner, irrespective of their disabilities. However, students with multiple disabilities often face significant challenges in traditional classrooms, where standard teaching methods and curriculum frameworks may not accommodate their unique learning needs. Sharma, Mehta and Gupta (2019) emphasise that curriculum modifications enhance engagement and retention among students with disabilities. These students may experience difficulties in accessing content, engaging with peers, and demonstrating their knowledge, leading

to disparities in academic performance and overall educational outcomes.

The Samacheer Kalvi curriculum framework in Tamil Nadu, India, emphasises inclusivity in primary education. However, for students with multiple disabilities, achieving meaningful inclusion requires targeted interventions and strategies to adapt the curriculum. Differentiated curriculum design involves modifying teaching practices, lesson content, learning materials, and assessments to identify the needs of the students with disabilities. Mittal and Ghosh (2021) highlight that teacher training significantly improves the implementation of inclusive teaching strategies. It emphasises use of simplified content, visual and tactile aids, hands-on learning experiences, and individualised instruction to bridge the learning gaps and

ensure that students can actively participate in the classroom. Singh and Mehta (2021) demonstrated that hands-on learning strategies improve student engagement and retention.

Teacher trainees play a vital role in implementing curriculum adaptations in teaching practice. They introduce innovative approaches in the classroom, adjusting their methods to accommodate the diverse learning styles of students with multiple disabilities. Through targeted interventions, teacher trainees help create an environment that fosters academic growth, boosts confidence, and enhances classroom engagement among these students. Kumar, Gupta and Reddy (2020) found that visual aids and tactile learning materials enhance academic performance in science and mathematics.

This study investigates the impact of differentiated curriculum design on the academic performance of Class 4 students with multiple disabilities in science, social science, and mathematics under the Samacheer Kalvi framework. Using an experimental approach, the study examines how simplifying lesson content, incorporating visual and tactile aids, implementing hands-on learning activities, and providing individualised instruction can improve learning outcomes.

Objectives of the Study

1. To assess the impact of differentiated curriculum design on the academic performance of students with multiple disabilities.
2. To evaluate engagement and participation during classroom activities.
3. To analyse the role of teacher trainees in implementing adaptive teaching practices.

Multiple Disabilities

Children with multiple disabilities face diverse challenges, including intellectual, physical, sensory, or behavioural impairments, requiring specialised support for effective learning. Differentiated curriculum design and Universal Design for Learning (UDL) play essential roles in creating inclusive classrooms, though they serve distinct purposes. Differentiated curriculum design focuses on modifying lesson content, instructional methods, and assessments based on individual student needs, ensuring personalised learning experiences through simplified content, multi-sensory teaching, and adaptive assessments. Meanwhile, UDL provides a structured framework that makes learning accessible to all students by integrating multiple means of engagement, representation, and expression. It ensures that teaching materials are flexible and inclusive from the outset, using varied instructional formats such as visuals, audio, hands-on activities, and assistive technologies. While differentiated instruction customises learning for individual students, UDL proactively removes barriers, making the curriculum accessible to everyone. Patel and Rao (2019) emphasise that adaptive assessments help students demonstrate their knowledge effectively through customised evaluation methods.

Inclusive Education: An educational approach where students with disabilities learn alongside their non-disabled peers in a mainstream setting with appropriate support and accommodations (Sharma, Mehta and Gupta, 2019).

Differentiated Curriculum Design: A flexible teaching framework that modifies content, process, and assessment to accommodate diverse learning needs (Johnson and Miller, 2018).

Multiple Disabilities: A condition where a student has two or more impairments (for example, intellectual, physical, sensory, or behavioural) that significantly impact their learning abilities (Wilson, Parker and Harris, 2016).

Universal Design for Learning (UDL): An educational framework that promotes flexible teaching methods, materials, and assessments to ensure that all students, regardless of their abilities or disabilities, have equal access to learning.

UDL Principles in Supporting Students with Multiple Disabilities

The Universal Design for Learning (UDL) is a research-based framework that provides a flexible approach to teaching by accommodating the variability of all learners. It is built around three core principles as discussed below.

1. Multiple means of engagement sustain interest and motivation by providing choices in how students participate. For example, use of sensory activities (for example, tactile or auditory stimuli)

to engage students with sensory impairments.

2. Multiple means of representation present information in varied formats to cater to different learning needs. For example, use of large-print materials, audio descriptions, or 3D models for students with visual or cognitive impairments.
3. Multiple means of action and expression allow students to demonstrate knowledge in diverse ways. For example, letting students use verbal responses, tactile tools, or assistive devices to complete assessments.

Differentiated Curriculum Design

Differentiated curriculum design for children with multiple disabilities involves modifying educational content, teaching strategies, and classroom environments to meet their unique needs. Key strategies of Differentiated Curriculum Design include:

- Multisensory materials
- Assistive technologies
- Differentiated instruction
- Development of social-emotional learning

By breaking down tasks into manageable steps and creating accessible learning spaces, educators can ensure active participation and meaningful learning for all students. Such adaptations not only support children with multiple disabilities but also promote inclusivity, understanding, and growth in the entire classroom community. Fernandez, Jacob and Matthews (2022) highlight that positive teacher-student relationships boost motivation, participation, and academic success.

Purpose of the Study

This study explains about how modified curriculum improves academic performance, motivation, and attendance of students with multiple disabilities in inclusive classrooms. It evaluates flexible teaching methods to enhance teacher training and curriculum reform for better inclusivity.

Methodology

Study Design

The study utilised an experimental design with pre- and post-intervention assessments to evaluate the academic performance of students with multiple disabilities at primary level.

Sample

Participants: The sample comprised (Table 1) 10 students with multiple disabilities, five from each of two government schools in Chennai.

Table 1: Description of Sample

Student	Disabilities
Student 1	Visual and cognitive
Student 2	Hearing and physical
Student 3	Cognitive and speech
Student 4	Visual and physical
Student 5	Sensory and cognitive
Student 6	Autism and hearing
Student 7	Physical and cognitive
Student 8	Speech and sensory
Student 9	Hearing and cognitive
Student 10	Physical impairment with associated condition

Class Level: 4 Standard

- Subjects: Science (My Body Awareness), Social Science (Our India), and Mathematics (Numbers Concepts).
- Grouping: Students were categorised into high, middle, and low performers based on their pre-test scores.

Intervention

Teacher trainees implemented the intervention (Table 2) using differential curriculum adaptation strategies designed to address the unique learning needs of students with multiple disabilities.

The lesson plan incorporates Science ("My Body Awareness"), Social Science ("Our India"), and Mathematics ("Numbers Concepts") while applying Universal Design for Learning (UDL) principles to support students with multiple disabilities (Table 2). It focuses on engagement, accessibility, and inclusivity by using multi-sensory teaching methods, adaptive assessments, and differentiated instruction. However, while the subjects are taught simultaneously, they remain parallel rather than fully interdisciplinary, as they lack a unifying theme that connects concepts across disciplines for deeper learning integration.

Lesson Plan and Concepts

1. Science (Class 4, Term 1)

Lesson: My Body Awareness

Concepts

- Structure and function of human body parts (for example, eyes, ears, nose, skin)
- Importance of sense organs

Table 2: Intervention Plan for Students with Multiple Disabilities

Category	Details
Implementation Duration	2 months (3 classes per week)
Target Group	Class 4 students with multiple disabilities in an inclusive classroom
Purpose	To enhance academic performance, engagement, and retention through differentiated curriculum strategies aligned with Universal Design for Learning (UDL)
Key Strategies	• Simplified Content: Breaking down lessons into smaller, manageable units. • Multi-sensory Learning: Using visual, tactile, and auditory aids to support different learning needs. • Hands-on Activities: Engaging students through interactive and experiential learning methods. • Adaptive Assessments: Allowing students to demonstrate knowledge in multiple formats (verbal, practical, and using assistive tools). • Individualised Support: Providing personalised instruction and scaffolding based on student needs.
Subjects Covered	Science, Social Science, and Mathematics
Assessment Methods	• Pre- and Post-Tests to evaluate learning improvement. • Classroom Observations to assess student engagement and participation. • Practical Evaluations using hands-on activities to gauge concept understanding.
Expected Outcomes	• Improved comprehension and retention of subject matter. • Increased engagement and participation in learning activities. • Development of confidence and social interaction through peer-supported activities. • Strengthened teacher-student relationships for better academic support.
Implementation Team	Teacher trainees under the supervision of experienced educators
Instructional Tools and Materials	• Science: 3D models, sensory-based materials, and interactive charts. • Social Science: Tactile maps, flashcards, and digital learning tools. • Mathematics: Manipulatives, number blocks, and tactile number cards. • Assistive Technologies: Alternative Augmentative Communication (AAC) devices, large-print materials, and text-to-speech tools.

- Introduction to the skeletal system
- Maintaining hygiene and health

2. Social Science (Class 4, Term 1)

Lesson: Our India

Concepts

- Physical features of India (mountains, plains, plateaus, rivers)
- States and Union Territories of India
- National symbols (flag, emblem, animal, bird, etc.)

3. Mathematics (Class 4, Term 1)

Lesson: Numbers Concepts

Concepts

- Place value and face value (up to 6 digits)
- Comparing and ordering numbers
- Rounding numbers to the nearest 10, 100, and 1000

This study implemented a range of differentiated teaching strategies and methods to meet the unique learning needs of students with multiple disabilities, in alignment with Universal Design for Learning (UDL) principles. The strategies aimed to simplify content, enhance engagement, and provide flexible assessment methods to ensure inclusivity and accessibility.

Teaching strategies and methods included:

1. Simplified and Structured Content

- Lessons were simplified by breaking down complex concepts into smaller, manageable parts.
- Visual aids such as charts, images, and flashcards were used to present information clearly.
- For example, in Science, body parts were introduced using interactive models and

songs, while in Mathematics, number concepts were simplified with the help of counting blocks.

2. Multi-sensory Teaching Approaches

- Teaching strategies incorporated visual, tactile, and auditory stimuli to enhance learning.
- Tactile materials like 3D models, textured objects, and sensory activities were used.
- In Social Science, tactile maps helped students identify geographical features, while sensory activities, such as touching different textures, were used to reinforce concepts in Science.

3. Use of Assistive Technologies

- Technologies such as text-to-speech software were used to assist students with reading difficulties.
- Communication boards were provided to help non-verbal students express their understanding.

4. Flexible Assessment Methods

- Assessments were adapted to accommodate diverse learning needs.
- Students were allowed to respond through oral explanations, practical demonstrations, or by creating visual portfolios.
- For example, in Mathematics, students demonstrated their understanding of place value using manipulatives like number blocks.

5. Peer-assisted Learning

- Strategies such as buddy systems and group activities were introduced to promote social interaction and collaborative learning.

- Students were paired to work together on tasks like matching body parts in Science or solving simple math problems.

6. Sensory-friendly Classroom Adaptations

- The classroom environment was adapted to support students with sensory sensitivities.
- Quiet zones were created for students who required a calm space, and sensory tools like stress balls and textured materials were provided to enhance focus and engagement.

7. Regular Feedback and Positive Reinforcement

- Continuous feedback was provided to guide student learning.
- Positive reinforcement strategies, such as praise, rewards, and recognition, were used to motivate students and encourage participation.

These differentiated teaching strategies and methods contributed to improved academic performance, engagement, and participation

among students with multiple disabilities. The flexible and inclusive approach ensured that students could access learning content, express their understanding, and actively participate in the learning process.

Data Collection

Pre- and post-test scores were recorded to assess academic performance levels categorised into High, Middle, and Low for each subject. Classroom observations captured student engagement, participation, and teacher-student interactions.

Hypothesis

The implementation of differentiated curriculum design strategies significantly improves the academic performance of students with multiple disabilities in Science, Social Science, and Mathematics in Lesson 1.

Results and Findings

Table 3: Pre-test and Post-test Scores for Science, Social Science and Mathematics

S. No.	Sample	Science (Pre-test)	Science (Post-test)	Social Science (Pre-test)	Social Science (Post-test)	Mathematics (Pre-test)	Mathematics (Post-test)
1	Student 1	35	48	36	46	38	47
2	Student 2	30	44	32	45	34	44
3	Student 3	20	32	18	30	16	28
4	Student 4	15	28	15	27	14	25
5	Student 5	25	40	22	38	20	35
6	Student 6	40	50	40	50	42	50
7	Student 7	38	49	39	48	40	50
8	Student 8	18	30	20	33	18	30
9	Student 9	22	35	25	37	24	38
10	Student 10	28	42	30	43	30	43
Total Average		27.1	39.8	27.7	39.7	27.6	39.0

Table 4: Overall Performance across Subjects

Subject	Pre-test Average	Post-test Average	Improvement (Marks)	Improvement (%)
Science	27.1	39.8	+12.7	46.8
Social Science	27.7	39.7	+12	43.3
Mathematics	27.6	39.0	+11.4	41.3

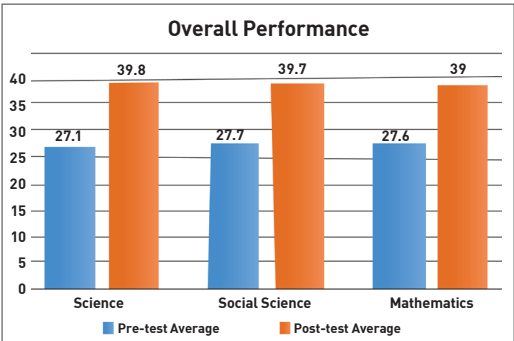


Fig. 1. Overall performance of pre- and post-test scoring for subjects (Science, Social Science, Mathematics)

Interpretation

1. Science

- Pre-test average: 27.1
- Post-test average: 39.8
- Improvement: +12.7 marks (46.8% increase)

The highest improvement was observed in Science, reflecting the success of hands-on or visually driven strategies (Table 4).

2. Social Science

- Pre-test average: 27.7
- Post-test average: 39.7
- Improvement: +12 marks (43.3% increase)

Contextual learning methods and practical examples contributed to the improved understanding. (Table 4)

3. Mathematics

- Pre-test average: 27.6
- Post-test average: 39.0
- Improvement: +11.4 marks (41.3% increase)

Visual aids and practical problem-solving techniques proved effective in improving numeracy skills. (Table 4)

The consistent improvement across all subjects highlights the effectiveness of differentiated curriculum design strategies in addressing the learning needs of students with multiple disabilities.

The improvement across all three subjects highlights the consistent effectiveness of the intervention strategies applied during Lesson 1.

The results in Tables 3 and 4 clearly demonstrate that the implementation of differentiated curriculum design strategies significantly enhanced the academic performance of students with multiple disabilities. The consistent improvement across Science, Social Science, and Mathematics suggests that these strategies effectively addressed the learning needs of these students.

- Science showed the highest improvement (46.8%), reflecting the success of hands-on or visually driven strategies. (Table 4)
- Social Science (43.3%) and Mathematics (41.3%) also exhibited substantial gains, suggesting that personalised teaching methods like contextual learning and practical examples contributed to these outcomes. (Table 4)

The findings emphasise the importance of inclusive practices in creating equitable learning opportunities for all students, enabling them to achieve better academic outcomes and fostering a sense of accomplishment. Wilson, Parker and Harris (2016) found that simplified lesson content reduces cognitive load and enhances learning outcomes.

Overall Performance

The data highlights the efficacy of the inclusive differentiated curriculum design strategies in enhancing the learning outcomes of students with multiple disabilities across core subjects. The consistent improvement in all three subjects demonstrates the adaptability and effectiveness of the approach, fostering better engagement and comprehension among the students. Gupta, Jain and Verma (2017) assert that peer collaboration fosters social interaction and academic growth among students with disabilities.

Recommendations

Continued Implementation of Inclusive Strategies

Schools should continue to adopt and refine differentiated curriculum design strategies to cater to diverse learning needs.

Subject-specific Adaptations

Personalised approaches for Science, Social Science, and Mathematics should be further developed to address unique learning challenges.

Teacher Training

Regular training sessions should be conducted for teachers on inclusive teaching methods and differentiated instruction. According to Johnson and Miller (2018), individualised instruction improves comprehension, builds confidence, and increases classroom participation.

Monitoring and Feedback

Establish a structured system for ongoing monitoring and feedback to track student progress and refine instructional strategies.

Resource Allocation

Provide sufficient resources, including assistive technologies, teaching aids, and support staff.

Conclusion

This study highlights the significant benefits of differentiated curriculum design in enhancing the academic performance of students with multiple disabilities Table 4, Fig. 1. Notable improvements were observed, including a 46.8 per cent increase in Science, 43.3 per cent in Social Science, and 41.3 per cent in Mathematics as shown in Fig. 1, demonstrating the effectiveness of these methods in promoting better comprehension and engagement.

The findings emphasise that adopting inclusive educational strategies can help create fair learning environments where

students of all abilities can reach their full academic potential. The study advocates for integrating differentiated curriculum designs as a key element of educational

systems globally. Thomas and Samuel (2020) state that using manipulates and real-life applications enhances understanding of mathematical concepts.

REFERENCES

- ADAMS, M. AND S. BROWN. 2018. Curriculum Differentiation for Learning Disabilities. *Educational Research Quarterly*. Vol. 19, No. 3. pp. 40–55.
- BANERJEE, A. AND S. PAUL. 2020. Modifying Curriculums for Students with Disabilities. *Special Education Today*. Vol. 7, No. 2. pp. 67–89.
- FERNANDEZ, R., P. JACOB AND K. MATTHEWS. 2022. Teacher-Student Relationships in Inclusive Education. *Journal of Educational Psychology*. Vol. 19, No. 1. pp. 10–25.
- GREEN, R. AND J. FOSTER. 2017. Visual Learning Strategies in Special Education. *Journal of Inclusive Practices*. Vol. 10, No. 2. pp. 54–68.
- GUPTA, A., S. JAIN AND K. VERMA. 2017. Peer Collaboration in Inclusive Classrooms. *Asian Journal of Special Education*. Vol. 5, No. 1. pp. 30–45.
- HARRIS, K. AND P. VINCENT. 2021. Building Peer Interaction in Inclusive Classrooms. *Contemporary Pedagogy*. Vol. 13, No. 1. pp. 89–104.
- JOHNSON, B. AND T. CARTWRIGHT. 2019. Role of Inclusive Education in Student Confidence. *Learning for All*. Vol. 23, No. 4. pp. 12–27.
- JOHNSON, T. AND R. MILLER. 2018. Individualized Instruction for Students with Disabilities. *Disability Studies Journal*. Vol. 12, No. 2. pp. 145–160.
- KUMAR, V., S. GUPTA AND A. REDDY. 2020. Impact of Visual Aids on Learning Outcomes. *International Journal of Learning Disabilities Research*. Vol. 10, No. 4. pp. 210–225.
- LEWIS, H. AND R. SCOTT. 2020. Collaborative Learning in Inclusive Settings. *International Journal of Special Needs Education*. Vol. 8, No. 3. pp. 35–50.
- MARTIN, A. AND L. DANIELS. 2018. Adaptive Curriculum Strategies for Inclusive Learning. *Innovations in Education*. Vol. 15, No. 3. pp. 33–50.
- MITTAL, S. AND P. GHOSH. 2021. Role of Teacher Training in Inclusive Education. *Education for All Quarterly*. Vol. 18, No. 1. pp. 25–38.
- PATEL, K. AND D. RAO. 2019. Assessing the Impact of Adaptive Assessments. *Journal of Assessment and Inclusion*. Vol. 14, No. 3. pp. 80–95.

- SHARMA, P., A. MEHTA AND R. GUPTA. 2019. Inclusive Education Practices in Primary Schools. *Journal of Inclusive Pedagogy*. Vol. 15, No. 3. pp. 45–59.
- SINGH, N. AND P. MEHTA. 2021. Hands-on Learning in Inclusive Classrooms. *Global Perspectives in Education*. Vol. 9, No. 2. pp. 101–116.
- SMITH, C. AND V. PATEL. 2019. The Role of Assistive Technology in Inclusive Classrooms. *Technology for Inclusion*. Vol. 12, No. 4. pp. 72–90.
- TAYLOR, K. AND P. ROBERTS. 2022. Inclusive Curriculum Design: Lessons from Practice. *Journal of Global Education Practices*. Vol. 17, No. 1. pp. 15–35.
- THOMAS, R. AND L. SAMUEL. 2020. Inclusive Strategies in Mathematics Education. *Mathematics for All Journal*. Vol. 22, No. 3. pp. 67–82.
- WALKER, J. AND N. THOMAS. 2021. Strategies for Mathematics Inclusion. *Mathematics Education Quarterly*. Vol. 22, No. 4. pp. 45–65.
- WILSON, J., L. PARKER AND M. HARRIS. 2016. The Role of Simplified Content in Inclusive Education. *Inclusive Pedagogy Studies*. Vol. 8, No. 4. pp. 55–70.



Can We Live on Our Planet Without Destroying It?

Date: 13 November 2024

Source: University of Groningen

With eight billion people, we use a lot of the Earth's resources in ways that are likely unsustainable. Klaus Hubacek, Professor of Science, Technology and Society at the University of Groningen, the Netherlands, takes stock of the situation. How much land, water, and other resources does our lifestyle require? And how can we adapt this lifestyle to stay within the limits of what the Earth can give? It is possible, Hubacek shows, but it will require policies based on scientific evidence.

Our consumption patterns affect the environment, that much we know. A clear example is the concentration of carbon dioxide in the atmosphere. It has been rising at an increasingly faster rate since the 1960s, resulting in global warming, along with all its dire consequences. There is a limit to the amount of consumption the Earth can support, and in 2009, scientists defined nine

'planetary boundaries' as indicators of when we have reached that limit. Crossing them may lead to irreversible damage to the Earth's stability and resilience. These planetary boundaries include indicators such as ocean acidification and the global use of fresh water. In 2023, six of these planetary boundaries had already been crossed.

Hubacek has devoted his academic career to studying how humanity is performing in terms of these planetary boundaries, and what . needs to change to prevent us from crossing them even further. According to him, 'the basic calculation is: given a certain number of people on the planet and the planetary boundaries, how much can we consume to stay inside these limits?'.

The divide between rich and poor

At the moment, the richest one per cent of the world's population produces 50 times more greenhouse gases than the four billion people in the bottom 50 per cent. The divide between the rich and the poor on this planet is a common thread in Hubacek's work. He is one of the authors of a paper, published

in the journal *Nature* on 13 November, that describes this issue. Using an extensive dataset covering up to 201 consumption groups across 168 countries, the paper analyses the impact of spending patterns on six key environmental indicators.

The analysis reveals how different consumer behaviours contribute to planetary transgressions, and concludes that if the world's top 20 per cent of consumers shifted their consumption habits toward more sustainable patterns found within their group, they could reduce their environmental impact by 25 to 53 per cent. The study also shows that changing consumption patterns in just the food and services sectors could help bring critical planetary boundaries back within safe limits.

Changing our lifestyle to stay within the boundaries

In previous papers, Hubacek researched specific solutions that could help us balance our lives to better deal with the planetary boundaries. In a study published last August, he showed that if a diet with less red meat and more legumes and nuts was adopted by the richest part of the world, food-driven emissions would fall by 17 per cent, even when the inhabitants of poorer nations increase their meat consumption.

And just last month, Hubacek co-authored a paper describing how the livestock sector is dangerously transgressing several of the planetary boundaries. The paper argues that any measures to counter this negative effect should be 'region-specific': 'Obviously, there will be differences. A plant-based diet is not suitable for traditional Mongolian nomads, who depend on yaks and their milk.'

Hubacek keeps pointing to solutions when he identifies transgressions of planetary boundaries. 'However, we shouldn't focus so much on creating new technical solutions, as there are already so many solutions which we don't implement,' he argues. 'And most governments subsidise bad behaviour.' For example, subsidies for fossil fuels globally are overcompensating for the mitigation effect that we achieve through carbon pricing, such as carbon taxes and carbon trading schemes. 'And there are also many inconsistent policies, such as stimulating the use of heat pumps and, at the same time, raising the price of the electricity they use.'

It is possible

What Hubacek shows is that not all hope is lost: humanity can stay within the planetary boundaries. But it seems that there is little political will to tackle issues such as climate change. Hubacek: 'This worries me. And it causes real fear in the younger generation.' Hubacek underlines that his science is not activism-driven. 'I'm doing this work first and foremost because of my academic interest. But I also don't want to waste my time on something that is meaningless. What we need are evidence-based policies.'

Researchers Examine the Persistence of Invisible Plastic Pollution

Date: 17 October 2024

Source: Rutgers University

Plastic pollution — tiny bits of plastic, smaller than a grain of sand — is everywhere, a fact of life that applies even to newborn rodents, according to a Rutgers Health study

published in the journal *Science of the Total Environment*.

Researchers have long understood that micro- and nanoplastic particles (MNPs), which enter the environment through oxidation and natural degradation of consumer products, are easily deposited in the human body through inhalation, absorption and diet. Experts also understand that these pollutants can cross the placental barrier and deposit in fetal tissues.

What's been unclear is whether these particles remained in tissue long after birth. The Rutgers Health researchers found that they do, at least in rats. Their data that could have implications for human health.

"Nobody wants plastic in their liver," said Phoebe A. Stapleton, an associate professor of pharmacology and toxicology at the Rutgers Ernest Mario School of Pharmacy, and the study's senior author. "Now that we know it's there — as well as in other organs — the next step is to understand why and what that means."

To assess the persistence of micro- and nanoplastic particles in neonatal tissue following maternal exposure, Stapleton and colleagues exposed six rats to aerosolised food-grade plastic powder for 10 days during pregnancy. Rodents are good test subjects for this type of study, Stapleton said, because humans and rodents both possess a hemochorial placenta, meaning that maternal and fetal blood don't come into direct contact during circulation. Two weeks after birth, two newborn rats — one male and one female were tested for micro- and nanoplastic exposure. In both cases, the same type of plastic that the mothers inhaled during pregnancy were found in the offspring's

lung, liver, kidney, heart and brain tissue. No plastics were found in a control group.

Stapleton said the findings are one more piece of evidence illustrating the potential dangers of micro- and nanoplastics in the environment. "These results raise concerns for the toxicological impacts associated with MNPs exposure, maternal-fetal health, and systemic MNPs particle deposition," the researchers wrote.

Micro- and nanoplastics are a ubiquitous pollutant, and have been detected in food, farmland, seawater and snow. Plastics have even been found in the world's deepest oceans and highest mountains. These invisible pollutants are potentially hazardous to human health. An increasing body of evidence suggests a strong correlation between micro- and nanoplastic particles and cancer, inflammation, impaired immune function, tissue degeneration and cardiovascular problems.

Stapleton said she hopes her findings help create a sense of urgency among policymakers to make more funding available for research. "Without answers we can't have policy change," she said.

Eventually, the persistence of these materials in human tissue could lead to greater regulation, Stapleton said. While plastics have undoubtedly improved consumer products, too little is known about their long-term health impacts. As researchers fill knowledge gaps, regulators will be better equipped to protect public health, she said. "I don't think we'll ever get rid of plastics altogether," she said. "They're too important for modern life. But I do think we might get to a point where we'll have some policies to indicate which ones are less toxic than others."

Research Shows Solitude is Better for Your Health When It's Not Too Intense

Date: 17 December 2024

Source: Oregon State University

Hiking by yourself deep in a forest and similar episodes of intense solitude are not as likely to restore energy and enhance social connectedness as less complete forms of solitude, such as reading in a café or listening to Spotify while commuting, research by Oregon State University suggests.

The findings are important because of solitude's role in building connectedness, a key factor in a person's overall health picture. According to the U.S. Centre for Disease Control and Prevention, strong social ties are linked with a longer lifespan, better mental health and a lower risk of serious illness, including heart disease, stroke and dementia.

Morgan Quinn Ross, assistant professor of communication in the OSU College of Liberal Arts, and Scott Campbell of the Ohio State University surveyed nearly 900 adults in the United States and found that activities that provide less complete forms of solitude, like playing a game on your phone or going to a movie by yourself, offer some advantages over a solitary drive in the desert or writing in a secluded cabin. "We learned that less complete solitude is more likely to restore energy and maintain a feeling of connection with others," Ross said. "In a world where social interaction is almost always just a click away, we need to understand how to balance social interaction with different types of solitude."

Ross and Campbell examined conditions under which an individual's solitude might be "shaded" by people and/or technology; accessibility to others and engagement with media can shade the solitude experience by causing time alone to be more social in nature, they note.

The researchers built a matrix of solitude that includes a base level — no interaction with people — and a total level, which refers to being inaccessible to others and not engaging with media. The matrix allowed them to investigate the tradeoff of solitude — i.e., does experiencing it more completely maximise restoration, while experiencing it less completely maximises relatedness?

Ross notes that a commonly held theory, Communicate Bond Belong, posits that social interaction can build relatedness with others at the expense of social energy, and that solitude can restore social energy but at the cost of relatedness. Social energy describes a person's capacity for social interaction and can be thought of as a battery that can be fully charged, partially charged or drained.

"Our study suggests that solitude is in fact not the flipside of social interaction," Ross said. "Whereas more intense social interaction yields connection but depletes energy, more intense solitude depletes both energy and connection. Solitude does not seem to function simply as a way to regain energy used in social interaction."

The scientists also learned that solitude was less detrimental to well-being for individuals who thought it helped them restore energy and maintain connection, regardless of how much energy their social interactions cost them. Interestingly, these findings typically hold for both extroverts and introverts,

said Ross, who added that one suggestion based on the study that people might try is attempting to seek solitude only when constructively motivated to do so.

"If you have a positive attitude toward solitude — because you use it to restore energy and know that you will be able to connect with people later — then choosing solitude will probably make you feel better," he said. "But if you choose solitude because of a negative attitude toward social interaction — because you don't want to talk to people — it will probably make you feel worse."

A Fossil First: Scientists Find 1.5-million-year-old Footprints of Two Different Species of Human Ancestors at Same Spot

Date: 29 November 2024

Source: Rutgers University

More than a million years ago, on a hot savannah teeming with wildlife near the shore of what would someday become Lake Turkana in Kenya, two completely different species of hominins may have passed each other as they scavenged for food. Scientists know this because they have examined 1.5-million-year-old fossils they unearthed and have concluded they represent the first example of two sets of hominin footprints made about the same time on an ancient lake shore. The discovery will provide more insight into human evolution and how species cooperated and competed with one another, the scientists said.

"Hominin" is a newer term that describes a subdivision of the larger category known as

hominids. Hominins includes all organisms, extinct and alive, considered to be within the human lineage that emerged after the split from the ancestors of the great apes. This is believed to have occurred about 6 million to 7 million years ago.

The discovery, published today in science offers hard proof that different hominin species lived contemporaneously in time and space, overlapping as they evaded predators and weathered the challenges of safely securing food in the ancient African landscape. Hominins belonging to the species *Homo erectus* and *Paranthropus boisei*, the two most common living human species of the Pleistocene Epoch, made the tracks, the researchers said.

"Their presence on the same surface, made closely together in time, places the two species at the lake margin, using the same habitat," said Craig Feibel, an author of the study and a professor in the Department of Earth and Planetary Sciences and Department of Anthropology in the Rutgers School of Arts and Sciences.

Feibel, who has conducted research since 1981 in that area of northern Kenya, a rich fossil site, applied his expertise in stratigraphy and dating to demonstrate the geological antiquity of the fossils at 1.5 million years ago. He also interpreted the depositional setting of the footprint surface, narrowing down the passage of the track makers to a few hours, and showing they were formed at the very spot of soft sediments where they were found. If the hominins didn't cross paths, they traversed the shore within hours of each other, Feibel said. While skeletal fossils have long provided the primary evidence for studying human evolution, new data from

fossil footprints are revealing fascinating details about the evolution of human anatomy and locomotion, and giving further clues about ancient human behaviours and environments, according to Kevin Hatala, the study's first author, and an associate professor of biology at Chatham University in Pittsburgh, Pennsylvania.

"Fossil footprints are exciting because they provide vivid snapshots that bring our fossil relatives to life," said Hatala, who has been investigating hominin footprints since 2012. "With these kinds of data, we can see how living individuals, millions of years ago, were moving around their environments and potentially interacting with each other, or even with other animals. That's something that we can't really get from bones or stone tools."

Hatala, an expert in foot anatomy, found the species' footprints reflected different patterns of anatomy and locomotion. He and several co-authors distinguished one set of footprints from another using new methods they recently developed to enable them to conduct a 3D analysis.

"In biological anthropology, we're always interested in finding new ways to extract behaviour from the fossil record, and this is a great example," said Rebecca Ferrell, a programme director at the National Science Foundation who helped fund this portion of the research. "The team used cutting-edge 3D imaging technologies to create an entirely new way to look at footprints, which helps us understand human evolution and the roles of cooperation and competition in shaping our evolutionary journey."

Feibel described the discovery as "a bit of serendipity." The researchers

uncovered the fossil footprints in 2021 when a team organised by Louise Leakey, a third-generation palaeontologist who is the granddaughter of Louis Leakey and daughter of Richard Leakey, discovered fossil bones at the site.

The field team, led by Cyprian Nyete, mainly consists of a group of highly trained Kenyans who live locally and scour the landscape after heavy rains. They noticed fossils on the surface and were excavating to try and find the source. While cleaning the top layer of a bed, Richard Loki, one of the excavators, noticed some giant bird tracks, then spotted the first hominin footprint. Leakey coordinated a team in response that excavated the footprint surface in July 2022. Feibel noted it has long been hypothesised that these fossil human species coexisted. According to fossil records, *Homo erectus*, a direct ancestor of humans, persisted for 1 million years more. *Paranthropus boisei*, however, went extinct within the next few hundred thousand years. Scientists don't know why.

Both species possessed upright postures, bipedalism and were highly agile. Little is yet known about how these coexisting species interacted, both culturally and reproductively.

The footprints are significant, Feibel said, because they fall into the category of "trace fossils" — which can include footprints, nests and burrows. Trace fossils are not part of an organism but offer evidence of behaviour. Body fossils, such as bones and teeth, are evidence of past life, but are easily moved by water or a predator.

Trace fossils cannot be moved, Feibel said. "This proves beyond any question that not only one, but two different hominins were walking on the same surface, literally within

hours of each other," Feibel said. "The idea that they lived contemporaneously may not be a surprise. But this is the first time demonstrating it. I think that's really huge."

New Study Challenges Social Media's Mental Health Impact

Date: 7 November 2024

Source: Curtin University

A new Curtin University study has challenged the perception heavy social media use has a significant impact on mental health, finding little to no relationship between the two. In fact, not only does the research indicate the amount of time spent on social media has a negligible effect on mental health indicators such as depression, anxiety and stress — the result isn't always negative, either.

Study lead and PhD candidate Chloe Jones said it was important to stress the findings don't suggest social media use is harmless or has no impact on mental health, however the relationship between the two likely has many complex layers. "For example, a connection to a supportive online community could be a lifeline for people living in isolation, but hours of scrolling Instagram influencers could be really unhelpful if you have body image concerns," Jones said.

While most previous studies on social media use have relied on self-reported estimates from participants, researchers from the Curtin School of Population Health collected mobile phone data from more than 400 people ranging from 17–53 years old, to accurately measure how much time they spent on social media in the past week.

The team then compared the usage data against the participants' levels of depression, anxiety, stress and attentional control. They found social media use was very weakly associated with anxiety and not associated with depression or stress. It was also found to have a weak positive association with attentional control, suggesting increased social media use is linked with slightly better performance in maintaining attention. "If we are going to make well-informed decisions in this space, it needs to be based on quality data and our research demonstrates when you objectively measure time spent on social media, the effects are tiny or non-existent," Jones said.

Supervising author Associate Professor Patrick Clarke said the study could be the starting point for future research investigating how users interact with social media and what personal characteristics could influence the effects of social media use on mental health, for better and for worse. "For example, while all of the associations were weak at best, the study found different platforms recorded different effects: TikTok usage saw a small positive association with attentional control, while Facebook usage saw a small association with distress among users," Associate Professor Clarke said. "We did consider the age of users — we thought maybe TikTok users are just younger and that's why they have better attentional control — but even when allowing for age that association was still there. "This study only considered the amount of time participants spent on social media, so what this research could be flagging is how long we spend on social media might matter less for mental health, as opposed to how we're using it and engaging with it."

Particle that Only has Mass When Moving in one Direction Observed for First Time

Date: 10 December 2024

Source: Penn State

For the first time, scientists have observed a collection of particles, also known as a quasiparticle, that's massless when moving in one direction but has mass in the other direction. The quasiparticle, called a semi-Dirac fermion, was first theorised 16 years ago, but was only recently spotted inside a crystal of semi-metal material called ZrSiS. The observation of the quasiparticle opens the door to future advances in a range of emerging technologies from batteries to sensors, according to the researchers.

The team, led by scientists at Penn State and Columbia University, recently published their discovery in the journal *Physical Review X*.

"This was totally unexpected," said Yinming Shao, assistant professor of physics at Penn State and lead author on the paper. "We weren't even looking for a semi-Dirac fermion when we started working with this material, but we were seeing signatures we didn't understand and it turns out we had made the first observation of these wild quasiparticles that sometimes move like they have mass and sometimes move like they have none."

A particle can have no mass when its energy is entirely derived from its motion, meaning it is essentially pure energy travelling at the speed of light. For example, a photon or particle of light is considered massless because it moves at light speed. According to

Albert Einstein's theory of special relativity, anything travelling at the speed of light cannot have mass. In solid materials, the collective behaviour of many particles, also known as quasiparticles, can have different behaviour than the individual particles, which in this case gave rise to particles having mass in only one direction, Shao explained.

Semi-Dirac fermions were first theorised in 2008 and 2009 by several teams of researchers, including scientists from the Université Paris Sud in France and the University of California, Davis. The theorists predicted there could be quasiparticles with mass-shifting properties depending on their direction of movement — that they would appear massless in one direction but have mass when moving in another direction.

Sixteen years later, Shao and his collaborators accidentally observed the hypothetical quasiparticles through a method called magneto-optical spectroscopy. The technique involves shining infrared light on a material while it's subjected to a strong magnetic field and analysing the light reflected from the material. Shao and his colleagues wanted to observe the properties of quasiparticles inside silver-coloured crystals of ZrSiS.

The team conducted their experiments at the National High Magnetic Field Laboratory in Florida. The lab's hybrid magnet creates the most powerful sustained magnetic field in the world, roughly 9,00,000 times stronger than the Earth's magnetic field. The field is so strong it can levitate small objects, such as water droplets.

The researchers cooled down a piece of ZrSiS to –452 degrees Fahrenheit — only a few degrees above absolute zero, the lowest

possible temperature — and then exposed it to the lab's powerful magnetic field while hitting it with infrared light to see what it revealed about the quantum interactions inside the material.

"We were studying optical response, how electrons inside this material respond to light, and then we studied the signals from the light to see if there is anything interesting about the material itself, about its underlying physics," Shao said. "In this case, we saw many features we'd expect in a semi-metal crystal and then all of these other things happening that were absolutely puzzling."

When a magnetic field is applied to any material, the energy levels of electrons inside that material become quantised into discrete levels called Landau levels, Shao explained. The levels can only have fixed values, like climbing a set of stairs with no little steps in between. The spacing between these levels depends on the mass of the electrons and the strength of the magnetic field, so as the magnetic field increases, the energy levels of the electrons should increase by set amounts based entirely on their mass — but in this case, they didn't.

Using the high-powered magnet in Florida, the researchers observed that the energy of the Landau level transitions in the ZrSiS crystal followed a completely different pattern of dependence on the magnetic field strength. Years ago, theorists had labelled this pattern the " $B^{2/3}$ power law," the key signature of semi-Dirac fermions.

To understand the bizarre behaviour they observed, the experimental physicists partnered with theoretical physicists to develop a model that described the electronic structure of ZrSiS. They specifically focused on

the pathways on which electrons might move and intersect to investigate how the electrons inside the material were losing their mass when moving in one direction but not another.

"Imagine the particle is a tiny train confined to a network of tracks, which are the material's underlying electronic structure," Shao said. "Now, at certain points the tracks intersect, so our particle train is moving along its fast track, at light speed, but then it hits an intersection and needs to switch to a perpendicular track. Suddenly, it experiences resistance, it has mass. The particles are either all energy or have mass depending on the direction of their movement along the material's 'tracks.'"

Oldest Modern Human Genomes Sequenced

Date: 12 December 2024

Source: Max Planck Institute for Evolutionary Anthropology

When few genomes have been sequenced from early modern humans, who first arrived in Europe when the region was already inhabited by Neanderthals. An international team led by researchers at the Max Planck Institute for Evolutionary Anthropology has now sequenced the oldest modern human genomes to date. The genomes were recovered from seven individuals who lived between 42,000 and 49,000 years ago in Ranis, Germany and Zlatý kůň, Czechia. These genomes belonged to individuals who were part of a small, closely related human group that first split off from the population that left Africa around 50,000 years ago and later settled the rest of the world. Although they separated early, the Neanderthal DNA in their

genomes traces back to an admixture event common to all people outside Africa, that the researchers date to around 45,000–49,000 years ago, much later than previously thought.

After modern humans left Africa, they met and interbred with Neanderthals, resulting in around two to three percent Neanderthal DNA that can be found in the genomes of all people outside Africa today. However, little is known about the genetics of these first pioneers in Europe and the timing of the Neanderthal admixture with non-Africans.

A key site in Europe is Zlatý kůň in Czechia, where a complete skull from a single individual who lived around 45,000 years ago was discovered and previously genetically analysed. However, due to the lack of archaeological context, it was not possible to link this individual to any archaeologically defined group. A nearby site, the Ilsenhöhle in Ranis in Germany, about 230 km from Zlatý kůň, is known for a specific type of archaeology, the Lincombian-Ranisian-Jerzmanowician (LRJ), which dates to around 45,000 years ago. It has long been debated whether the LRJ culture was produced by Neanderthals or early modern humans. Although mostly small fragments of bones are preserved in Ranis, a previous study was able to analyse mitochondrial DNA from thirteen of these remains and found that they belonged to modern humans and not Neanderthals. However, since the mitochondrial sequence only constitutes a miniscule part of the genetic information, the relationships to other modern humans remained a mystery.

Linking Zlatý kůň and Ranis

A new study published in *Nature* analysed the nuclear genomes of the thirteen specimens

from Ranis and found that they represented at least six individuals. The size of the bones indicated that two of these individuals were infants and, genetically, three were males and three were females. Interestingly, among these individuals were a mother and daughter, as well as other, more distant, biological relatives. The team also sequenced more DNA from the female skull found at Zlatý kůň, producing a high-quality genome for this individual. "To our surprise, we discovered a fifth- or sixth-degree genetic relationship between Zlatý kůň and two individuals from Ranis," says Arev Sümer, lead author of the study, "This means that Zlatý kůň was genetically part of the extended family of Ranis and likely also made LRJ-type tools."

Among the six individuals from Ranis, one bone was particularly well preserved, in fact it is the best preserved modern human bone from the Pleistocene for DNA retrieval. This allowed the team to obtain a high-quality genome from this male individual, referred to as Ranis13. Together, the Ranis13 and Zlatý kůň genomes represent the oldest high-quality modern human genomes sequenced to date. When analysing genetic variants related to phenotypic traits, they found that Ranis and Zlatý kůň individuals carried variants associated with dark skin and hair colour as well as brown eyes, reflecting the recent African origin of this early European population.

By analysing the segments inherited from the same ancestor in the Ranis and Zlatý kůň genomes, the researchers estimate that their population consisted of at most a few hundred individuals who may have been spread out over a larger territory. The authors found no evidence that this small early modern human

population contributed to later Europeans or any other worldwide population.

A narrower timeframe for the shared Neanderthal admixture

Members of the Zlatý kůň/Ranis population coexisted with Neanderthals in Europe, raising the possibility that they may have had Neanderthals among their recent ancestors after they migrated to Europe. Previous studies on modern humans from over 40,000 years ago, had found evidence of such recent admixture events between modern humans and Neanderthals. However, no such evidence for recent Neanderthal admixture was detected in the genomes of the Zlatý kůň/Ranis individuals. "The fact that modern human groups, which may have arrived in Europe later, carry such Neanderthal ancestry while Ranis and Zlatý kůň do not could mean that the older Zlatý kůň/Ranis lineage may have entered Europe by a different route or did not overlap as extensively with the regions where Neanderthals lived," speculates Kay Prüfer, who co-supervised the study.

The Zlatý kůň/Ranis population represents the earliest known divergence from the group of modern humans that migrated out of Africa and dispersed later across Eurasia. Despite this early separation, the Neanderthal ancestry in Zlatý kůň and Ranis originated from the same ancient admixture event that can be detected in all people outside Africa today. By analysing the length of the segments contributed from Neanderthals in the high-coverage Ranis13 genome and using direct radiocarbon dates on this individual, the researchers dated this shared Neanderthal admixture to between 45,000 and 49,000

years ago. Since all present-day non-African populations share this Neanderthal ancestry with Zlatý kůň and Ranis, this means that around 45,000 to 49,000 years ago, a coherent ancestral non-African population must still have existed.

"These results provide us with a deeper understanding of the earliest pioneers that settled in Europe," says Johannes Krause, senior author of the study. "They also indicate that any modern human remains found outside Africa that are older than 50,000 years could not have been part of the common non-African population that interbred with Neanderthals and is now found across much of the world."

Memories are not only in the Brain, New Research Finds

Date: 7 November 2024

Source: New York University

It's common knowledge that our brains — and, specifically, our brain cells — store memories. But a team of scientists has discovered that cells from other parts of the body also perform a memory function, opening new pathways for understanding how memory works and creating the potential to enhance learning and to treat memory-related afflictions.

"Learning and memory are generally associated with brains and brain cells alone, but our study shows that other cells in the body can learn and form memories, too," explains New York University's Nikolay V. Kulkushkin, the lead author of the study, which appears in the journal *Nature Communications*.

The research sought to better understand if non-brain cells help with memory by borrowing from a long-established neurological property — the massed-spaced effect — which shows that we tend to retain information better when studied in spaced intervals rather than in a single, intensive session better known as cramming for a test.

In the *Nature Communications* research, the scientists replicated learning over time by studying two types of non-brain human cells in a laboratory (one from nerve tissue and one from kidney tissue) and exposing them to different patterns of chemical signals — just like brain cells are exposed to patterns of neurotransmitters when we learn new information. In response, the non-brain cells turned on a "memory gene" — the same gene that brain cells turn on when they detect a pattern in the information and restructure their connections in order to form memories. To monitor the memory and learning process, the scientists engineered these non-brain cells to make a glowing protein, which indicated when the memory gene was on and when it was off. The results showed that these cells could determine when the chemical pulses, which imitated bursts of neurotransmitter in the brain, were repeated rather than simply prolonged — just as neurons in our brain can register when we learn with breaks rather than cramming all the material in one sitting. Specifically, when the pulses were delivered in spaced-out intervals, they turned on the "memory gene" more strongly, and for a longer time, than when the same treatment was delivered all at once.

"This reflects the massed-space effect in action," says Kukushkin, a clinical associate

professor of life science at NYU Liberal Studies and a research fellow at NYU's Center for Neural Science. "It shows that the ability to learn from spaced repetition isn't unique to brain cells, but, in fact, might be a fundamental property of all cells." The researchers add that the findings not only offer new ways to study memory, but also point to potential health-related gains.

"This discovery opens new doors for understanding how memory works and could lead to better ways to enhance learning and treat memory problems," observes Kukushkin. "At the same time, it suggests that in the future, we will need to treat our body more like the brain - for example, consider what our pancreas remembers about the pattern of our past meals to maintain healthy levels of blood glucose or consider what a cancer cell remembers about the pattern of chemotherapy."

Mathematical Modelling Leads to a Better Understanding of Prostate Cancer

Date: 14 November 2024

Source: University of Cologne

With researchers at the University of Cologne develop three-dimensional mathematical model of prostate cancer. The model depicts various processes, including tumour growth, genetic evolution and tumour cell competition. It may also be applicable to other forms of cancer.

A team led by Dr. Yuri Tolkach at the University of Cologne's Faculty of Medicine and University Hospital Cologne has investigated

prostate tumours and developed an advanced, realistic, three-dimensional model of prostate cancer with the help of mathematical modelling. The model depicts tumour growth, genetic evolution and the competition between subclones — different cell populations within a tumour. It shows, among other things, that the development of an aggressive tumour requires 'strong' genetic changes that immediately give the tumour cells special survival advantages. These must occur early in the course of tumour development, when the tumour is still small. The study also shows that the distribution of subclones within a tumour has an impact on diagnostic approaches such as biopsies.

Prostate cancer is the most common cancer in men. However, the mechanisms of tumour development, particularly the development of aggressive tumours, are still largely unclear in prostate cancer and other malignant tumours for two reasons: Firstly, tumours are often only discovered when they have already reached a considerable size. The time span between the development of the tumour and the diagnosis, which can be 10 to 30 years, is therefore not taken into account. Secondly, state-of-the-art methods such as next-generation sequencing (NGS), which make it possible to comprehensively characterise the tumour at subclone level, are costly and extremely complex to evaluate. For these reasons, only a few tumours worldwide have so far been examined in this way.

"Our study shows that we can use mathematical modelling to address important, previously unanswered questions about the development of malignant tumours and thus gain clinically relevant insights. Our model is universally applicable and can

also be used for other malignant tumour types," explained senior physician and co-leader of the study, Dr. Yuri Tolkach from the Institute of General Pathology and Pathological Anatomy at University Hospital Cologne.

"With our new model, we can reproduce the complex spatial structure of a prostate tumour, which grows like a root system in the tissue," explained postdoc and co-leader of the study, Dr. Florian Kreten, who previously worked at the Institute for Applied Mathematics at the University of Bonn. He added, "Conventional mathematical models of tumour growth and evolution could not be applied to these structures. From a mathematical point of view, the underlying growth mechanism is extremely fascinating and has raised a number of new questions. Our work shows how biology can inspire mathematical research." In future, the scientists hope to be able to further develop the models and to include the interaction between the tumour and the immune system.

Improved Catalyst Turns Harmful Greenhouse Gases into Vleaner Fuels, Chemical Feedstocks

Date: 26 November 2024

Source: DOE or Oak Ridge National Laboratory

A chemical reaction can convert two polluting greenhouse gases into valuable building blocks for cleaner fuels and feedstocks, but the high temperature required for the reaction also deactivates the catalyst. A team led by the Department of Energy's Oak Ridge National Laboratory has found a way to thwart deactivation. The strategy may apply broadly to other catalysts.

The team improved a reaction called dry reforming of methane that converts methane and carbon dioxide into syngas, a valued mixture of hydrogen and carbon monoxide used by oil and chemical companies worldwide. The team has applied for a patent for their invention as a way to minimise catalytic deactivation.

"Syngas is important because it's a platform for the production of a lot of chemicals of mass consumption," said ORNL's Felipe Polo-Garzon, who, with ORNL's Junyan Zhang, led the study published in *Nature Communications*.

Improving the catalyst that speeds syngas production could have enormous impact on global energy security, cleaner fuels and chemical feedstocks. In countries lacking oil reserves, syngas derived from coal or natural gas is critical for making diesel and gasoline fuels. Moreover, syngas components can be used to make other commodity chemicals. Hydrogen, for example, can be used as a clean fuel or as a feedstock for ammonia to create fertiliser. Methanol, an alcohol that can be made from syngas, is a source of ingredients for producing plastics, synthetic fabrics and pharmaceuticals. Methanol is also a good carrier of hydrogen, which is hard to pressurise and dangerous to transport. As the simplest alcohol, methanol contains the highest ratio of hydrogen to carbon; it can be safely transported and converted to hydrogen at the destination.

"This [dry reforming of methane] reaction sounds attractive because you are converting two greenhouse gases into a valuable mixture," Polo-Garzon said. "However, the issue for decades has been that the catalysts required to carry out this reaction deactivate

quickly under reaction conditions, making this reaction nonviable on an industrial scale."

To attain significant conversion of reactants, the reaction must be conducted at temperatures greater than 650 degrees Celsius, or 1,200 degrees Fahrenheit. "At this high temperature, the catalysts undergo two deactivation processes," Polo-Garzon said. "One is sintering, in which you lose surface sites that undertake the reaction. The other is the formation of coke — basically solid carbon that blocks the catalyst from contacting the reactants."

Catalysts work by providing a large surface area for reactions. Metal atoms such as nickel have electronic properties that allow them to temporarily bind reactants, making chemical bonds easier to break and create. Sintering causes nickel particles to clump, reducing the surface area available for chemical reactions.

Likewise, coking chokes a catalyst. "During the reaction on the catalyst surface, methane will lose its hydrogen atoms one by one until only its one carbon atom is left," Zhang said. "If no oxygen bonds to it, leftover carbon will aggregate on the catalyst's nickel surface, covering its active face. This coking deposition causes deactivation. It is extremely common in thermal catalysis for hydrocarbon conversion."

Today, most commercial syngas is made by steam reforming of methane, a process that requires large amounts of water and heat and that also produces carbon dioxide. By contrast, dry reforming of methane requires no water and actually consumes carbon dioxide and methane. By tuning interactions between the metal active sites and the support during catalyst synthesis, the scientists suppressed coke formation and

metal sintering. The new catalyst provides outstanding performance for dry reforming of methane with extremely slow deactivation. The novel catalyst consists of a crystalline material called a zeolite that contains silicon, aluminum, oxygen and nickel. The zeolite's supportive framework stabilises the metal active sites.

"Zeolite is like sand in composition," Zhang said. "But unlike sand, it has a sponge-like structure filled with tiny pores, each around 0.6 nanometres in diameter. If you could completely open a zeolite to expose the surface area, 1 gram of sample would contain an area around 500 square metres, which is a tremendous amount of exposed surface."

To synthesise the zeolite catalyst, the researchers remove some atoms of aluminum and replace them with nickel. "We're effectively creating a strong bond between the nickel and the zeolite host," Polo-Garzon said. "This strong bond makes our catalyst resistant to degradation at high temperatures." The high-performance catalyst was synthesised at ORNL's Center for Nanophase Materials Sciences. Zili Wu, leader of ORNL's Surface Chemistry and Catalysis group, served as a strategy advisor for the project. Zhang performed infrared spectroscopy, revealing that nickel was typically isolated and bound by two silicon atoms in the zeolite framework.

At DOE's Brookhaven National Laboratory and SLAC National Accelerator Laboratory, ORNL's Yuanyuan Li led X-ray absorption spectroscopy studies detailing the electronic and bonding structures of nickel in the catalyst. At ORNL, Polo-Garzon and Zhang used a technique called steady-state isotopic transient kinetic analysis to measure catalyst

efficiency — the number of times a single active site converts a reactant into a product. X-ray diffraction and scanning transmission electron microscopy characterised the structure and composition of materials at the nanoscale.

"In the synthesis method, we found that the reason the method works is because we're able to get rid of water, which is a byproduct of the catalyst synthesis," Polo-Garzon said. "We asked colleagues to use density functional theory to look into why water matters when it comes to the stability of nickel."

At Vanderbilt University, Haohong Song and De-en Jiang performed computational calculations showing that removing water from the zeolite strengthens its interactions with nickel.

Next, the researchers will develop other catalyst formulations for the dry reforming of methane reaction that are stable under a broad range of conditions. "We're looking for alternative ways to excite the reactant molecules to break thermodynamic constraints," Polo-Garzon said.

"We relied on rational design, not trial and error, to make the catalyst better," Polo-Garzon added. "We're not just developing one catalyst. We are developing design principles to stabilise catalysts for a broad range of industrial processes. It requires a fundamental understanding of the implications of synthesis protocols. For industry, that's important because rather than presenting a dead-end road in which you try something, see how it performs, and then decide where to go from there, we're providing an avenue to move forward."

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