Original Article

Roadmap for a Systems Biology Initiative in Iran

Abstract

Background: Systems biology is an interdisciplinary approach, which will fundamentally transform the way biology is perceived and studied. Subsequently, biomedical knowledge, medical practice, health systems, and related industries will be changed. This change will ultimately lay the foundation for the new generation of medicine or high-performance medicine, so-called personalized medicine. The results of this renovation are already emerging at five levels: knowledge level, patient level, therapist level, health system level, and industry level. A national roadmap is the right way to shape the future in a conscious, effective, and preconceived way. **Methods:** Here, we provide a roadmap to expand systems biology approach in Iran, which can serve as a model for other countries with similar resources and strategic situation. We begin with field studies to map the current situation in the field and potential promoters and deterrents. We then identify key players and evaluate their power and benefit from expansion of systems biology approach. Finally, we provide strategies, key action areas, and feasible actions, as well as achievable goals and realistic vision and mission in a 10-year timeline, all in light of guidance from experts and pioneers in the field of systems biology. **Results:** We identified the strategic position of Iran at WO area, which means the need to focus on conservative strategies to minimize the weaknesses leveraging opportunities. **Conclusions:** Implementation of our suggestive 10-year roadmap will enhance the current situation of Iran in systems biology field to be the pioneer in west asia and a major player in the world.

Keywords: *Big data, bioinformatics, holism, integration, systems biology*

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Introduction

Life begins at the molecular level, where small inorganic particles form molecules, which in turn create cells that interact in dynamic and complex ways. These cells, whether part of single-celled organisms or multicellular systems with billions of cells, contain molecules such as nucleic acids, proteins, lipids, and metabolites. In advanced living systems, these cells organize into tissues and organs that function collectively for survival. Biological complexity is evident across all these levels, from intracellular responses to the coordinated growth of entire organisms.

The study of living systems has fascinated philosophers and scientists for centuries. Advances in molecular biology, chemistry, and physics have transformed this curiosity into systematic exploration, particularly after the sequencing of the human genome in 2001. This milestone marked a revolution, yet as our comprehension of cellular and molecular components and processes advances it also highlights the challenges of understanding the intricate interplay among molecular and cellular components. While molecular biology, excelled at identifying these components, it struggled to connect them into cohesive networks and explain their collective behavior.[1] The past two decades have witnessed an explosion in high-throughput technologies, enabling the collection of vast biological datasets. These datasets encompass comprehensive views of cellular components such as the genome, proteome, and metabolome. Concurrently, the emergence of bioinformatics methods and tools has facilitated the analysis and integration of these datasets, fostering a more holistic understanding of biological systems.[1,2]

To address the complexity of living systems, two primary approaches are employed: the reductionist approach and systems thinking. Reductionism dissects systems into smaller components to understand

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their behavior, which has been pivotal in elucidating the chemical basis of numerous living processes. However, this approach falls short in addressing the emergent properties of highly complex biological systems. Systems thinking, by contrast, adopts a holistic perspective, integrating diverse information and examining interactions among components and with their environment.[3-10]

Systems biology applies systems thinking to study the dynamic interactions within biological systems. It uses computational tools and mathematical models to analyze complex networks and regulatory mechanisms. This approach views diseases as imbalances within these networks and emphasizes restoring equilibrium through targeted interventions. Systems biology's integrative nature holds transformative potential for fields such as pharmacology, biotechnology, and clinical research.[2,11,12]

Systems biology: Definition and scope

The foundation of systems biology, known as systems thinking, is based on three main aspects of (i) recognizing all actors and stakeholders related to a system, (ii) determining communication networks among them, as well as (iii) gaining a quantitative and scalable understanding of the impact of these networks on each other and the environment.[13] However, the exact definition of systems biology, varies among researchers,[11,12,14-20] mainly due to differences in the definition of systems.[21]

While some equate systems biology with bioinformatics, the former is broader.[1] Bioinformatics specializes in computational analysis of high-throughput data, whereas systems biology demands a holistic viewpoint and an interdisciplinary foundation.[22] Therefore, although knowing bioinformatics tools and computational methods are necessary to enter this field of science, these are not equivalent to each other.

Systems biology can be viewed as an "umbrella" encompassing various "omics" disciplines, including genomics, proteomics, and metabolomics, as well as their integration within cells, tissues, and organs.[1,23] This comprehensive approach ensures that researchers avoid the pitfall of focusing narrowly on a single omics layer.[14] Instead, they analyze diverse networks and interactions across components, requiring expertise in biology, mathematics, biostatistics, informatics, and data science.

In another point of view, the definition of systems biology is based on the definition of its components. "Biology" is the study of living things and "system" is "a separate unit whose existence can be maintained through the interrelationships of its components." By this point of view, it seems that conducting systems research requires the use of both reductionist and integrated approaches to be able to identify both the properties of components and their complex interactions. This finally determines how these components and their interactions lead to the permanence of this whole unit.[24]

In a more applied view, systems biology means the analysis of the interaction of biological molecules and cells at the system level in both health and disease.[25,26] By fostering collaboration across disciplines, systems biology can reshape healthcare systems and drive innovation in biotechnology and pharmaceutical industries.[27] Integrating clinical perspectives with cutting-edge analytical technologies, interdisciplinary research can not only extend our understanding of biological systems but also improve disease diagnosis and treatment.[11,12] This breadth is critical for tackling complex diseases such as cancer, cardiovascular diseases, and diabetes, which are characterized by intricate molecular and cellular imbalances.[28]

Systems biology seems to be a general scientific term which can be rephrased to make it more specific. Systems medicine is an example, which is the application of systems biology in medical concepts, research, and services. Systems medicine applies mathematical, statistical, and advanced modeling, aiming to identify complex networks that describe underlying mechanisms of diseases, the reasons for their progression and regression, how they respond to treatment, and how to reduce side effects of these treatments, alongside with methods to prevent their occurrence.[29]

Finally, Leroy Hood (the American scientist who first introduced the term systems biology) in 2009 defines systems biology as an attempt to provide a holistic view of biological science. The only possible way to understand the features of a system is to define its components, the interactions between them, and then look at how they change in response to stimuli. Employing this method, the first step is to define a model that can describe the system. Subsequently, by making changes in that system, various hypotheses are tested and examined to see whether the obtained results are in accordance with the desired model. Finally, although understanding of the system cannot be achieved all in once, models are developed that can gradually more and more accurately predict the behavior of a system.[19]

Systems biology: A paradigm-shift in biology?

The importance of the emergence of systems biology approach is such that some consider it as a paradigm shift in biology.[15] The term "paradigm shift" refers to a psychological process that, by gradually transforming patterns and ideas, can eventually alter the way projects are done.[30] Biology has undergone paradigm shifts at several points, the most important of which are the developments after Mendel and Darwin. Some do not see the emergence of systems biology as a shift in paradigm, but according to the definition provided, some consider it to be the latest conceptual evolution in biology.[31] The emergence of this approach has undoubtedly fostered a new mindset among life scientists and has gradually altered patterns and concepts in perspectives and related research.

Challenges and opportunities

Despite its promise, systems biology faces significant challenges, particularly in data integration and analysis. The sheer volume, heterogeneity, and complexity of omics and clinical data exacerbate the "big data to knowledge" issue, requiring advanced computational models capable of simulating complex interactions while delivering accurate, reproducible results. Interoperability among datasets, standardization of data formats, and overcoming biases in datasets are persistent issues that hinder effective integration and generalizability.[32]

Another notable challenge lies in the translation of computational models into actionable insights. While theoretical frameworks and simulations are abundant, their validation in real-world experimental and clinical settings is often limited, delaying the application of systems biology findings in precision medicine and drug development. Furthermore, ethical concerns, including data privacy, informed consent, and equitable access to systems biology-driven healthcare innovations, present critical obstacles.

By addressing these challenges, systems biology can revolutionize biomedical research and healthcare. Its interdisciplinary nature not only advances scientific understanding but also bridges gaps between biology, engineering, and computational science. As the field matures, it will play a pivotal role in addressing global health challenges and driving the next wave of innovation in life sciences.[33]

Current state and future prospects

The rapid evolution of systems biology has created a growing market for its applications in personalized medicine, drug discovery, and biotechnology. For example, the global market for systems biology is expected to grow significantly as industries adopt omics technologies and integrate them with computational tools. Countries such as the United States, Germany, and Japan have established comprehensive systems biology initiatives, often backed by government funding and interdisciplinary consortia. These initiatives underscore the importance of aligning science and technology policies with market needs, promoting innovation through collaboration among academia, industry, and policymakers.

Iran's roadmap for systems biology must draw inspiration from these global examples, prioritizing funding, infrastructure development, and workforce training. Establishing national centers of excellence, fostering international partnerships, and creating platforms for interdisciplinary research will be essential. Policymaking frameworks should focus on long-term sustainability, with policies that encourage public–private partnerships and provide incentives for research and development.

According to the urgent need to promote systems biology in the presence of upfront challenges, a systems biology roadmap is imperative. Designing such a roadmap will help to promote systems biology while appropriately handling the above challenges.

Designing and implementation of new projects requires continuous planning. A prerequisite for this is understanding the current situation by examining the internal and external factors affecting the projects. Strategists and analysts should identify the strengths, weaknesses, opportunities, and threats around field. Analyzing external factors will illuminate opportunities and threats. Based on these insights, as well as the internal strengths and weaknesses, goals, procedures, and policies are then determined. Strategic analysis, and strategy formulation and selection, are two important primary components of the strategic management process, which requires the identification and analysis of internal and external influencing factors. Here we provide a roadmap to promote systems biology in Iran and appropriately overcome current challenges, in the view of expert opinions and strategic analysts.

Methods

First, we identified the current status, internal and external influencers (promoters and opponents), stakeholders, and strategic factors, using field studies including interviews with experts at different levels. Next, we used Delphi technique[34,35] to assess the potential and actual situation of the influencers. We also used strengths, weaknesses, opportunities, and threats (SWOT) technique[36] to compile actionable strategies leveraging the identified influencers. We finally define specific key areas and corresponding actions based on these strategies.

Field studies

Interviews

Firstly, we performed semistructured interviews with 13 Iranian pioneers in the field of systems biology, as the members of "Iranian Systems Biology Committee." The purpose of this interview was to identify the definitions and boundaries of systems biology, its applications, and the reasons for the need to develop a national roadmap for it. Furthermore, the interview aimed for identifying the desired vision of experts in this field for the country, key areas of activity from their point of view, obstacles, threats, and opportunities, as well as stakeholders in the development of this approach. The questions of semistructured interviews are given in Supplementary Table 1.

Questionnaires

We provided two questionnaires aiming to weigh the influential factors and evaluate the power and benefit of the stakeholders from the experts' point of view. We published the questionnaires to the core audience of the main Iranian annual systems biology meeting. Then we used a two-round Delphi technique,[34] to determine our current general strategic situation for the purpose of the roadmap and evaluate the position of different stakeholders in the power and benefit matrix. A consensus threshold of 75% agreement among experts was applied to determine the level of agreement of the first round. This threshold was chosen based on previous Delphi studies in the field, which suggest that a 75% agreement rate ensures a robust level of consensus. At the end of the first round, experts' responses were analyzed, and items that did not reach the 75% agreement threshold were revised and presented in the second round. In the second round, the revised items were presented to the experts, and their responses were analyzed to determine the final results. Full questionnaires are provided in Supplementary Tables 2 and 3.

The first questionnaire was designed to evaluate the potential influence of internal and external factors (named as weight) and the current status of each factor in the country (named as score). Experts in the factor weighting questionnaire expressed their views on the impact of each internal and external factor by choosing a decimal number between 0 and 1 (With 0 and 1 meaning the minimum and maximum effect of the factor on the development of systems biology approach, respectively). In the factor scoring questionnaire, the opinion of experts regarding the current situation of each internal and external factor in the country was assessed according to the Likert scale[37] with a numerical allocation between 0 and 4 (0 = very bad, 1 = bad, 2 = average, 3 = good, and 4 = very good).

The second questionnaire was designed to evaluate the stakeholders, based on their power and benefit upon the development of systems biology approach. Here, power means the current ability and level of authority of the stakeholders or the ability and level of authority imagined for them in the future to act to achieve the expected results of the project. The power of stakeholders can consist of legal-, financial-, or knowledge power. The profit and income that stakeholders will gain if the project goals are met, are considered as benefits. In this questionnaire, the experts expressed their views on the level of power and benefit of the stakeholders by specifying a number between 0 and 4 according to the Likert scale[37] (0 = very low, 1 = low, 2 = medium, 3 = high, and 4 = very high).

Evaluation and analysis of strategic factors and stakeholders

After collecting questionnaires and receiving expert opinions, and to determine the strengths, weaknesses, threats, and opportunities for each internal and external factor, the average opinions of respondents regarding the weight and score of each factor were calculated. In the internal factor analysis section, if the final score of each factor, i.e., the average score of the respondents, is <2, that factor is considered as a weakness and if it is more than 2, the factor is considered as the country's strength in developing the systems biology approach. In addition, if the total score, i.e., the average score of all internal factors is more than 2, it indicates that internal factors are strong in total, and if this score is <2, it indicates the weakness of the country in developing this approach.

Similarly, in the external factor analysis section, if the final score of each factor, i.e., the average score of the respondents, is <2, that factor is considered as a threat, and if more than 2 is calculated, the factor is considered as an opportunity to develop the systems biology approach. Furthermore, if the total score of external factors, i.e., the average score of all factors in this category is more than 2, it indicates that external factors are an opportunity to develop the systems biology approach, and if this score is less than 2, external factors are considered as a threat to the development of this approach.

These scores are eventually normalized according to the given weights as follows: First, weights of each internal or external category (strength/weakness/opportunity/threat) are summed up and each weight is divided by the summed value to give a normalized weight. Second, each score is multiplied by the normalized weight to give a normalized score. These scores are then used as the basis for defining country's general strategic position in SWOT matrix.

The overall strategic position of Iran is then defined in SWOT matrix, by showing the average score of internal factors on x-axis, and the average score of external factors on y-axis, with 2 at the center of matrix (x = 2 and y = 2).

For evaluating the stakeholders, we used the power–benefit matrix to categorize them and identify the key actors. We chose this method for stakeholder analysis because of its ability to differentiate stakeholders based on the type of interaction with them. Henceforth in the next steps, appropriate strategies can be used to communicate with each of the stakeholders. Based on the two criteria of power and benefit, stakeholders were divided into four categories: key actors, founders, institutions, and the public.

All these helped to draw realistic vision and mission, aims, and indices for the purpose of this project.

Strengths, weaknesses, opportunities and threats – Strategies, key areas, and actions

Among many techniques that can be used to analyze strategic cases, we used the SWOT matrix as a very popular approach.[36] Developing macrostrategies and proposing strategic measures to develop the systems biology approach was based on the identified opportunities and threats, strengths and weaknesses, as well as the strategic position obtained. The information obtained from data analysis in the previous section was used as input at this stage to develop practical strategies. Analyzing the situation and determining the practical strategies constituted a strategic balance between the driving factors (including environmental opportunities and strengths) against the deterrents (environmental threats and weaknesses) and to eliminate them.

In SWOT analysis, four strategic positions emerge from the intersection of opportunities and threats with strengths and weaknesses:

- Offensive position (SO)
- Reversible or conservative (WO) position
- Diversity–competitive position (ST)
- Defensive position (WT).

We define the Iran's general strategic situation and propose strategies in any of the above categories to maximize

Table 1: External and internal influencing factors in developing systems biology in Iran

Influencer type	Entry	Influencer	Weight	Normalized weight	Score	Balanced score
Opportunity	O1	Existence or ability to provide appropriate hardware for storage, exchange, and analysis (exogenous)	0.9	0.2	2.1	0.42
	O2	Ability to analyze data in this area with freely available software	0.9	0.2	3	0.6
	O3	Ability to access omics data abroad: including open access data, restricted data, or access through collaboration	0.9	0.2	2.32	0.46
	O4	Resistance of the country's systems biology development program to international limitations	0.8	0.18	3.5	0.63
Threat	T1	Existence or ability to provide appropriate hardware to produce omics data (exogenous)	0.4	0.09	1.14	0.1
	T2	Possibility of conducting research in the form of international teams	0.5	0.11	1.69	0.18
Total			4.4			2.39
Strengths	S1	Interested and talented human resources in the field of biomedicine	1	0.1	4	0.4
	S2	Interested and talented human resources in the field of data analysis	1	0.1	4	0.4
	S3	The importance of developing systems biology from the perspective of strategic and upstream documents of the country	0.4	0.04	2.1	0.08
	S4	Existence or ability to provide appropriate hardware to generate omics data (endogenous)	0.4	0.04	2.1	0.08
	S5	Existence or ability to provide appropriate hardware for storage, exchange, and analysis (endogenous)	0.9	0.09	2.7	0.24
Weaknesses	W1	Proper management of specialized human resources in research activities	0.7	0.07	1.55	0.1
	W2	Ability and skill to create interdisciplinary and group collaborations	0.7	0.07	1.87	0.13
	W3	Ensuring the implementation of strategic documents in the country and the commitment of managers to them in long-term decision-making	0.4	0.04	1.46	0.05
	W4	Awareness of industry managers related to systems biology (pharmaceutical, food, agriculture, livestock, biotechnology, laboratory sciences, health services, etc.)	0.5	0.05	1.1	0.05
	W5	Awareness of national level managers related to systems biology (Supreme Council of the Cultural Revolution, Vice President for Science and Technology, Ministries of Science and Health, Ministry of Agriculture, etc.)	0.4	0.04	1.6	0.06
	W6	Awareness of senior and middle managers of education and research (heads and deputies of universities, research institutes, etc.)	0.7	0.07	1.5	0.1
	W7	Awareness of the academic community (such as professors, researchers, students, etc.)	0.5	0.05	1.87	0.09
	W8	Existence of supporting and investing industries related to this approach, such as the pharmaceutical industry	0.6	0.06	1.28	0.07
	W9	Possibility of preventing the implementation of weak projects with the name of systems biology and making the face of this field vulgar in the country	0.7	0.07	0.9	0.06
	W10	Possibility to pay attention to the application of systems biology in industry (whether goods or services) along with the academic structure	0.6	0.06	0.7	0.04
	W11	The relevance of the titles of the existing university courses to the new generation of biology and systems biology	0.5	0.05	0.7	0.04
Total			10			1.95

Weight: Potential influence of internal and external factors; Score: The current status of each factor in the country the opportunity of timely meeting the project goals in developing systems biology approach. In the SO area, opportunities should be taken advantage of by utilizing strengths to develop a systems biology approach. In the WO situation, we must take advantage of opportunities to minimize the country's weaknesses in developing this approach. In the ST section, we should use the country's strengths to avoid threats in developing a systems biology approach. Moreover, finally in the WT part, efforts should be made to minimize weaknesses and avoid potential threats in the development of a systems biology approach.

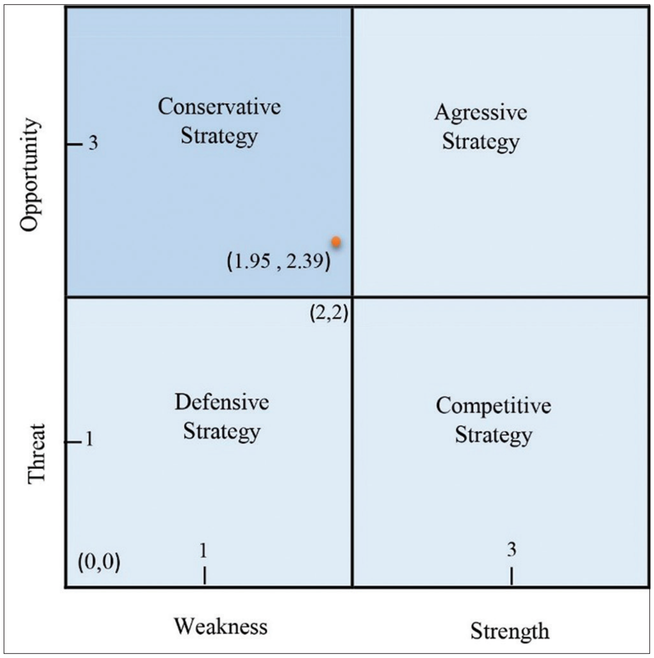

Figure 1: Strategic position of developing a systems biology approach in Iran

After drawing strategies, we identified key areas in which strategic actions need to take place and specified practical actions along each strategy, all in light of expert opinions.

Results

Field studies and analyzing the questionnaires by the Delphi technique, shed light on the internal and external influencers [Table 1] and subsequently, general strategic situation of Iran in developing systems biology approach [Figure 1].

As shown in Table 1, four major opportunities and two threats were found as external influential factors by expert opinions. Opportunities outweighed threats in terms of score and weight. Among internal factors, five major strengths and 11 weaknesses were identified. Although the number of identified weaknesses is more than strengths, scores that are given to strengths compared to weaknesses are promising. With reference to Figure 1, the overall strategic position of Iran based on our SWOT matrix is in

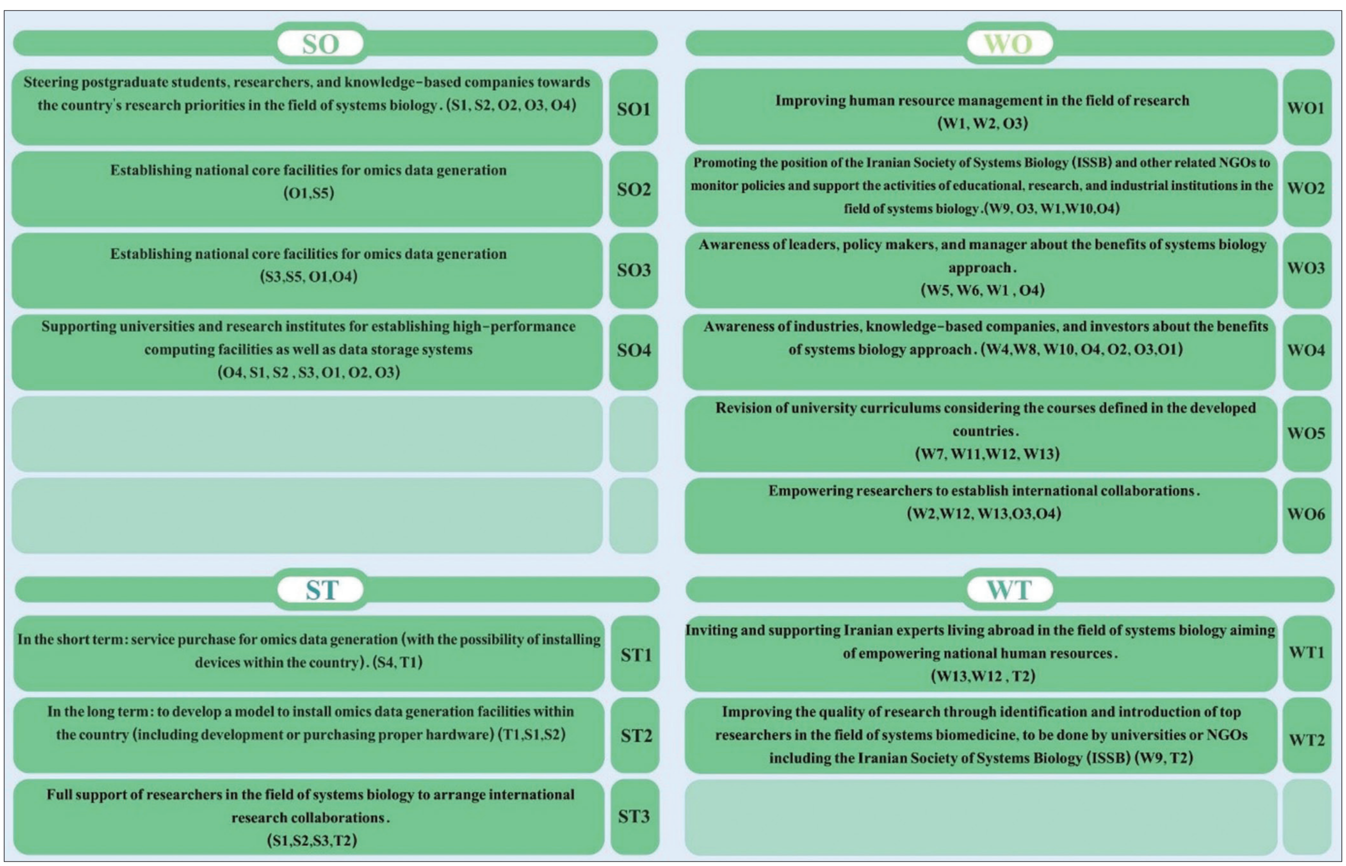

Figure 2: Power–benefit matrix of stakeholders in developing a systems biology approach in Iran

WO area, implicating the need to focus on conservative strategies. This means sticking to strategies which minimize the weaknesses leveraging opportunities.

Identification of influential factors also yielded the identification and assessment of the stakeholders, according to the country's governmental and social context [Figure 2]. These stakeholders are assigned to four clusters based on expert scores: (1) Key players are those with both power and interest in systems biology such as ministry of health and medical education as well as biotechnology development council. (2) Facilitators

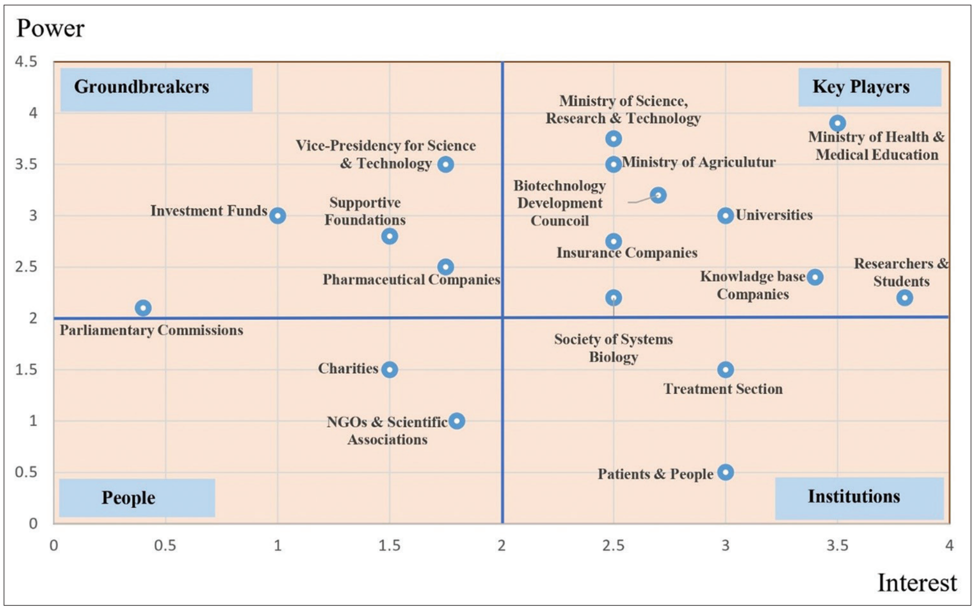

Figure 3: Defined strategies in each of the four strengths, weaknesses, opportunities and threats strategic situation categories

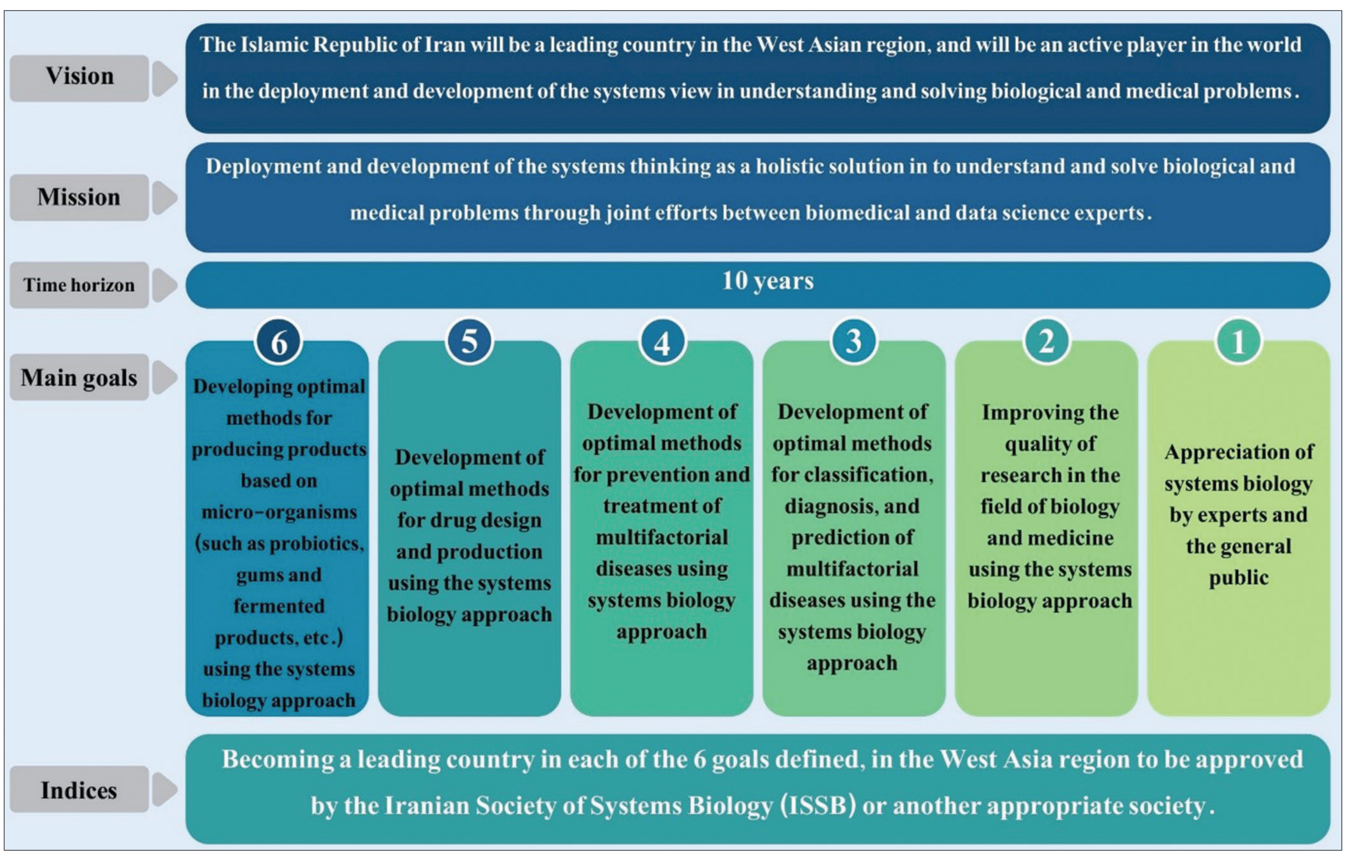

Figure 4: Strategic pillars of developing a systems biology approach in Iran

are organizations which have high power but low interest in systems biology such as investment funds or vice-presidency of science and technology. (3) Users which have high interest in systems biology but low power like patients and treatment section. (4) Other institutions who have both low power and low interest in systems biology, e.g., NGOs or scientific associations and charities.

Based on all these results, including influential factors and stakeholders, and leveraging SWOT technique, we then drew facilitator strategies [Figure 3] to get advantage of strengths and opportunities while minimizing the costs of weaknesses and the threats. Since the overall strategic position of Iran falls within the WO range, the strategies defined in this range have higher priorities for implementation. Therefore, six strategies, namely WO1 to WO6 have been proposed as shown in Figure 3 to leverage opportunities to address weaknesses. For instance, the WO2 strategy has been proposed to cover the weaknesses W1, W9, and W10 by utilizing the opportunities O3 and O4. Furthermore, alongside the main WO strategies, strategies were defined for the other three positions, i.e., SO, ST, and WT, as shown in Figure 1, so that they can be used in defining actions if needed.

In strategic planning, aligning strategies helps to establish a vision for the subject at hand. This vision should be described through a set of goals. Utilizing the extracted strategies and expert opinions, as illustrated in Figure 4, we defined a vision and six main goals for the strategic development plan of the systems biology in Iran. To achieve these goals, as illustrated in Figure 5, we identified appropriate executive actions, resulting in 28 actions, categorized into six key areas that correspond to the selected strategies. The appropriate timeframe for implementing each action to achieve the goals, along with the designated party responsible for execution, is outlined in Figure 5.

Herewith, we also provide an implementation framework in Figure 6, as a summary of the whole roadmap.

Discussion

Systems biology is an interdisciplinary and holistic approach that has the potential to revolutionize research and development in life sciences. The successful development of systems biology in the country requires participation and cooperation among various organizations and experts across biology, engineering, computational sciences, and other related disciplines.

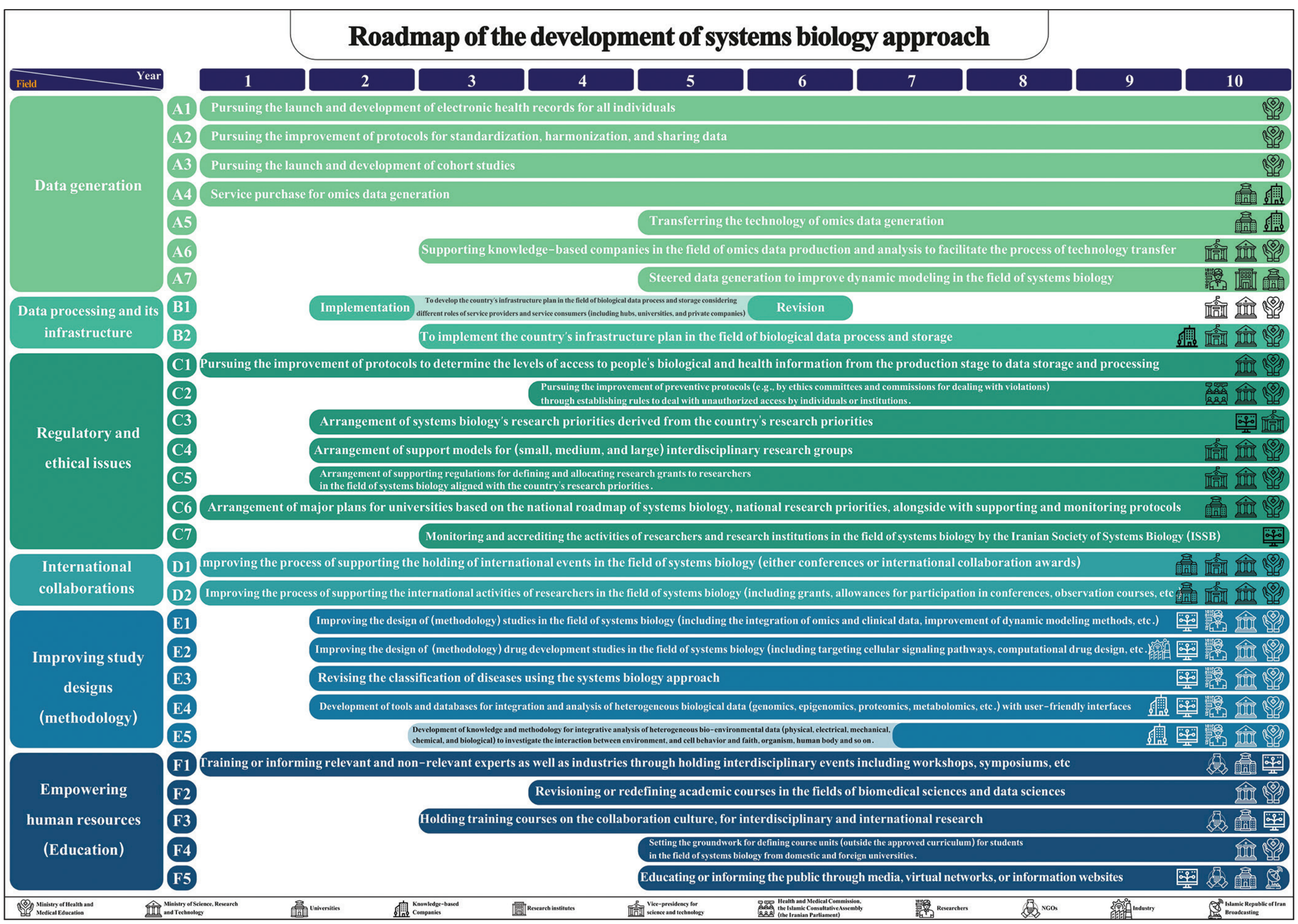

Figure 5: Key areas and actions of the systems biology roadmap in Iran

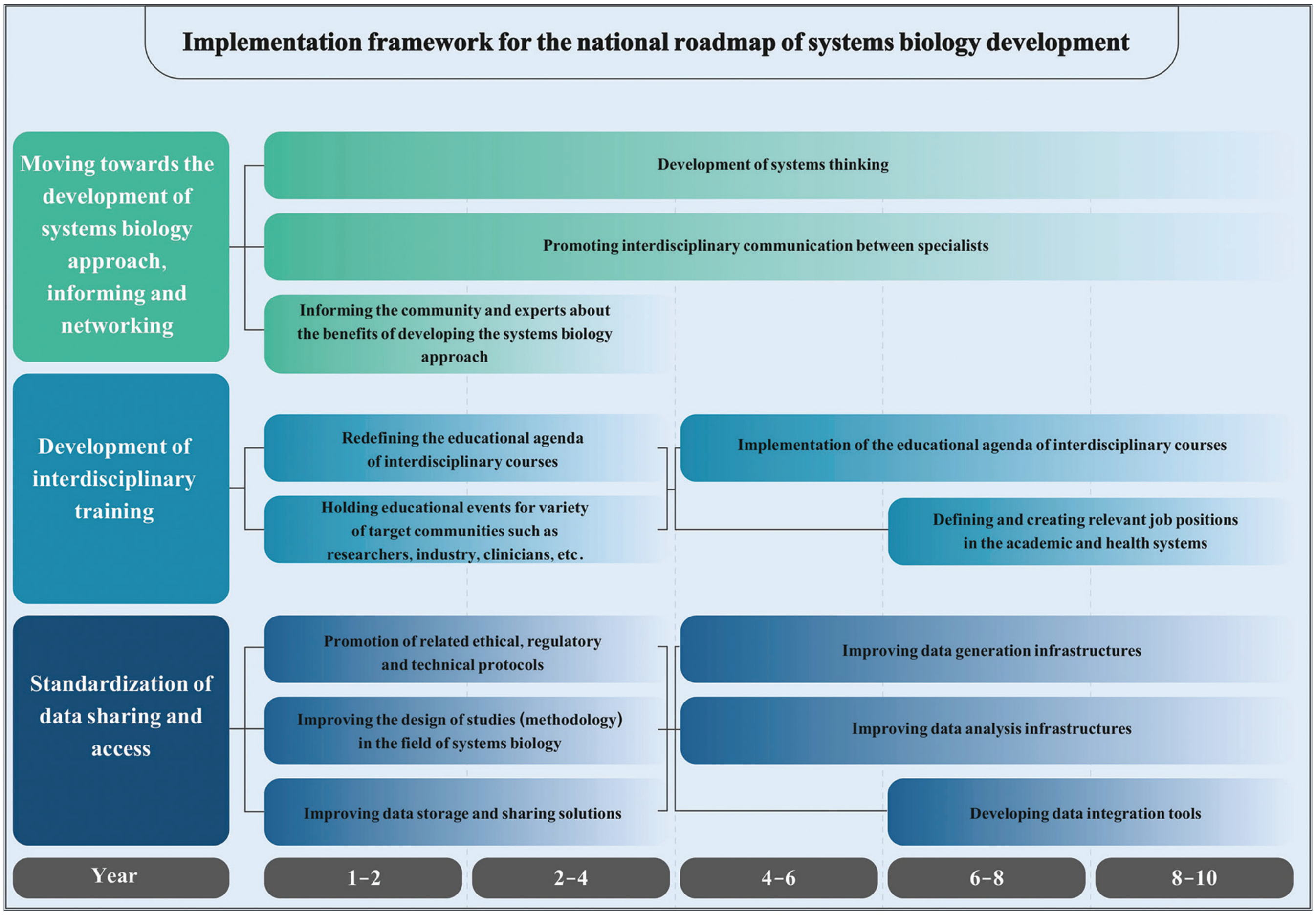

Figure 6: Implementation framework for the roadmap of developing a systems biology approach in Iran

This study marks a significant effort toward laying a foundation for systems biology development by adopting a structured and comprehensive approach. Initially, extensive analyses were conducted to examine the measures taken by leading countries, serving as a benchmark for best practices. The SWOT was then identified through expert input, providing critical insights into the nation's potential to embrace this transformative field. These findings informed the formulation of a clear vision, mission, strategic goals, and practical measures to advance systems biology.

Despite the strengths highlighted in this study – such as access to talented and motivated personnel – there are several limitations worth discussing. The SWOT analysis, while a valuable tool, is inherently subjective and depends on the perspectives and experiences of the experts consulted. In addition, the lack of quantitative data to support certain identified factors limits the robustness of the conclusions. Future studies should aim to complement expert opinions with data-driven methodologies, such as bibliometric analyses and economic assessments, to better substantiate the identified SWOT.

The findings of this study have implications not only for advancing systems biology in Iran but also for guiding its implementation in resource-limited settings. The proposed roadmap emphasizes the need for strategic investments in education, infrastructure, and international collaboration, while also addressing the challenges of interdisciplinary training, data integration, and ethical considerations. However, significant barriers remain, including limited funding for large-scale initiatives, the need for cross-sector collaboration, and the potential resistance to change from traditional academic and research structures.

By addressing these barriers, this study could serve as a catalyst for systems biology development in the region, enabling innovative solutions to pressing health and environmental challenges. It underscores the importance of establishing a cohesive framework to guide stakeholders in building the necessary infrastructure, policies, and partnerships. The systematic approach described here could be adapted and scaled to similar contexts, further amplifying its global relevance.

Conclusion

This study provides a critical first step toward realizing the vision of systems biology development in Iran. It highlights both the immense potential of this interdisciplinary approach and the need for coordinated efforts to overcome implementation challenges. Future work should focus on refining the proposed strategies, fostering cross-disciplinary collaborations, and addressing gaps in infrastructure and policy to ensure the sustainable growth of systems biology in the country.

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Conflicts of interest

There are no conflicts of interest.

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Supplementary Table 1: Interview questions with 13 Iranian pioneers in the field of systems biology, as the members of "Iranian Systems Biology Committee"

Question
What is your definition of systems biology? In other words, what features should a biomedical project have to be considered in the field of systems biology?
To where you see the scope of systems biology? Biological sciences? Medicine? Pharmacology? Microbiology? Immunology? Genetics? Physiology? Psychology? Agriculture?
What keywords would you suggest for studying in the field of systems biology?
Why do you think systems biology is important? What in the world today requires us to consider the biology of systems important?
What do you know about the approach of other countries in this regard? Their vision? Their strategic documents? How is their research funded?
How do you see our country in this regard? Basically, is it appropriate for our country to invest in this field? Is it possible for our country to excel in this field? Or do you think another field is more appropriate? What are our comparative advantage? Relative weakness? Strengths? Threats?
What is the desired future (not the dream future) of our country in this regard? What results do you think are possible to achieve in the 5-, 10-, and 15-year time horizons?
In order to realize the development of systems biology in the country, in your opinion, in what key areas planning and activity is needed?
Which academic disciplines should be involved to achieve the desirable future?
What logical steps must be taken to achieve the desirable future?
What are the most important obstacles to achieving the desirable future?
What are the institutions in power (scientific, legal, financial, etc.) for the development of systems biology in Iran?
What are the beneficiary institutions for the development of systems biology in Iran?

Supplementary Table 2: Questionnaire for evaluating the weight and score of different influencers on the development of systems biology approach

Name (optional)	Position	University/institution	Field of study	Degree

Entry	Class	Influencer
1	Human resources	Access to capable or interested and talented human resources in the field of biomedicine
2		Access to capable or interested and talented human resources in data science
3		Proper management of specialized human resources in research activities
4		Ability and skill to create interdisciplinary and group collaborations
5	Strategic documents	The importance of developing systems biology from the perspective of strategic and upstream documents of the country
6		Ensuring the implementation of relevant strategic documents in the country and the commitment of managers to them in long-term decision-making
7	Awareness of the importance of systems biology	Awareness of national level managers related to systems biology (supreme council of the cultural revolution, vice president for science and technology, ministries of science and health, ministry of agriculture, etc.)
8		Awareness of senior and middle managers of education and research (heads and deputies of universities, research institutes, etc.)
9		Awareness of industry managers related to systems biology (pharmaceutical, food, agriculture, livestock, biotechnology, laboratory sciences, health services, etc.)
10		Awareness of the academic community (such as professors, researchers, students, etc.)
11	Infra-structures	Existence or ability to provide the appropriate hardware to generate omics data
12		Existence or ability to provide appropriate hardware for storage, exchange and analysis of big data
13		Ability to analyze data with freely available software
14		Existence of supporting and investing industries related to this approach, such as the pharmaceutical industry
15	Education and research	Possibility of preventing the implementation of weak projects called systems biology and making the face of this field vulgar in the country
16		Possibility to pay attention to the function of systems biology in industry (whether goods or services) along with the academic structure
17		The relevance of the titles of the existing university courses to the new generation of biology i.e., systems biology
18		Possibility of conducting research activities in the form of international teams
19		Ability to access omics data abroad: including open access data, restricted data, or access through collaboration
20		Existence of sanctions against Iran to supply the required materials and equipment

Supplementary Table 3: Questionnaire for evaluating the power and benefit of different stakeholders in the development of systems biology approach

Name (optional)	University/institution	Field of study	Degree
Entry	**Stakeholder**		
1	Vice President for Science and Technology		
2	Presidential Biotechnology Development Headquarters		
3	Ministry of Health		
4	Ministry of Science		
5	Ministry of Agriculture		
6	Ministry of Defence		
7	Ministry of Information		
8	Relevant commissions in the Islamic Consultative Parliament (such as the Health Commission or the Education and Research Commission)		
9	Universities of Medical Sciences		
10	Universities under the Ministry of Science		
11	Researchers and graduate students in the field of systems biology		
12	Hospitals and treatment clinics		
13	Veterinary clinics		
14	Physicians		
15	Patients		
16	Pharmaceutical companies		
17	Companies active in the field of systems biology		
18	Investment funds		
19	The Revolutionary Guards		
20	People include charities and NGOs		
21	Insurance Companies		
22	Supportive foundations such as the Barakat Foundation		

NGO: Non-governmental organization