ANIMAL PATHOLOGY, MORPHOLOGY, PHYSIOLOGY, PHARMACOLOGY AND TOXICOLOGY

ПАТОЛОГИЯ ЖИВОТНЫХ, МОРФОЛОГИЯ, ФИЗИОЛОГИЯ, ФАРМАКОЛОГИЯ И ТОКСИКОЛОГИЯ

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Development of an Intelligent System for Diagnosing Rumen Acidosis in Cows. Part 2: Computer Implementation

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Abstract

Introduction. In the first part of the study, the relevance of improving the methods of rumen acidosis diagnostics in cows based on the intelligent systems was substantiated and the use of fuzzy set theory as a tool for such systems was proposed. The structure of the hierarchical-type intelligent system was developed, and formalization of the problem was completed. In the second part of the study, computer implementation of the fuzzy-logic-based intelligent system for diagnosing acidosis was completed using Xcos tool of Scilab software, and a computer application was developed in the Scilab+Scinotes environment as its practical implementation.

Materials and Methods. The study was conducted at Ural State Agrarian University and Northern Trans-Ural State Agricultural University from 2022 to 2025. The intelligent system techniques, fuzzy set theory and fuzzy logic methods, and Mamdani fuzzy inference system were used to conduct the study. A computer model for rumen pathology assessment was created based on the generalized smart system by means of Xcos tool of Scilab software. Computer implementation of the intelligent system was completed in the Scilab+Scinotes environment.

Results. For solving a problem of hierarchical-type intelligent system, the production rule bases, which included various combinations of diagnostic parameters and respective degrees of rumen acidosis pathology, were developed. Synthesis of fuzzy systems was performed using SciFLT tool of Scilab software. A generalized model of an intelligent system for diagnosing rumen acidosis in cows was developed using Xcos tool of Scilab software. Computer implementation of the intelligent diagnostic system was completed in Scilab software with embedded Scinotes text editor.

Discussion and Conclusion. The model of an intelligent system proposed by the authors is innovative and can be recommended for practical implementation into the expert advisory systems, for automation of veterinary workstations, and for using in modern veterinary telemedicine technologies.

Keywords: rumen acidosis in cows, rumen acidosis pathology, diagnostics, intelligent diagnostic system, fuzzy set theory, computer implementation

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Оригинальное теоретическое исследование

Создание интеллектуальной системы диагностирования ацидоза рубца у коров. Часть 2: Компьютерная реализация

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Аннотация

Введение. В первой части работы обоснована актуальность совершенствования методов диагностирования ацидоза рубца у коров на базе интеллектуальных систем и предложено использовать в качестве инструментария такой системы теорию нечетких множеств. Была разработана структура интеллектуальной системы иерархического типа и выполнена формализация задач. На втором этапе исследований выполнена компьютерная реализация интеллектуальной нечеткой системы на нечеткой логике диагностирования ацидоза в среде Xcos приложения Scilab, а для практического применения — разработана компьютерная программа в среде Scilab+Scinotes.

Материалы и методы. Исследование проведено в Уральском государственном аграрном университете и Государственном аграрном университете Северного Зауралья в период с 2022 по 2025 гг. Использованы методы интеллектуальных систем, теории нечетких множеств, нечеткой логики, нечеткий вывод выполнен методом Мамдани. Программная реализация модели оценки патологии рубца в обобщенной интеллектуальной системе выполнена средствами Xcos приложения Scilab. Компьютерная реализация интеллектуальной системы выполнена в среде Scilab+Scinotes.

Результаты исследования. Созданы базы продукционных правил для задачи интеллектуальной системы иерархического типа, включающие различные сочетания диагностических параметров и соответствующие им степени патологии ацидоза рубца. Проведен синтез нечетких систем в среде SciFLT приложения Scilab. Разработана обобщенная модель интеллектуальной системы диагностирования ацидоза рубца у коров в среде Xcos приложения Scilab. Выполнена компьютерная реализация интеллектуальной системы диагностирования в программах Scilab и Scinotes.

Обсуждение и заключение. Предложенная авторами модель интеллектуальной системы обладает новизной и может быть рекомендована для практического использования в советующих экспертных системах, для автоматизации рабочего места врача-ветеринара, в современных технологиях ветеринарной телемедицины.

Ключевые слова: ацидоз рубца у коров, патология ацидоза рубца, диагностирование, интеллектуальная система диагностирования, теория нечетких множеств, компьютерная реализация

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Introduction. Ensuring sustainable development of animal husbandry is a key objective stipulated in the State Program for the Development of Agriculture in the Russian Federation [1]. Thus, the primary objective of the industry recognized at the government level for the nearest future is annual growth of cattle population and reduction of its mortality[1].

Rumen acidosis is one of the most widespread diseases in cattle. It is called “the prime cause underlying all health problems in cows” [2] and “the most acute problem of any herd, both the high-yielding or ordinary one” [3]. All this justifies the necessity to improve the diagnostics of acidosis at any stage of the disease. For this purpose, we have created an intelligent system for diagnosing rumen acidosis in cows. At the first stage of the study [4], formalization of the tasks was carried out based on the concept of fuzzy logic: a set of diagnostic parameters for assessing the degree of acidosis pathology was justified; the structure of the hierarchical-type intelligent system was developed; the problem was formalized using the fuzzy set theory methods. The objective of the second part of the study is to complete computer implementation of the earlier formalized fuzzy-logic-based intelligent system for assessing the rumen acidosis pathology in cows.

To achieve this objective, the following tasks were defined:

1) development of the rule bases to solve a problem of hierarchical-type intelligent system;

[1] *Strategy for the Development of Agro-Industrial and Fishery Complexes of the Russian Federation for the Period up to 2030*. Approved by the Resolution of the Government of the RF No. 2567-r of September 8, 2022.

2) synthesis of fuzzy systems using SciFLT tool of Scilab software;

3) development of a generalized model of an intelligent system for diagnosing rumen acidosis using Xcos tool of Scilab software;

4) computer implementation of the intelligent diagnostic system in Scilab software with embedded Scinotes text editor.

Materials and Methods. The study was conducted at Ural State Agrarian University (Ekaterinburg) and Northern Trans-Ural State Agricultural University (Tyumen) from 2022 to 2025. Methods of veterinary medicine, the intelligent system techniques, fuzzy set theory and fuzzy logic methods, along with Mamdani fuzzy inference system were used to conduct the study. Synthesis of fuzzy systems was performed using SciFLT for Scilab software (Scilab Consortium, France). A computer model for rumen pathology assessment was created based on the generalized smart system by means of Xcos tool of Scilab software. Computer implementation of the intelligent system was completed in the Scilab+Scinotes environment.

Research Results

1. Development of the production rule bases. Various combinations of diagnostic parameters and corresponding to them degrees of acidosis pathology were taken to develop the rule bases. The degree of pathology will vary from "Permanent" to "Acute", and the linguistic variable will take values from "Min" (the animal is healthy) to "Max" (acute phase).

Significant dependencies of the disease degree from the *pH* of rumen contents *(pH*) and Fat content in milk *(F)* should be determined according to the rules of fuzzy set theory ("If A = B and C = D and ... then $m_i = n_j$ and ...") and be based on the known data [5–22].

The developed fuzzy production rule bases for inferencing the function $Y_{12} = f(pH, F)$, the function $Y_{34} = f(Pulse\ Rate, Respiratory\ Rate)$, and the resulting function for the Degree of Acidosis Pathology $DAP = f(Y_{12}, Y_{34})$ are presented in Tables 1–3.

Table 1

Rule base for inferencing the function $Y_{12} = f(pH, F)$

Values of the linguistic variable *"pH"*	Values of the output fuzzy subsets "*pH* – Fat content, Y_{12}" upon changing the fuzzy function "Fat content, F"				
	Minimum, Min	Low, L	Average, Av	High, H	Maximum, Max
Highest Acidity, HighestAc	Max	Max	H	Av	L
Moderate Acidity, ModAc	Max	H	Av	L	L
Neutral	H	Av	L	Min	Min
Moderate Alkalinity, ModAlk	Av	L	L	Min	Min
Highest Alkalinity, HighestAlk	L	Min	Min	Min	Min

Table 2

Rule base for inferencing the function $Y_{34} = f(PR, RR)$

Values of the linguistic variable "Pulse Rate, *PR*"	Values of the output fuzzy subsets "Respiration – Pulse, Y_{34}" upon changing the fuzzy function "Respiratory Rate, RR"				
	Minimum, Min	Low, L	Average, Av	High, H	Maximum, Max
Minimum, Min	Min	Min	Min	L	Av
Low, L	L	L	L	Av	H
Average, Av	L	Av	Av	H	Max
High, H	Av	Av	H	Max	Max
Maximum, Max	Av	H	Max	Max	Max

Table 3

Rule base for inferencing the function $DAP = f(Y_{12}, Y_{34}) = f(pH, F, PR, RR)$

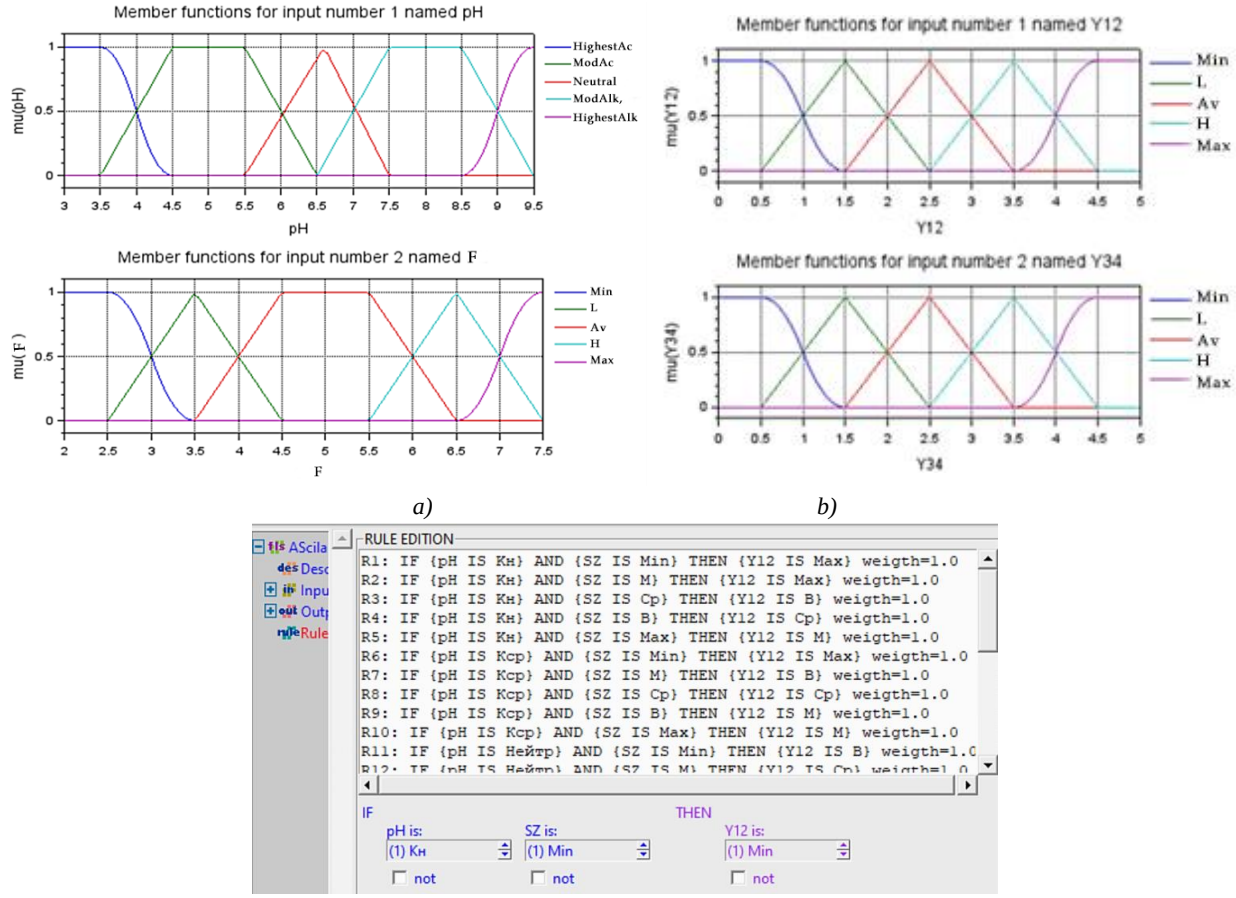
Values of the linguistic variable "*pH* – Fat content,Y_{12}"	Values of the output fuzzy subsets *"DAP"* upon changing the fuzzy function "Respiration–Pulse, Y_{34}"				
	Minimum, Min	Low, L	Average, Av	High, H	Maximum, Max
Minimum, Min	Min	Min	Min	L	L
Low, L	Min	Min	L	Av	Av
Average, Av	Min	L	Av	H	H
High, H	L	Av	H	H	Max
Maximum, Max	Av	H	Max	Max	Max

2. Synthesis of fuzzy models of the problem. Fuzzy inference operations and synthesis of fuzzy models of the problem were performed using the rule bases. The SciFLT Editor toolbox for Scilab software was used to implement the developed formal formulation of the fuzzy inference problem, which is part of the intelligent system structure[4]. Fuzzy inference for obtaining the resulting membership functions is shown in Fig. 1a–c. In accordance with the fuzzy inference methodology[5], on the example of the function $Y_{12} = f(pH, F)$, the operations were performed in the following order:

1) fuzzification of problem variables (Fig. 1*a–b*);

2) development of a rule base (Fig. 1c).

After completing fuzzy inference and defuzzification, the resulting functions $Y_{12} = f(pH, F)$; $Y_{34} = f(PR, RR)$ and $DAP = f(Y_{12}, Y_{34})$ were obtained. They are shown graphically in Fig. 2.



a) *b)*

c)

Fig. 1. Fuzzy inference operations by means of SciFLT toolbox: a) *pH* and F variables; b) Y_{12} and Y_{34}; c) fuzzy inference rule base for the function $Y_{12} = f(pH, F)$

Note: Russian and Latin symbols in Fig. 1 c) correspond to the English equivalents as follows:
Кн – HighestAc
Кср – ModAc
Нейтраль – Neutral
Щср – ModAlk,
Щн – HighestAlk
SZ – F
Мин – Min
M – L
Ср – Av
B – H

[4]*Scilab*. URL: https://www.scilab.org (accessed: 19.06.2024).
[5]Piegat A. *Fuzzy Modeling and Control: with 96 Tables.* Heidelber, New York: Physica Publ.; 2001.760 p.

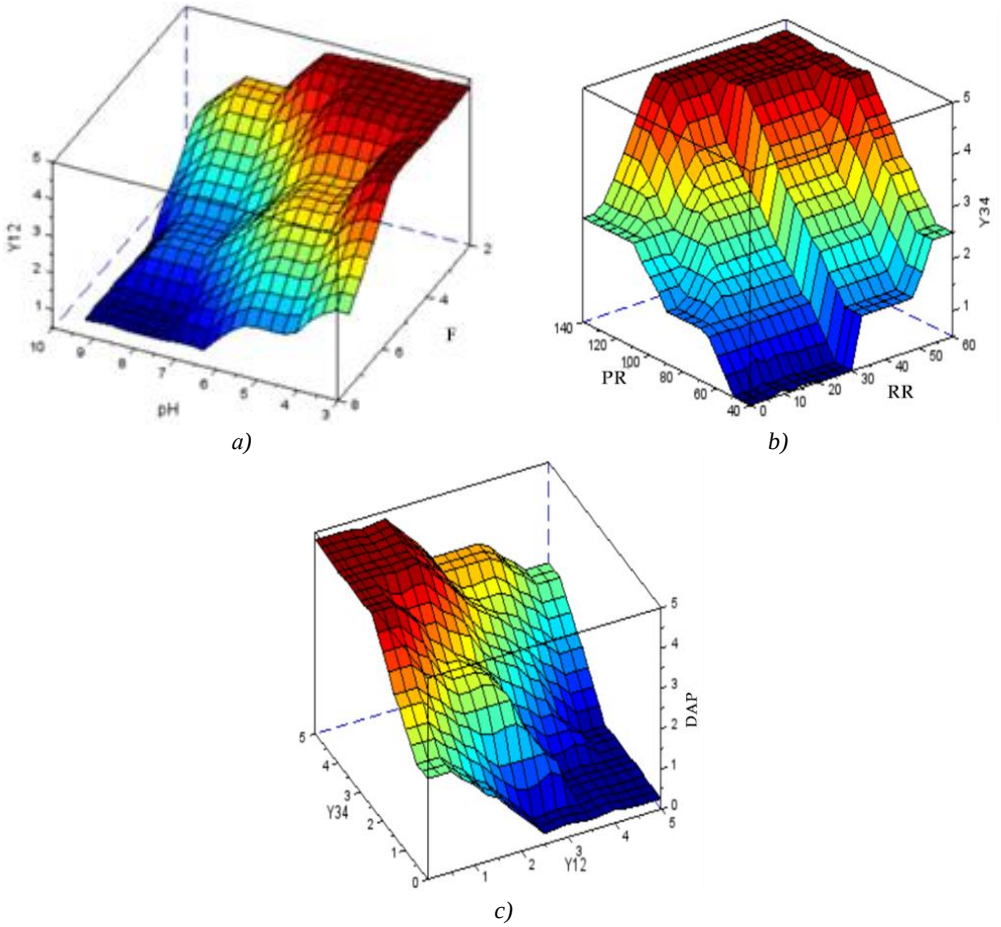


Fig. 2. Resulting functions: *a* — $Y_{12} = f(pH, F)$; *b* — Y_{34} = f(PR, RR); *c* — $DAP = f(Y_{12}, Y_{34})$

3. Development of a generalized model of an intelligent diagnostic system. Figure 3 demonstrates a model of an intelligent system created by means of Xcos toolbox, which uses Constant visual blocks for inputting initial data and Mux multiplexers for generating a data sequence vector and transmitting data to Controller blocks. These blocks address the corresponding fuzzy systems to obtain fuzzy inference results. The calculation results are displayed on a virtual electronic display.

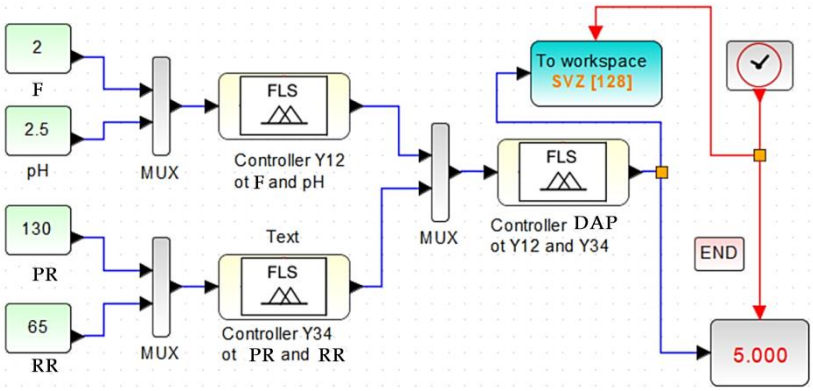
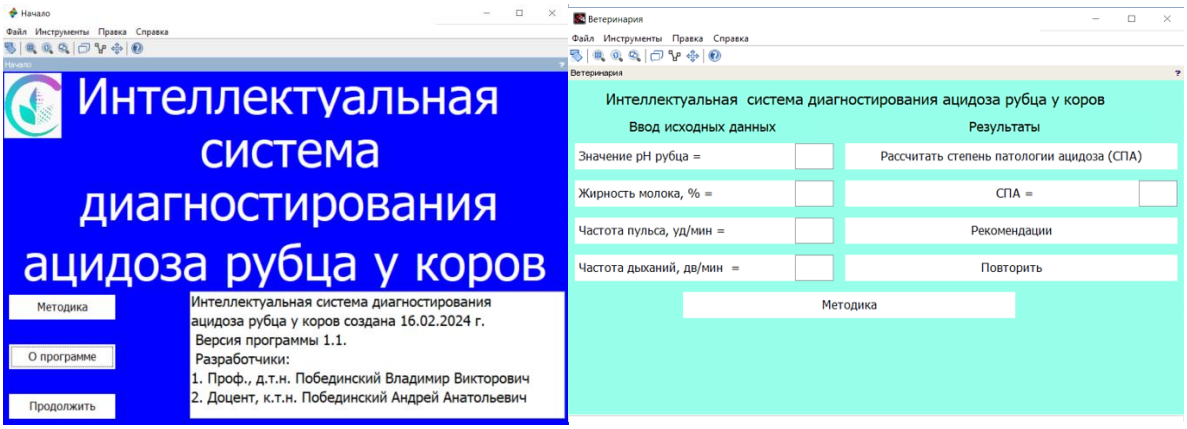


Fig. 3. Model of an intelligent system created by means of Xcos toolbox

4. Computer implementation of the intelligent diagnostic system. To be used in practice, the model requires a user interface. Scilab+Scinotes were used for its development. The main visual interface forms are shown in Figure 4. They provide the information about the program, documentation, input/output data, and recommendations for treating rumen acidosis depending on its pathology degree.



a) *b)*

Fig. 4. The main user interface forms of the program: a — home form; *b* — data input/output and program operation form

Note: Russian texts in Fig. 4 a) correspond to the English equivalents as follows:
Методика – Methodology
О программе – About the program
Продолжить – Continue
Интеллектуальная система диагностирования ацидоза рубца у коров создана 16.02.2024г. Версия программы 1.1.
Разработчики:
1.Проф., д.т.н. Побединский Владимир Викторович
2.Доцент, к.т.н. Побединский Андрей Анатольевич
An intelligent system for diagnosing rumen acidosis in cows was developed on February 16, 2024. Program version 1.1.
Developers:
1. Vladimir V. Pobedinskiy, Dr.Sci.(Eng.), Prof.
2. Andrey A. Pobedinskiy Cand.Sci.(Eng.), Associate Prof.

Note: Russian texts in Fig. 4 b) correspond to the English equivalents as follows:
Интеллектуальная система диагностирования ацидоза рубца у коров – An intelligent system for diagnosing rumen acidosis in cows
Ввод исходных данных – Input of initial data
Значение pH рубца = pH of rumen contents
Жирность молока, % = Fat content in milk, %
Частота пульса, уд./мин = Pulse Rate, beat/min
Частота дыханий, дв./мин = Respiratory Rate, move-ments/min
Результаты – Results
Рассчитать степень патологии ацидоза (СПА) – Calculate degree of acidosis pathology
СПА = DAP
Рекомендации – Recommendations
Повторить – Repeat
Методика – Methodology

Discussion and Conclusion. The Artificial Intelligence undoubtedly has great potential for development in the agro-industrial complex. The intelligent system for diagnosing rumen acidosis pathology in cows proposed by the authors is innovative and can be implemented into the expert advisory systems, be used for automation of workplaces of the veterinarians and in modern veterinary telemedicine technologies or for other purposes.

The adequate work of the system is an issue of particular importance, due to impossibility to apply the traditional, standard approaches to it. Unlike other models, intelligent rule-based systems, i.e., fuzzy systems and neural networks, get trained throughout their entire existence cycle [23]. This means that upon changing external conditions (e.g., methods of treatment, pharmacological agents, or the occurrence of side effects), new sets of rules will be incorporated into the fuzzy production rule bases, and the operation of intelligent system will be automatically adjusted. If this procedure is automated by means of software rather than performed manually, the system becomes self-learning.

The standard basic treatment protocols have been inserted as a template into the process of forming treatment recommendations. Possibility for a veterinarian to adjust and clarify the treatment is obligatory foreseen, as the software remains an advisory tool for a veterinarian to make a final decision.

Summing up the study results, it can be concluded that the proposed intelligent system is capable of quite accurate diagnostics of acidosis pathology and is versatile due to its ability to improve the diagnostic process (by adding new rules to the rule bases or adding other diagnostic parameters) without requiring any changes to the program code.

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Claimed Contributorship:

VV Pobedinskiy: scientific supervision, formulating the main concept, aim and objectives of the research, development of a model and intelligent system software, preparing the text, formulating conclusions.

AA Pobedinskiy: justification of diagnostic parameters for an intelligent system, analysis of research results, correcting conclusions.

GA Iovlev: formatting and finalizing the text.

Conflict of Interest Statement: **the authors declare no conflict of interest.**

All authors have read and approved the final manuscript.

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