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## CHANGES IN THE AGE OF MAXIMUM PRODUCTIVITY OF RESEARCHERS IN THE 21<sup>ST</sup> CENTURY

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**Introduction.** *The modern ideas concerning the dependence of the productivity of researchers on their age, which were formed in the last century, has become quite relevant given the changes in the organization and nature of research activities over the past few decades.*

**Problem Statement.** *The study of this issue becomes especially relevant for the optimization of personnel policy in R&D institutions of Ukraine in connection with the undesirable changes in the age structure of researchers.*

**Purpose.** *The purpose of this research is to study the dynamics of publication activity of a group of members of the National Academy of Sciences (NAS of Ukraine) who are working today (or worked in past) in R&D sector.*

**Materials and Methods.** *Information base of research is the data of System Science Ukraine information and analytical systems, bibliography of researchers, the official statistic data of Ukraine, and conventional mathematical and statistical methods.*

**Results.** *The changes in the publication activity of 126 full members and associate members of the NAS of Ukraine, who were born in 1920–1940, have been studied. It has been found that the maximum number of publications in the age group up to 30 years is reported only for 1.2% of the group; that in the age group from 30 to 34 years is reported for 16.7%, which corresponds to the Harvey Lehman results of the 1930s. At the same time, the maximum number of publications is 34.1 for age group from 35 to 39 years, 12% for the age group from 40 to 44 years, and 16% for age group from 45 to 49 years. The second increase in the number of publications is observed 5–10 years after the first peak, with the second peak sometimes exceeding the first maximum.*

**Conclusions.** *Today, the age of greatest productivity of researchers has shifted by about 30 years. This is because of the fact that the dynamics of the researcher productivity is determined not only by age-related changes in the physiological capabilities of his/her body, but also the nature of work, which in modern science has changed dramatically as a result of increasing amount of R&D and engineering information, complexity of research methods and technologies, and spreading joint research.*

**Keywords:** *maximum number of publications, time of researcher formation, the National Academy of Sciences of Ukraine (NAS of Ukraine), the age of greatest productivity of researchers.*

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Even in the last century, after the Lehman classic researches [1, 2]<sup>1</sup> many researchers repeatedly dealt with studying the age of researcher's maximum productivity [5, 6, etc.]. It should be noted that the change in productivity with age may be explained by purely physiological reasons as a person grows up and his/her creative abilities increase, then with advancing aging, they gradually decrease. Naturally, if this is the only factor, the maximum productivity would be reached at the same age for an artist or a writer, and for a scientist/researcher working in any field of science, as well as for a representative of any other creative profession. Probably, Harvey Lehman shared this opinion, but he used the number of scholarly research publications as an indicator of productivity, therefore his research concerns, above all, the researchers. The same concerns further research [5]. The basic conclusions obtained in them are shown in Table 1.

It is clear that such studies cannot provide a very high accuracy, and the maxima on the curves are rather broad, because each researcher has his/her own destiny, individual way of entering science, career opportunities, and external conditions in which he/she has to work. However, it is considered that the works published after H. Lehman generally do not contradict his results. The only difference is that one more maximum of productivity has been detected, and in addition, it is easy to see: the more recent the study, the more "older" the maxima. These shifts towards older age groups are not very large, and it is quite logical to attribute them to statistical error, or to the influence of some unaccounted but not very important factors.

At the beginning of the last century, the study of age dependence of the researcher's productivity

<sup>1</sup> His study of the age dependence of creative productivity is considered the first one, although in 1925, *Petrograd* publishing house published a small book by I.Ya. Perna [3], which presented the results of studying the age dependence of the productivity of people of creative professions, and even earlier, in 1869, A. Kettle published the results of his research on the most productive age of theatrical workers.

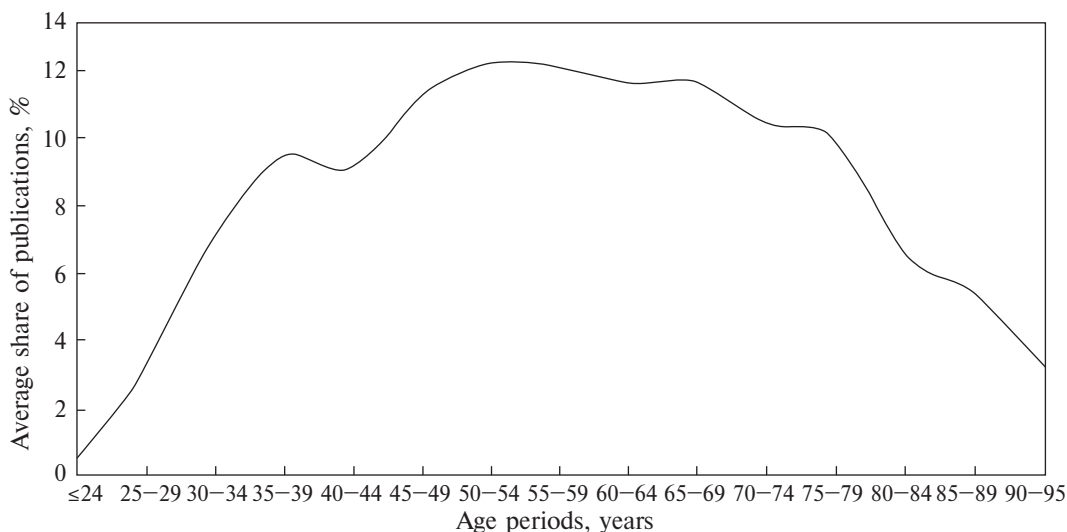
was mainly of academic interest, while in today's science, in which the researcher's profession has got widespread, this problem becomes very relevant. After all, the results of such research may be taken into account while forming research teams and, in general, while implementing human resource policy by science managers. The related problems become especially important in crisis conditions, in particular under the current conditions of Ukraine's science.

In [7], we have studied the dynamics of publishing activity of the members of the NAS of Ukraine using mainly the lists of printed research works of full and associate members from the bibliographic publications of the Academy as source data. As a result, it has been found that for more than half a century, after the Lehman research [1], there have been significant changes in the age dependence of the publishing activity of researchers. Its maximum has shifted by about 20 ÷ 25 years towards the older age groups. We have explained this by the fact that in modern science, the maximum of publishing activity depends not only on the physiological capabilities of a person, but also on the conditions in which he/she lives and works. These conditions have changed as well. In the process of his/her formation, the researcher needs to assimilate an incomparably increased amount of information, to master research methods that are much more complicated, and often, to spend many years to create an experimental facility, etc.

The conclusions presented in [7] were based on very smooth curves since they were built by group-

**Table 1. Basic Results of the Previous Studies of Productivity Maximum**

Authors	Age (years)	Peak achievements
A. Quetelet [4]	25 ÷ 50	50
N.Ya. Perna [3]	35 ÷ 40	
H.C. Lehman, [1, 2]	30 ÷ 35	
D. Pelz, F. Andrews [5]	(25 ÷ 39) – (45 ÷ 49)	
G.M. Dobrov et al. [6]	(40 ÷ 44) – (55 ÷ 59)	



**Fig. 1.** The age dynamics of publication activity of the NAS of Ukraine members, as averaged for the entire sample

ping the sample into ten-year age groups and included both today's researchers and those born in the 19<sup>th</sup> century. In addition, the data on publications of recent (or following the relevant biobibliographic publication) years were often unavailable. This did not raise any problems, as long as it was assumed that the maximum that was interesting for us fell on the young years, but the results led to a shift of our focus towards the age over 60 years.

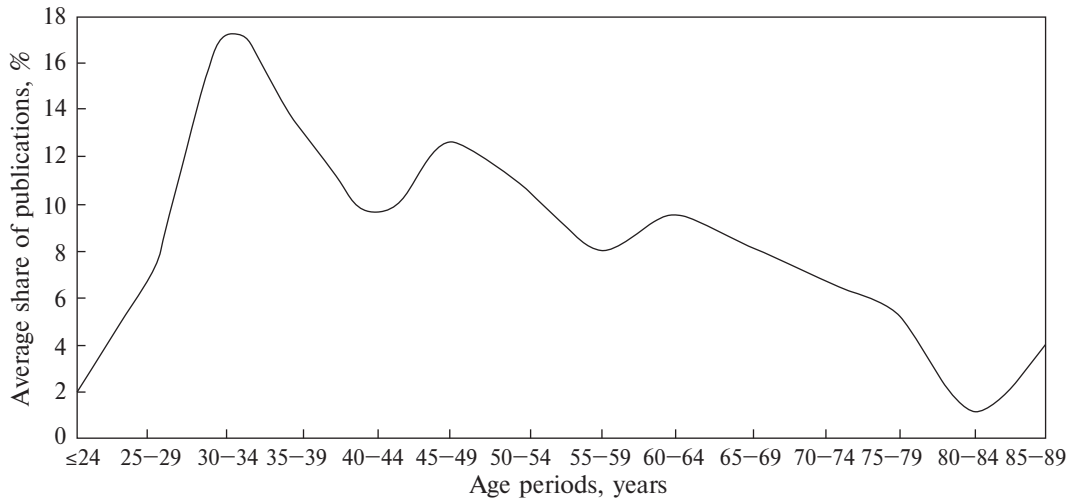
Today, it is possible to eliminate these shortcomings with the use of the capabilities of Bibliometrics of Ukrainian Science information and analytical system that has been actively developed now. It has already contained more than 52 thousand bibliographic portraits of Ukrainian researchers [8, 9]. In this regard, we have carried out a study, the results of which are offered in this paper.

Proceeding from the above, first of all, it is necessary to determine the parameters of the sample. Although from the point of view of studying the peculiarities of modern science, we are primarily interested in the activities of today's researchers or those who have lived in recent times, i.e. those who have worked or been working in the modern science. At the same time, in this case, it is not desirable to take into consideration the Academy

members younger than 60 ÷ 70 years, otherwise the dynamics of the period that is most interesting for us are distorted. Therefore, we have used the data on publications of the Academy members who were born between 1920 and 1945. The sample includes the lists of publications of 114 full members and 12 associate members of the NAS of Ukraine. Basically, they were representatives of the natural and engineering sciences: physics (25.4%), biology (22.2%), mathematics, mechanics, and cybernetics (19%), and engineering science (about 10 %).

The data on the number of publications have been divided into five-year periods according to the age groups used in the statistics, with the difference that we do not form "unlimited" age groups such as "≥60" or "≥70," but continue the five-year groups up to 90 years<sup>2</sup>. We have estimated the percentage of publications published by each researcher in the relevant five-year period out of the total number of papers published by him/her and averaged these data for the entire sample for each age group. Fig. 1 shows the results.

<sup>2</sup>Those few Academy members who have reached this age, as a rule, continue working and publishing scholarly research papers.



**Fig. 2.** The age dynamics of the average number of publications of the NAS of Ukraine members whose peak of publishing activity falls within 30 ÷ 34 years

For the age of about 40 years, we may see some traces of the maximum that was observed by H. Lehman for the age of 30–35 years and now has shifted towards the older groups. It is logical to assume that it is determined by the time of individual “maturation” of researcher in modern science. This maximum may be observed in the biobibliography of the vast majority of researchers. In the sample under review, those who do not have any maximum because their number of publications is constantly increasing with age accounts for only 3%<sup>3</sup>. For almost all members, a more or less noticeable drop in the productivity has been reported in the decade following the maximum; as a rule, it is significantly greater than the averaged one in Fig. 1, since this effect is smoothed by averaging as a result of diffusion of the first maximum in time.

As soon as in 5 or 10 years, there is reported a repeated increase in the number of publications,

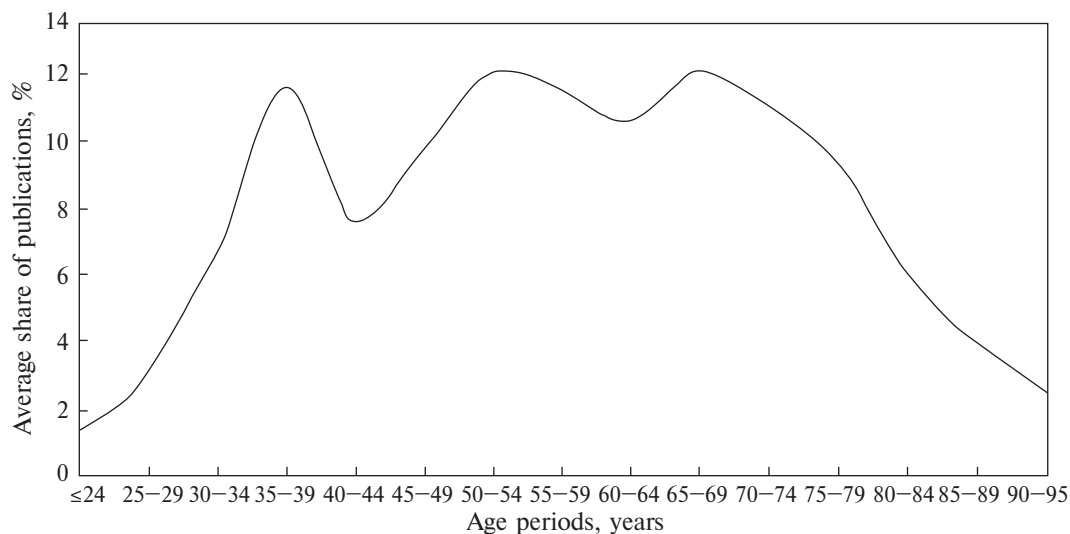
<sup>3</sup>This percentage was significantly higher among the chairmen of departments of higher education establishments [10], but most likely this may be explained by the fact that under the pressure of the Ministry of Education and Science of Ukraine to assess the efficiency based on very formal criterion (the number of publications), they started signing all publications of researchers who are employed at the department.

the second maximum studied in [5] and [6]. The second stage of growth in the publishing activity is associated with the expansion of collective creativity, with the formation of scientific schools.

Our sample contains only two scholars (mathematician and theoretical physicist) whose maximum publication activity falls within the age period from 25 to 29 years. In addition, in 10 ÷ 15 years, both have a new peak in the number of publications. Much more, but still few (16.7% of the sample) members of the Academy have the first maximum in the publishing activity at the age of 30 ÷ 34 years.

Given that the first maximum of productivity for different researchers is observed at different ages, which is not obvious from the averaged curve presented in Fig. 1, we have chosen the four groups of researchers: 1) those who have the first maximum of publishing activity within the age period of 30 – 34 years; 2) at the age of 35–39 years; 3) at the age of 40–44 years; 4) at the age of 45–49 years. The dynamics of productivity of the first one is shown in Fig. 2.

For this group, this is the maximum of publishing activity throughout the entire creative biography: in the subsequent years, the number of publications do not reach this level. That is, here we see an almost exact coincidence with the re-



**Fig. 3.** The age dynamics of the average number of publications of the NAS of Ukraine members whose first peak falls within 35 ÷ 39 years

sults of Harvey Lehman, but it should be noted that this concerns only a small number of researchers (mostly mathematicians, theoretical physicists, several historians, chemists, biologists, and one geophysicist).

The largest (34.1% of the sample) is the group of the researchers whose first maximum of productivity is observed at the age of 35 ÷ 39 years (the average characteristics are presented in Fig. 3). In contrast to the group discussed above, there are two more maxima that in terms of publishing activity even exceed the first one, with an interval of about 15 years.

The researchers who were included in this group were more good at creating fruitful research teams or worked under more favorable conditions. The general tendency towards decline in their publishing activity is observed as late as after 70 years. An increase in the number of publications for people over 70 years old may be explained by the fact that the researchers have managed to create a really powerful and creative research team within which they continue to work fruitfully (although it is possible that, in some cases, they continue to sign research works done by their subordinate team).

Among the studied group of researchers, there is about 12% of those whose first maximum of

productivity falls within the period from 40 to 44 years (see Fig. 4).

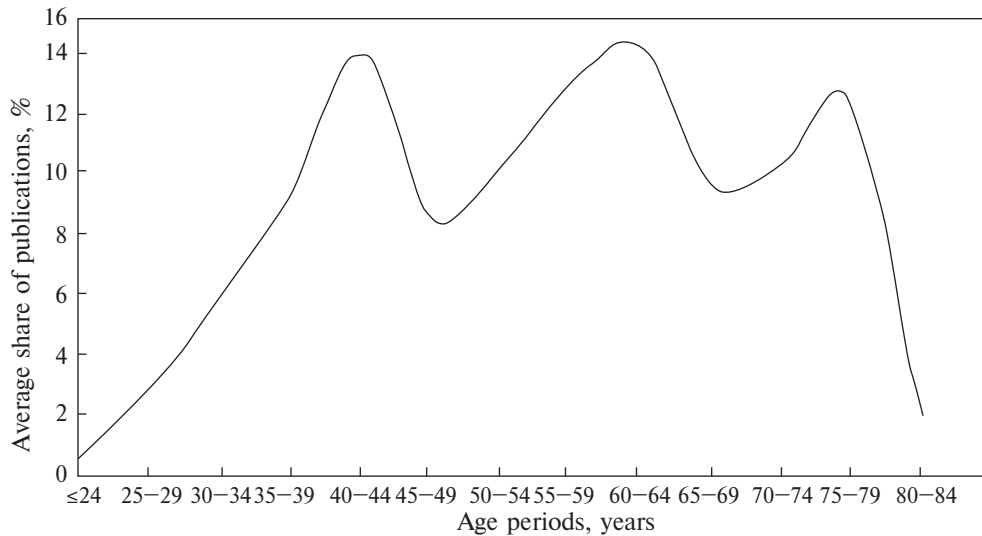
For this group, three maxima with an interval of 15 ÷ 17 years are clearly observed. At the same time, despite significant fluctuations in productivity, the general trend does not show signs of its significant decrease with age.

A group of researchers whose first maximum of publishing activity falls within the period from 44 to 49 years old accounts for about 16% of the sample (see Fig. 5). This group is characterized by the same fluctuations in productivity as in the above cases, but they are less pronounced and there is an obvious general trend of its decline (especially after 75 years).

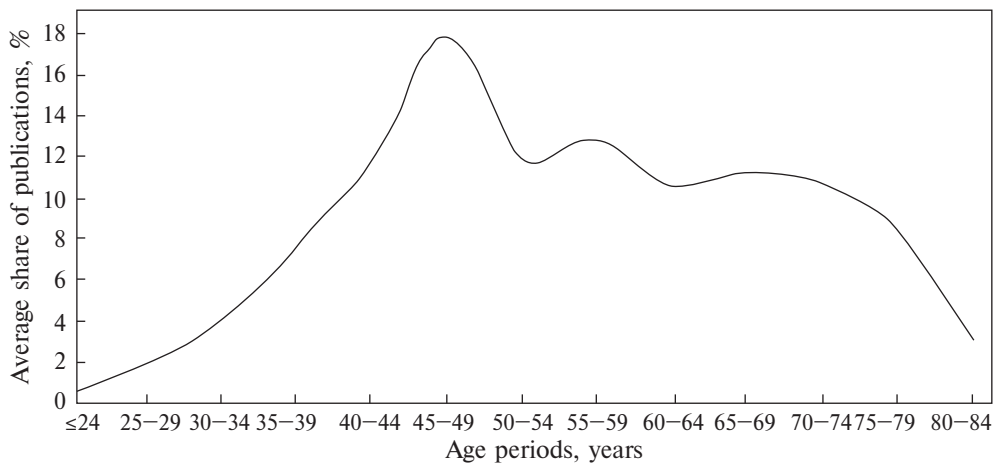
It should be noted that each group presented in Figs. 2–5 includes almost all fields of research. In addition, while constructing separate curves for physicists, mathematicians, biologists, and chemists selected from the total set of the analyzed biobibliographies, we have found no significant differences between them (see Fig. 6).

As one can see, the difference between them is minimal: most often the maximum publication activity of researchers in all four fields is observed within the age period from 50 to 60 years.

Given that the number of publications is not the most reliable indicator of researcher's effec-



**Fig. 4.** The age dynamics of the average number of publications of the NAS of Ukraine members whose first maximum falls within 40 ÷ 44 years



**Fig. 5.** The age dynamics of the average number of publications of the NAS of Ukraine members whose first maximum falls within 44 ÷ 49 years

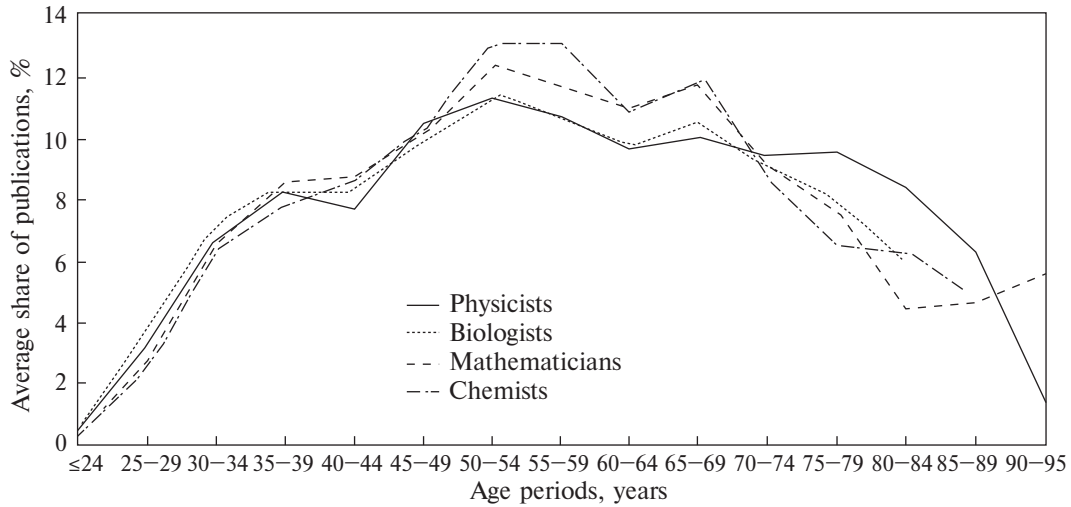
tiveness and usefulness, we have used the capabilities of Bibliometrics of Ukrainian Science scientometric database [9] to determine at what age the researchers publish their most cited works.

Fig. 7. shows the share of researchers who published their most cited research in the respective age period. As one can see, the maximum number corresponds to the age period from 55 to 59 years, which coincides with the maximum of publishing activity as averaged for the sample (Fig. 1).

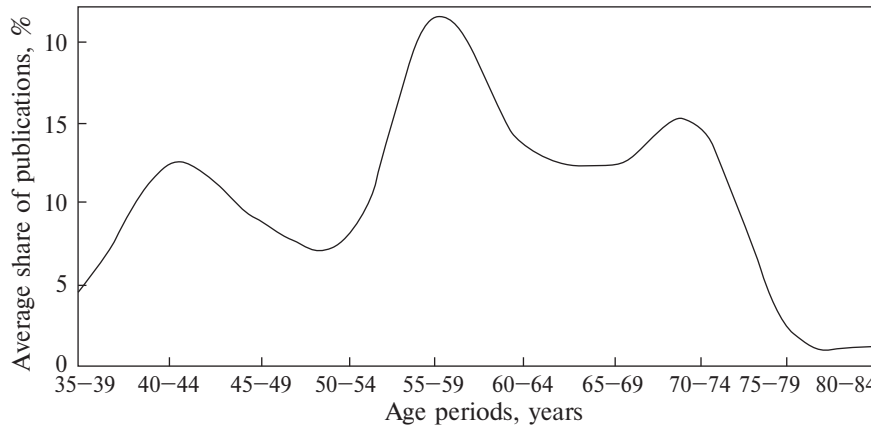
Thus, it is most likely, that an “average researcher” reaches the maximum creativity in his/

her life at the age of 55 ÷ 59 years (if the indicator is the publication of his/her most cited research), that is much later than an artist or a poet.

**Conclusions.** These results have shown that the dynamics of publishing activity of today’s researcher does not coincide with the dynamics of human physiological capabilities. There are good reasons to assume that the dynamics of publishing activity depend not only on the physiological capabilities, but also on the external conditions prevailing in science: today, the researcher matures longer because he/she needs to process much mo-



**Fig. 6.** The comparison of the dynamics of publication activity of the NAS of Ukraine members who work in different fields of science



**Fig. 7.** The share of researchers who published their most cited research work in the respective age period

re information than it was a hundred years ago and to master more complex research techniques. The extension of creative longevity is facilitated by the fact that collaboration and joint research are very widespread in most fields of science, in which each age group plays its specific role [13].

We do not question the fact that the vast majority of people have maximum opportunities for creativity at the age of 25–30 years, but there is no doubt that in the modern science, a young researcher has little chance to develop into a scientist. Over the past fifty – one hundred years, the amount of scientific and technical information

that shall be processed for this purpose has increased many times, the technique of scientific experiment has become much more complicated (in some cases, only design and creation of experimental facility takes many years).

Like every researcher has his/her own creative destiny, every research is done in its own way and under specific circumstances that affect the effectiveness, success and recognition in science. Nevertheless, our research has confirmed the assumption that despite numerous factors of influence for a person, there are general trends and patterns that characterize the research activity



as a whole, one of which is the trend of increasing the age of maximum productivity and duration of productive work.

In the current conditions, when the number of young researchers coming into R&D is extremely

insufficient, it is especially important that top managers of research institutions purposefully create research teams instead of waiting for spontaneous formation of the optimal dynamics of role functions of different age groups.

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## ЗМІНА ВІКУ МАКСИМАЛЬНОЇ ПРОДУКТИВНОСТІ ВЧЕНОГО ДО ХХІ СТОРІЧЧЯ

**Вступ.** Питання відповідності сучасним реаліям уявлення про залежність продуктивності роботи науковців від їх віку, які були сформовані у минулому столітті, стають досить актуальними у зв'язку зі змінами в організації та характері дослідницької діяльності, що відбулися за останні кілька десятиліть.

**Проблематика.** Вивчення означеного питання набуває особливої актуальності для оптимізації кадрової політики в наукових установах України у зв'язку з небажаними змінами вікової структури науковців.

**Мета.** Дослідити динаміку публікаційної активності групи членів Національної академії наук України, які працюють сьогодні (або працювали до останнього часу) в науці.

**Матеріали й методи.** Використано списки публікацій, наведені в біобібліографічних виданнях та інформаційно-аналітичній системі «Бібліометрика української науки», застосовано традиційні методи статистичного аналізу.

**Результати.** Досліджено зміни публікаційної активності з віком 126 членів і членів-кореспондентів Національної академії наук України, які народилися в 1920–1940 рр. Виявлено, що максимальна кількість публікацій спостерігається у віковій групі до 30 років тільки в 1,2 % вибірки; 30–34 роки – у 16,7 %, що приблизно відповідає результатами Харві Лемана 1930-х років. Водночас для груп 35–39 років становить 34,1 %; 40–44 роки – 12 %; 45–49 років – 16 %. Нове збільшення кількості публікацій спостерігалось здебільшого через 5–10 років після першого піку, причому другий пік часом навіть перевищує перший максимум.

**Висновки.** Вік найбільшої продуктивності для переважної більшості вчених нашого часу змістився приблизно на 30 років. Це зумовлено тим, що динаміка продуктивності роботи дослідника визначається не тільки віковою зміною фізіологічних можливостей його організму, а й характером праці, яка в сучасній науці кардинально змінилась внаслідок зростання обсягу науково-технічної інформації, ускладнення методів і технологій досліджень, поширення колективних досліджень.

**Ключові слова:** максимум публікаційної активності, час «визрівання» (становлення) вченого, НАН України, вік найбільшої продуктивності дослідника.