

## Review article

# The evolution of medical informatics in China: A retrospective study and lessons learned



Jianbo Lei<sup>a,b,\*</sup>, Qun Meng<sup>c</sup>, Yuefeng Li<sup>c</sup>, Minghui Liang<sup>d</sup>, Kai Zheng<sup>e,f</sup>

<sup>a</sup> Center for Medical Informatics, Peking University, Beijing, China

<sup>b</sup> Department of Biomedical Engineering, Southwest Medical University, Luzhou, China

<sup>c</sup> Center for Statistics and Information, National Health and Family Planning Commission, China

<sup>d</sup> National Institute of Hospital Administration, National Health and Family Planning Commission, China

<sup>e</sup> School of Public Health Department of Health Management and Policy, University of Michigan, Ann Arbor, USA

<sup>f</sup> School of Information, University of Michigan, Ann Arbor, USA

## ARTICLE INFO

## Article history:

Received 28 June 2015

Received in revised form 25 February 2016

Accepted 22 April 2016

## Keywords:

China medical informatics

Education and research

Disciplinary infrastructure

Discipline evolution

Suggestion

## ABSTRACT

**Background:** In contrast to China's giant health information technology (HIT) market and tremendous investments in hospital information systems the contributions of Chinese scholars in medical informatics to the global community are very limited. China would like to have a more important position in the global medical informatics community.

**Objective:** A better understanding of the differences between medical informatics research and education in China and the discipline that emerged abroad will better inform Chinese scholars to develop right strategies to advance the field in China and help identify an appropriate means to collaborate more closely with medical informatics scholars globally.

**Method:** For the first time, this paper divides the evolution of medical informatics in China into four stages based on changes in the core content of research, the educational orientation and other developmental characteristics. The four stages are infancy, incubation, primary establishment and formal establishment. This paper summarizes and reviews major supporting journals and publications, as well as major organizations. Finally, we analyze the main problems that exist in the current disciplinary development in China related to medical informatics research and education and offer suggestions for future improvement.

**Conclusions:** The evolution of medical informatics shows a strong and traditional concentration on medical library/bibliographic information rather than medical (hospital information or patient information) information. Misdirected-concentration, a lack of formal medical informatics trained teaching staff and mistakenly positioning medical informatics as an undergraduate discipline are some of the problems inhibiting the development of medical informatics in China. These lessons should be shared and learned for the global community.

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\* Corresponding author at: Center for Medical Informatics, Peking University, Beijing, China; No. 38, Xueyuan Road, Haidian District, Beijing 100191, China.

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## 1. Introduction

Medical informatics is defined [1] by experts of the American Medical Informatics Association as ‘the interdisciplinary field that studies and pursues the effective uses of biomedical data, information, and knowledge for scientific inquiry, problem solving and decision making, motivated by efforts to improve human health’. Medical informatics has a long history and established a comprehensive disciplinary infrastructure system. The discipline systems that have been gradually recognized include bioinformatics, image informatics, clinical informatics, public health informatics, nursing informatics, consumer health informatics and other branches. However, the evolution of medical informatics in China originated from the traditional medical information science or library science, which is very different in discipline systems, theory and research content compared to formal medical informatics. Recently, there has been rapid development of the application of health information technologies such as hospital information systems in China, although the development of medical informatics as a discipline has relatively lagged. The establishment and development of a discipline are inseparable from the establishment of a discipline system, major supporting journals and publications, and relevant organizations and associations. Medical informatics, which is an emerging, fast-developing and multidisciplinary discipline, faces many challenges and difficulties in China due to the formal informatics faculty deficit and other historical factors. To promote its development, this paper provides a systematic and comprehensive overview of the historical development stages of medical informatics, major publication and research content, and relevant organizations in China, elaborates the differences and connections between medical informatics and traditional medical information and library disciplines (which were considered ‘medical informatics’ for a long time in China), and also analyzes the existing problems and proposes suggestions for the field’s future development.

## 2. Four stages of the evolution of medical informatics

### 2.1. Infancy period (1979–1997)

This stage cannot be called a period of medical informatics. Instead, it was a period that oversaw the gradual formation of medical informatics, or to be precise medical information science. In 1979, China’s first medical informatics magazine the *Journal of Medical Information* (renamed *Journal of Medical Informatics* in 2006) was started [2], marking the germination of medical informatics-based research. However, during this period China’s medical informatics research focused on medical information (more frequently called intelligence), medical libraries and medical journals [3]. Such concentrations of medical bibliographical information research included reviews and summaries, the presentation of situations and reforms, development planning, and suggestions for medical bibliographical information rather than hospital information. The focus of medical library science is the generation of the medical library and the development direction of library management and its influencing factors, including training of librarians, collection development, management systems and the introduction of foreign libraries. From 1985 to 1987, in

order to train professional talent on medical library information, the Ministry of Education and the Ministry of Health approved the establishment of an undergraduate education program formally named medical library information in four institutes [the so-called ‘old four’ among related scholars: Tongji Medical University (now Tongji Medical College, Huazhong University of Science and Technology), Hunan Medical University (now Xiangya School of Medicine, Central South University), Norman Bethune Medical University (now Norman Bethune College of Medicine, Jilin University) and China Medical University] [4]. This program did make certain contributions to the development of the medical informatics discipline, although very limited genuine medical informatics professional talent was cultivated by this program. Indeed, the development of talent was restricted by the nature of this program because the teaching philosophy and the direction were based on medical library and bibliographical information rather than hospital information or patient information.

### 2.2. Incubation period (1998–2002)

This period marks the gradual incubation and transformation of medical informatics in China. In 1998 [4], the above mentioned four universities put the discipline ‘Medical Library Information’ into the category ‘Information Management and Information System’, which was a discipline established by the Ministry of Education. Other institutions began a similar discipline of medical information engineering or set disciplines such as hospital information management, health information management and information systems under another established major called ‘public health management’ within the School of Public Health. During this period, the research focus gradually shifted from medical (library/bibliographical) information to medical literature retrieval and new science and technology reviews, which was a service provided by librarians to offer researchers a systematic review on certain topics [3]. However, the traditional research focused on medical library and medical journal studies still dominated in this field because hospital information was not the focus of the government who paid for the technologies and there was a shortage of teachers in this field; this period was simply a transforming period in which the concept, teaching and research on medical informatics were discussed, but very few studies on medical informatics were truly performed.

### 2.3. Primary establishment period (2003–2009)

This period encompassed the early days of the genuine discipline of medical informatics. In 2003, medical informatics was separately listed in the professional catalogue of higher education by the Ministry of Education, and the name ‘Medical Informatics’ was formally established [4]. The traditional medical library information gradually faded out of sight; even traditional medical library research shifted its attention to the construction of digitalized libraries, medical library information services and library knowledge management. Emerging technologies based on the digitalization, network and individualization were on the rise. Importantly digital public health and hospital information systems made significant progress during this period due to the sharp rise

in practical application demands, especially those stimulated by the emergent demand of real time monitoring of SARS in 2003 by the government. At the same time, many high level hospitals begun to establish Health Information Systems (HIS), which was a typical clinical application of the theories and techniques of medical informatics discipline [5]. Digital medicine gradually became the focus, and genuine research and applications in the field of medical informatics emerged, such as electronic medical records, medical image storage and transmission systems and telemedicine [6,7]. Significantly the previously mentioned four universities gradually changed the name of the program to medical (medicine) informatics after 2003, and more institutions started to establish undergraduate specialties in medical informatics. Ironically, although hospital informatization developed rapidly in the application fields, in the academic fields a genuine disciplinary education system in medical informatics was seldom established due to the shortage of teachers with true medical informatics backgrounds. Although digital medicine began to attract some attention, it was not included in the core content of research and education in the program of medical informatics in universities. The Health Information Technologies (HIT) industry did not have the support of both trained medical informatics professionals and the achievements of scientific research from medical informatics. Graduates trained in the program of medical informatics, in fact medical library informatics, were not recognized by the HIT sector (i.e., HIT companies and the IT department of hospitals). Thus, the formal establishment of the medical informatics discipline had yet to be accomplished. A special phenomenon during this period was the “hot HIT industry cold academic medical informatics”. There was an obvious disconnect between medical informatics academic education and HIT practical application. Many IT departments of hospitals did not recognize medical informatics as a discipline because the graduates of so-called medical informatics programs, who were traditionally trained to work in medical libraries, were unable to work in their IT departments.

#### 2.4. Formal establishment period (2010-)

On April 6, 2009, *Opinions of the CPC Central Committee and the State Council on Deepening the Health Care System Reform* was officially issued. This marked the formal beginning of China's second ambitious health reform. The infrastructure of “Four beams and eight columns” designed to establish a basic medical and health care system for urban and rural residents was formally put forward by the Chinese government in this report. The construction of medical and health informatization was identified as one of the eight columns that support the health care system reform [8]. Since then, huge funds have been invested in the construction of China's medical and health informatization by the government and medical informatization users. However, the contradiction between the demands of applied talent and those educated in medical informatics programs is worsening, and the critical shortage of professional interdisciplinary talent able to meet the development requirements of health informatization under the new situation demands a prompt solution.

On April 13, 2010, the leadership of Peking University Health Science Center established the “Center for Medical Informatics of Peking University” (hereafter referred to as the Center) through the integration of relevant resources that existed in Peking university based on thorough investigation and the strategic promotion of interdisciplinary studies [9]. There were three significant differences between the Center and other universities in China. First, the Center planned to primarily recruit faculty with formal training in medical informatics in the U.S. or Europe. Second, the Center only cultivated graduate level students, including Masters and PhDs, specializing in medical informatics rather than undergrad-

uate students like other institutions. Third, the Center planned to perform systematic and comprehensive medical informatics teaching and scientific research as well as personnel training in complete accordance with the disciplinary system of the U.S. This establishment of U.S. equivalent of a medical informatics graduate program indicated the formal establishment of the discipline of medical informatics in China. The construction of the systematic discipline infrastructure of medical informatics (i.e., clinical informatics, public health informatics, nursing informatics, consumer health informatics and bioinformatics) was a gradual process and has become the focus of attention [10]. At present, the Center has recruited ten formal faculty members. Five of them were from overseas, and one of the five had formal medical informatics training at the PhD level in the U.S. Although the program has faced unexpected difficulties and challenges, significant progress has been made since its founding. For example, the Center led the writing of two national textbooks (“Introduction to Health Informatics” [11] and “Bioinformatics” [12]), trained six Master's level students and one PhD level student, published research papers in the *Journal of the American Medical Informatics Association* [13], *International Journal of Medical Informatics* [14], *BMC Medical Informatics and Decision Making* [15], *Journal of Artificial Intelligence in Medicine* [16], *PLoS One* [17,18], *Medinfo proceedings* [19,20] and others [21,22], and received approximately twenty millions RMB (equivalent of more than three million USD) in grant supports from 985 building world-class university projects and the national natural science fund of China. Moreover, the Center has initiated and co-organized an annual training program of high level applied informatics professionals, and health CIOs, with the trainees all selected from major hospitals nationwide. The four stages of medical informatics in China are summarized in following Fig. 1.

### 3. Analysis of major journals and articles on medical informatics

Medical informatics as an emerging interdisciplinary subject does not have its professional core journals in China. In the Chinese academic community, the promotion of faculty is generally based on papers published in the SCI/EI list, “Chinese Core Journals” or so-called “Peking University Core Journals list” [23]. The Peking University Core Journal List is announced every four years by the Peking University library, followed by lower level Core Journals of Science and Technology, which are accepted by Master's student theses. Even the three major medical journals run by the three related organizations (the *Chinese Journal of Medical Library and Information Science* designated by the academic authoritative organization “Chinese Medical Association: Medical Informatics Branch”, *China Digital Medicine*, sponsored by the largest industry-based organization “Chinese Hospital Association Information Management Committee”, and the *Chinese Journal of Health Informatics and Management*, sponsored by the center for statistics and informatics of the Ministry of Health”) are not among the Peking University Core List. This discrepancy means that professional and authoritative articles on medical informatics should only be published in these three journals, but these articles cannot be counted toward faculty promotion. Therefore, many authors have to publish their medical informatics articles in non-medical informatics but core journals, thereby making it more difficult to publish medical informatics articles and promote medical informatics faculty. For the same reason, it is common to see medical informatics articles distributed broadly in different journals in China. Lu et al. [24] performed an analysis of the literature from 1999 to 2008. The authors found that the Core Journals of Peking University published a total of 1484 medical informatics papers that were distributed in

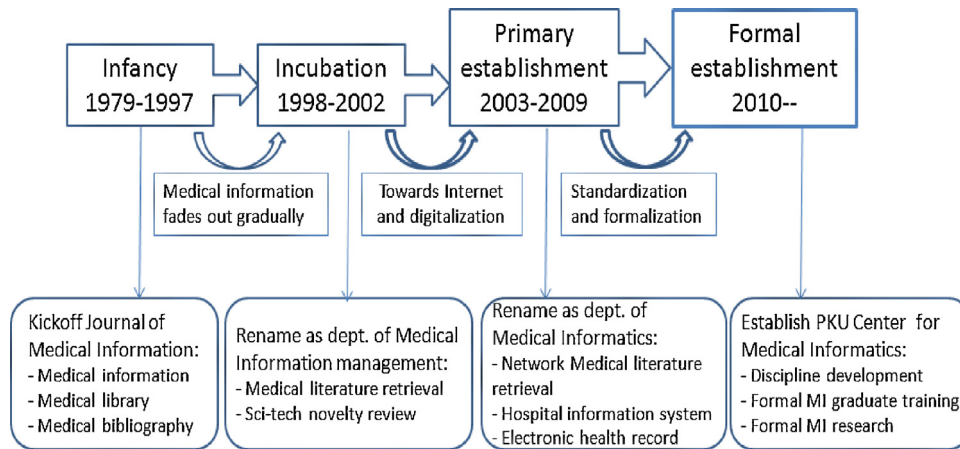


Fig. 1. Four stages of the evolution of medical informatics.

382 core journals. Core journals with more than 50 articles were the *Journal of Clinical Rehabilitative and Tissue Engineering Research* with 109 articles, *Chinese Hospital Management* with 92 articles and the *Chinese Journal of Hospital Management* with 68 articles. Non-core journals with a large number of medical informatics articles were the *Journal of Medical Informatics* with 533 articles, *Medical Information* with 480 articles and the *Chinese Journal of Medical Library and Information Science* with 457 articles.

Generally, there are nine types of medical informatics-related journals. These journals can be divided into two categories: journals with a focus on medical information or medical informatics (no core journals) and journals with a focus on hospital management and a minor focus on medical information (see Table 1). Problems (i.e., the lack of core journals, typically fewer than 30 citations, a shortage of high-yield authors, a small number of high-quality papers, and the loss of manuscripts) have seriously impeded the development of the discipline of medical informatics, which is a great concern for scholars.

In addition to the above analysis of journals, topics of medical informatics papers manifest the unduly close relationship between medical informatics and medical library/bibliographical information, indicating the lack of a genuine medical informatics discipline. Li et al. [3] and Du et al. [25] performed co-word clustering analyses on high-frequency keywords in the *Journal of Medical Informatics* and the *Journal of Medical Library and Information Science*; and summed up “five hot spots; two major areas; one big flaw” in the 30-year study of China’s medical informatics field. “Five hot spots” refer to medical library construction; medical collection services; medical journal studies; medical literature quantity studies and information retrieval; medical information and information services. “Two major areas” include medical library construction and services and medical information technology and application. “One big flaw” indicates the lack of scientific research on disciplinary systems; especially the theory; research scope; methodologies and technologies of medical informatics. The only deficiency of this conclusion is its confusion of medical information and medical informatics.

The “one big flaw” conclusion coincides with our discovery of the publication results of Chinese scholars in the major international medical informatics journal: *International Journal of Medical Informatics*. A quick investigation revealed that over the past six years (from 2010 to 2015), Chinese scholars from mainland China only published seven papers in this journal: one in 2010 [26], one in 2011 [27], one in 2014 [28], two in 2012 [29,30], two in 2013 [31,32] and none in 2015. Further analysis of the seven publications showed that the research methods were not theoretical or technical devel-

opments. Instead, two applied surveys [28,32], one was a review [30], and four involved simple data comparisons [26,27,29,31]. If we expand the time period to the past fifteen years (from 2000 to 2015), only 11 papers were included from mainland China scholars. In contrast to the giant market of the Chinese HIT industry and 87 academic programs [30] in medical informatics, the contribution of Chinese scholars to the global medical informatics community is very limited, and the underlying reasons should be identified.

Therefore, although a recent review of medical informatics in China claimed [30] that there were 55 undergraduates, 27 Masters level and 5 PhD level medical informatics programs in China, we must recognize that we should not confuse the current actual mainstream medical information/library science with medical informatics. Problem areas are revealed by the above analysis of the evolution of medical informatics in China, the current training background and the composition of teaching staff, the curriculum, and the research/publications of medical informatics both domestically and internationally. By taking that recognition into account, we can really realize the major problems we are facing in China in medical informatics programs and take corresponding actions.

#### 4. Major organizations of medical informatics

At the present stage, there are five medical informatics associations in China [4,33,34]. In 1981, the Chinese Institute of Electronics established the China Medical Informatics Association (CMIA), which is China’s only member in the International Medical Informatics Association (IMIA). In 1990, The Preventive Medical Information Section was set up by the Chinese Preventive Medicine Association (CPMA). In 1993, the Chinese Medical Association founded Chinese Society of Medical information (CSMI), which set its foot in modern medical informatics in 2003. In 1995, the Chinese Hospital Association established the China Hospital Information Management Association (CHIMA), which joined with National Institute of Hospital Administration of the Ministry of Health to hold the annual Chinese Hospital Information Network Conference and gradually developed into a grand platform for the industrial application of medical informatization. In 1984, a conference was convened in Guangxi by Ministry of Health of the PRC to mark the formal establishment of the Chinese Health Statistics Association. In June 2004, the Ministry of Civil Affairs approved the official renaming of the Chinese Health Statistics Association to the Association of China Health Informatics (ACHI).

**Table 1**  
Major journals on medical informatics.

Journal title	Publication time	Supervising organization	Publishing organization	Publish location	Publication cycle	Core journal*	Change of name
Medical Informatics	1979	Ministry of Health, PRC	China Academy of Medical Science	Beijing	Monthly	None	Original name Medical Information and renamed <i>Journal of Medical Informatics</i> before 2006 None
Medical Information	1987	Ministry of Science and Technology, PRC	Committee of Medical Information Editors	Shanxi	Bimonthly	None	None
Chinese Journal of Medical Library and Information Science	1991	Academy of Military Medical Sciences of PLA	Medical Library of the Chinese PLA of Academy of Military Medical Sciences of PLA	Beijing	Monthly	None	Renamed <i>Chinese Journal of Medical Library</i> , Bimonthly in 2000, and <i>Chinese Journal of Medical Library and Information Science</i> . Monthly in 2002. None
China Digital Medicine	2006	Ministry of Health, PRC	National institute of Hospital Administration of the Ministry of Health	Beijing	Monthly	Core Journals of Science and Technology	None
Chinese Hospital Management	1981	Heilongjiang Provincial Health Bureau	Periodical Office of Chinese Hospital Management	Heilongjiang	Monthly	Core Journals of Science and Technology, Chinese Core Journals	None
Chinese Journal of Medical Management	1985	China Association for Science and Technology	Chinese Medicine Association	Beijing	Monthly	Core Journals of Science and Technology, Chinese Core Journals	None
Journal of Preventive Medicine Information	1985	Sichuan Provincial Department of Health	Of Chinese Preventive Medicine Association Sichuan Center for Disease Control and Prevention	Sichuan	Monthly	Core Journals of Science and Technology	None
Chinese Journal of Information on Traditional Chinese Medicine	1994	State Administration of Traditional Chinese Medicine	Institute of Information on Traditional Chinese Medicine, China Academy of Traditional Chinese Medicine	Beijing	Monthly	Core Journals of Science and Technology	None
Chinese Journal of Health Informatics and Management	2004	Ministry of Health, PRC	Center for Health Statistics and Informatics	Beijing	Bimonthly	None	None

\* Web: <http://www.cceu.org.cn/demo/findcoreej.htm>.

## 5. Problems and suggestions

Although medical informatics in China has developed well in recent years, there are still some problems that urgently need to be resolved. First, this discipline has a weak foundation. As mentioned above, library science and philology occupied the major position in the early development of medical informatics, leaving computer science and information technology small room in which to grow. Second, the education infrastructure of this discipline needs to be improved. Although some Chinese institutions have set up research centers or graduate programs in medical informatics, most of the trainees educated in these programs are undergraduate level, and no complete or independent graduate school for medical informatics has been established. This is quite different from the practice of western countries, where medical informatics has been recog-

nized as a multidisciplinary field and education has started with graduate level students. Third, very few theoretical and technical research studies have been undertaken in this area, resulting in few published relevant works [5]. This lack has led to the unclear teaching direction of the discipline. Fourth, there are no core level Chinese medical informatics journals, which severely constrains the training of professionals, the promotion of their titles and the publication of high quality professional articles. The latter problem is due to the scarcity of teaching staff and professionals with comprehensive backgrounds in medical informatics. Only a small number of comprehensive talent has knowledge of both medicine and informatics, and even fewer are high quality professionals with formal medical informatics degree training [35,36]. This issue represents the largest bottleneck constraining the development of

medical informatics in China. All of these problems will hinder the development and application of medical informatics.

For the rapid and healthy development of medical informatics in China, first we must reshape an authentic discipline infrastructure by transforming from a medical information/library-oriented program to an informatics-centered program. This program should be able to prepare an informatics – based curriculum, teach professional theories, develop informatics – focused methods and techniques and establish a systematic and comprehensive teaching and research system for medical informatics. To achieve the above goals, we must introduce professional faculty with formal medical informatics training from abroad, who are able to publish methodologies/technologies-oriented original research papers in international medical informatics journals and collaborate with the global medical informatics community. Then, we should improve and accelerate the training of professional teachers and academic talent because this is the resource and driver to expedite the industrial side of development. To accomplish these goals, we should learn from foreign education programs that focus on high-level comprehensive graduate talent and integrate academic education and on-the-job training to establish a pragmatic educational system with a multi-level, balanced concentration, a variety of forms and attention to theories and methodologies. Third, we should also stress the training of applied talent stimulated by the huge demand of the booming market. High quality applied professionals will be conducive to the efficient translation of theoretical and methodological research in applied development in the huge HIT market, thereby promoting teaching and research and providing theoretical guidance for the development of the HIT industry. This approach will benefit the sustainable development of medical informatics as a discipline. Fourth, we should emphasize theoretical research and the development of core professional journals. We should take advantage of the huge demand of the industry and the generous national investment to conduct high level research on the theory, discipline system, proprietary technology and application of medical informatics to promote the systematic development of medical informatics as an independent discipline. Moreover, we should have our own core medical informatics journals so that our own scholars can publish relevant papers or monographs for promotion. Fifth, we should pay full attention to the leadership and coordination roles of existing associations related to medical informatics, to closely track the international development trends of each major area of specialization within this field, prepare a long-term development plan, set up projects focusing on theory and systems research, and promote the eventual comprehensive development of medical informatics eventually. Sixth, because medical informatics in western countries is an established discipline with a number of research directions and achievements, we should strengthen international cooperation and exchange by way of studying abroad and participating in high level forums and conferences to learn advanced concepts and technologies of the discipline in western countries, narrow the gap of research between Chinese scholars and the international community, avoid duplication of research and capital investment, and ultimately promote the brand new development of medical informatics as an independent discipline in China.

### Competing interests

The authors declare that they have no competing interests.

### Authors contributions

The work presented here was carried out in collaboration among all authors. JL and KZ formed the conception and study design. YL

### Summary points

- China's HIT industry has developed very rapidly because of huge demand and investment. China should have an important position in the global medical informatics community.
- However the contributions of Chinese scholars in medical informatics to the global community are very limited compared to China's huge HIT market and fast development of HITs.
- A systematic and comprehensive description of the history of medical informatics in China was given. A unique retrospective explanation of the evolution by four development stages was first proposed, each with distinguishing characteristics.
- The evolution of core concentrations from medical library/bibliographic information to medical (hospital information or patient information) informatics was identified.
- Misdirected-concentration, a lack of formal medical informatics trained teaching staff and mistakenly positioning medical informatics as an undergraduate discipline are some of the problems inhibiting the development of medical informatics in China.

did the literature review, and undertook data acquisition and data analysis. JL drafted the manuscript and KZ made significant revisions. QM, ML supervised the review method and interpretation of data and supplied valuable improvement suggestions

### Acknowledgements

This study was partly supported by the National Natural Science Foundation of China (NSFC) Grant #81171426 and #81471756.

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