

SCIENCE

VOL. 86

FRIDAY, AUGUST 27, 1937

No. 2226

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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal
Lancaster, Pa. Garrison, N. Y.
Annual Subscription, \$6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

THE CONTROL OF POPULATION GROWTH¹

By Professor S. J. HOLMES
UNIVERSITY OF CALIFORNIA

UNLESS I misread the signs of the times, we are approaching a period in which nations will give more attention than formerly to the control of their population growth. Hitherto, as a rule, population has been suffered to take care of itself. Nations have adopted measures for the conservation of their natural resources of coal, iron, oil, forests and animal life, but they have given little heed to the conservation of their human material, and much less to the improvement of its quality. According to the familiar teachings of Malthus, population is subjected to an automatic regulation in that it tends to increase faster than its means of support, and hence increases until conditions become so bad that further growth becomes impossible.

For the majority of mankind, therefore, Malthus believed that there was little prospect of escape from a life of hardship and toil. The only hope he held out

¹ Address before the annual joint meeting of the chapters of Phi Beta Kappa and Sigma Xi of the University of Washington.

by which human beings could avoid the unhappy lot which their reproductive propensities inevitably bring upon them was in so-called prudential restraint, or voluntary abstention from marriage, or its postponement until numbers became reduced to the point at which there would be plenty for all.

Malthus was evidently unaware of the extent to which many peoples have contrived to avoid the drastic checks which nature imposes upon unregulated fertility. His celebrated essay brought out the very important principle that population tends to increase faster than the means for its support, and that nature regulates its growth by her none too gentle methods. The rapid growth of population during the nineteenth century following the publication of this essay was hailed by many of Malthus's opponents as affording a refutation of his gloomy conclusions. In this century the population of Europe increased from 187,000,000 to over 406,000,000; that of England and Wales from

10,600,000 to 76,938,000; and that of the United States from nearly 6,000,000 to over 77,000,000. No period of recorded history has seen so rapid a growth of population as occurred during the nineteenth century, and probably a like proportional increase will never occur again.

This phenomenal growth was due mainly to two causes, both of which were the direct result of the advancement of science: (1) the development of industry resulting from scientific discoveries which increased greatly the means of supporting life, and (2) the lowering of the death rate which followed upon advances in medicine and hygiene. In many places the increased density of population led to much hardship among the working classes and enhanced the operation of Malthusian checks. Doubtless the population of Europe and North America would have increased even much more rapidly than it did were it not for the advent of the birth control movement and the consequent decline of the birth rate. In France and the United States this decline set in during the early part of the nineteenth century, but apparently it did not affect most of the nations of northern and western Europe until sometime in the seventies, and its advent in southern and eastern Europe came several years later.

Although for a time the death rate in some countries declined more rapidly than the birth rate, thus leading to a more rapid natural increase of the population, the rate of natural increase has been falling for the past few decades. Since the world war the decline has sunk to lower and lower levels. In the recent literature on population problems one can not fail to notice a pronounced change of attitude. A few years ago there was much apprehension over the prospect of over-population with all the disagreeable consequences which such a situation entails. At present there are frequent expressions of uneasiness over an actual decrease of numbers in the not distant future. Most civilized countries still show a substantial surplus of births, and it has generally been assumed that so long as this condition obtains the reproductive rate of a people is sufficient for a continued increase of numbers. Only recently have vital statisticians become aware that this conclusion is not necessarily true. An excess of births over deaths may occur as a result of a favorable age distribution, although the reproductive rate is inadequate for permanent increase. Under such conditions the growth of a population would sooner or later come to an end even if the birth rate and the death rate in each age group were to remain precisely the same. As has been shown by Kuckzynsky in his volume on "The Balance of Births and Deaths," most of the nations of northern and western Europe owe their present excess of births over

deaths to the favorable age composition of their inhabitants, and were it not for this fact their population would be decreasing in number at the present time. The "true" reproductive rate of England and Wales is the lowest of all, but perhaps the most spectacular decline in population growth has occurred in Germany. Up to 1914 the population of Germany had been growing rapidly. The birth rate was still fairly high despite its previous decline. After the war the birth rate fell to unprecedented levels. One important factor was the limitation of births in the proletariat amounting to a veritable *Geburtstreik*. In 1930 not only the birth rate, but the stabilized rate of increase in Germany was below that of France, which was doubtless good news to the French. In 1933 the birth rate fell to the remarkably low level of 14.7 per 1,000, a rate which placed Germany almost in the van of the low-birth-rate countries of the world, and caused her stabilized rate of increase to be far below the level required for continued reproduction.

At present the Slavic peoples of Europe are increasing about twice as rapidly as those of Germanic stock. Naturally this situation is very disquieting to a people persuaded of their innate superiority and ambitious to secure a position of dominant influence among the nations of the earth. France, too, always fearful of aggression on the part of her powerful rival, has been for many years greatly exercised over her very slow increase. Hence the numerous articles, books and pamphlets bemoaning the decline of the birth rate, and the determined but futile efforts to suppress Neo-Malthusian practices and propaganda.

In Italy there have been vigorous efforts to check the decline of the birth rate and to increase the population by limiting emigration, by the financial encouragement of Italian women in other countries to return to their native land to give birth to their babies, and by various other methods. Greatly overpopulated as Italy is in relation to her rather meager natural resources, her able and enterprising leader, intoxicated by the dream of a new Roman Empire, is making strenuous efforts to stimulate population growth as a means to power. In one of his impassioned and grandiloquent outbursts Mussolini declared that "We must be able at a given moment to mobilize 5,000,000 men thoroughly armed; we must strengthen our navy, while aviation must be on such a large scale and so powerful that the noise of its motors must surpass any other noise, and the area of the wings of our airplanes must obscure the sun from our land."

Other nations are much more complacent over their population problems. In some countries there is a fairly widespread conviction that over-population exists and that the prospect of an impending decrease is not to be deplored. Many nations are content to

let the natural increase of their inhabitants take care of itself. But in the family of nations some members are very much concerned with the means of increasing their numbers, whether for the purpose of aggression or security. Everywhere there is an awakening of interest in problems of population growth. Peoples no longer look upon the perpetuation of their kind as determined by Providence, like the rainfall and the temperature. The decline of the birth rate, the realization that this decline is largely the product of voluntary causes and the fact that the extent of the decline is very different in different countries have brought prominently to the minds of all thoughtful people the importance of population problems for national welfare and even national security. Not only has there been a great increase in the literature on population, but there have been a number of population congresses, national and international, in which various phases of the subject, political, economic, biological and even eugenic, have been discussed by prominent authorities. The recognition of the fact that unequal rates of population growth afford one of the basic causes of war and that they give rise to many vexatious problems of adjustment has led the governments of several countries to participate officially in these congresses. The study of population growth and international migrations has become one of the fields of investigation supported by the League of Nations in its endeavors to promote the cause of peace. One of our chief students of population has written a volume entitled "Danger Spots in World Population," in which he calls attention to the precarious situations which result from the unequal rates of increase in different countries of the globe. The co-existence of grossly over-populated countries, such as India, China and Japan, along with under-populated areas, such as Australia, New Zealand and parts of North America, South America and Africa, is a constant provocative to aggression, especially where immigration is excluded from the sparsely settled regions. A strong nation whose already overerowed people are increasing rapidly in numbers and are faced with the prospect of subsisting with ever lower standards of living is in a difficult situation. If she can not obtain relief by increase of trade she is apt, when opportunities offer, to seek a larger place in the sun by force. It need occasion no surprise, therefore, that some of the more aggressive nations of the earth have pursued their course of expansion in flagrant disregard of all treaty obligations and principles of fair dealing. Probably no one is so simple as to suppose that these nations will pay more than a hypocritical lip service to the moral conventions which are supposed to be binding upon the dealings of nations. Force and force only will they respect.

In the struggle for existence that goes on in the human species war is only an incidental and occasional phase. The biological victories that are really important from the evolutionary standpoint are determined by the balance of births and deaths. In the long course of evolution tribe has supplanted tribe and nation has prevailed over nation. Biological advancement has come about largely by the successive replacement of racial stocks. Whether the replacement has involved the extermination of the vanquished, as in the conflicts of the Children of Israel, or has resulted from the less painful method of peaceful penetration and differential fertility, the outcome is just as fatal to the losing competitor. Biological struggle for numerical supremacy and selective survival are bound to go on even in the most pacifist of all possible worlds. The way in which the struggle works out depends upon conditions to which the contending parties have usually paid little heed. Not infrequently peoples defeated in war multiply more rapidly than their conquerors. Hence the military victory may go to one party and the biological victory to another. It may happen that a people is eventually replaced by its slaves, which was surely not an intended or even a foreseen result of conquest. From the biological point of view victory has usually been stupidly managed. When certain political or economic objectives have been attained a victorious nation is usually content to rest upon its laurels.

The causes of war are varied. Conditions of dynastic succession, religion, the ambitions of leaders to achieve renown as conquering heroes and to add to the glory and prestige of their country by annexing conquered territory, and, above all, the endeavor to enlarge opportunities for economic gain, especially for the ruling classes, have all played their part in embroiling the nations of the world in strife. Where there are influential parties interested for financial or other reasons in provoking a war of aggression, an episode like the sinking of the *Maine* or an offense to national dignity can arouse a wave of angry feeling which may precipitate a war.

Nations like individuals quarrel over a great variety of interests. Often their conflicts seem to be guided by no more reasonable motives than those which formerly more than now were prone to occur between individual human beings. Man is by nature a fighting animal. He is endowed with a generous measure of group pugnacity which he owes to the fact that his native endowments have been moulded through long ages of tribal warfare and selective survival. He is easily led to fight for his kind. His natural loyalty to his own makes him ever willing to risk life and limb to promote the welfare of his group. Like an ant or termite which rushes out to attack the offender that

molests its abode, man is prompted by a deep instinctive urge to join in any fray in which his fellows may be engaged, even if he has no more comprehension than the ant or termite of what it is all about. Where the pressure of numbers or the richer resources of other lands tempt people to overflow their boundaries, the average representative of the human species is easily persuaded to participate in any aggressive enterprise that promises to bring rewards to his tribe or nation. People take pride in the territorial expansion of their country, even though it brings them no personal gain. They like to belong to a great and powerful nation which is able to play a dominating rôle in world affairs. So long as there is prospect of gain through aggressive warfare, the hope of establishing a universal reign of peace is not very encouraging.

During the nineteenth century there have been many wars of which unequal rates of population growth were in part the cause and in part the effect. Population pressure, of course, does not always lead to war. For obvious reasons it does not do so in small and weak countries. Nor does it do so in countries which are large and weak, like India and China. The teeming millions of these grossly over-populated lands live under conditions of poverty, ignorance and hardship which make them incapable of defence against a foreign aggressor. Their very numbers contribute to their weakness. In these countries population growth does not constitute a menace to nations with modern military equipment. If any countries have a provocation to go to war for the acquisition of territory, it is these. But they are effectively hemmed in and forced to suffer the consequences of their unrestrained reproduction.

The countries which are the greatest menaces to world peace are those which combine military efficiency and a growing population. As Dr. Harold Cox has stated, "The growth of population not only creates occasions for war, but makes war inevitable." In his opinion the only remedy for the evil is the voluntary limitation of numbers. But this presupposes that nations may not only have the power, but also the desire to control the increase of their inhabitants.

Many countries, as we have seen, have no definite population policy. The smaller nations of northern and western Europe already have a fairly large population in relation to their resources, and are not particularly desirous of further increase. Moreover, most of them are faced with an actual decrease in the near future, and they may soon come to bestir themselves in taking measures to avoid this eventuality. In England there is a widespread conviction that the country is overpopulated. Emigration is encouraged, especially to the colonies. There is little opposition to the propaganda of the Neo-Malthusians. With the large

numbers of unemployed workers supported by the dole, efforts to stimulate the increase of population would not meet with general approval, although there are many Englishmen who view with apprehension the diminishing birth rate of their country. It is quite otherwise with France. For decades there have been lamentations over the low birth rate, which threatens a loss of man power required for defense. Nevertheless, the French have never been able to do anything very effective in counteracting this evil. Their family allowance system which was made compulsory in 1932 does not afford sufficient financial inducement to have made any demonstrable increase in the birth rate.

The population policy of Germany has been for a long time directed toward stimulating an increase in numbers. As France has long viewed with alarm the more rapid growth of the population of Germany, so the Germans have been fearful of the portentous fertility of the Slavs. Before the world war the Germans were greatly concerned over finding the means of supporting their rapidly increasing millions. Typical of many statements is the following by Arthur Dix: "Because the German people nowadays increase at the rate of 800,000 inhabitants a year, they need both room and nourishment for the surplus. As a world power in the world market we must assert our place and make it secure in order that the younger hands may find room and opportunity for employment." In 1911 General Bernhardt, with his usual delightful frankness, declared that, "strong, healthy, and flourishing nations increase in numbers. From a given moment they require a continual expansion of frontiers, they require more territory for the accommodation of their surplus populations. Since almost every part of the globe is inhabited, new territory must, as a rule, be obtained at the cost of its possessors—that is to say, by conquest, which thus becomes a law of necessity." And in a somewhat later work on "Our Future," he stated: "We must endeavor by all means in our power to acquire new territories throughout the world because we must preserve to Germany the millions of Germans who will be born in the future, and we must provide for their food and employment. They ought to live under a German sky, and lead a German life."

The world war gave a setback to these ambitions. Germany was shorn of her colonies, and suffered a loss of territory on her eastern and her western frontiers and was effectively disarmed in the hope of rendering her helpless for some time to come. After the war her birth rate declined to an extent that threatened an actual decrease in numbers in the near future, but this has not changed her policies in regard to population. Now she is resolutely preparing to win back by force what she has lost through the fortunes of war.

Thoroughly alarmed over the decline of her birth rate, Germany has made strenuous efforts through patriotic propaganda and the more effective inducements of financial rewards to encourage marriage and to increase births. In both these endeavors she has been, at least temporarily, successful. One of the measures which has apparently been the most effective is the system of loans to certain classes of workers at the time of marriage. A newly married couple, if the wife has been employed for a given length of time, may receive a thousand marks, to be repaid on very easy terms. If a child is born one fourth of the loan is remitted, and the entire loan is cancelled when there are four children. Following the inauguration of this system the number of marriages increased from 7.9 per thousand in 1932 to 9.7 per thousand in 1933, and to 11.2 per thousand in 1934, when 37.4 per cent. of the couples received loans. The birth rate in 1934 rose suddenly from 14.7 per thousand to 18.0 per thousand, resulting in 47,825 more births than occurred in the first quarter of the previous year. According to Burgdörfer, "60 per cent. of the increase in births comes from marriages which were concluded with the help of loans." An incidental result of this population policy has been a striking decrease of illegitimate births and abortions. Where couples beget illegitimate children they find it advantageous to marry and secure a loan. According to Mr. D. V. Glass, there were, between August, 1933, and March, 1934, "part cancellations of loans in respect to 43,101 children who must have been conceived before marriage." Doubtless the birth of a large proportion of these children would have been prevented by abortion were it not possible to take care of the situation by marrying and obtaining a loan. It does not seem likely that the additions to the population resulting from this system will greatly improve the quality of the German people, but at least it results in a substantial addition to their numbers, which is, of course, its principal object.

It would not be correct to say, however, that the present population policy of Germany takes no account of quality. One important aspect of it is the effort to curtail the multiplication of the hereditarily defective classes. The recent sterilization law provides for the sterilization of the feeble-minded, epileptic, insane, and those suffering from hereditary defects which make them a burden to society. In the first year of its operation over 50,000 sterilizations were made; a number greater than the number sterilized in the U. S. since the passage of the first statute in 1899. Thus far sterilization seems to have been carried out in a fair and equitable manner without racial discriminations which, it has been feared, might be made.

Another important aspect of the German population policy is the endeavor to induce the right kind of

people to live on the land. It is a well-known fact that urban dwellers are relatively infertile. The inhabitants of most cities, and especially large cities, do not reproduce sufficiently to maintain their numbers. The growth of cities comes largely through migration from the surrounding areas. In the long run, the character of the population of a country depends upon the kind of people who inhabit the land. Naturally the Germans want the land settled by healthy, industrious and prolific people of "Aryan" stock. They are endeavoring in several ways to stimulate a back to the land movement, and it has been proposed to extend the loan system to the peasant population, and to offer very substantial stipends for the children of approved peasant families. With a discriminatory loan system much can be done toward determining the character of the rural population, and hence the future population of the nation. The German experiments in the control of population growth are of great interest, not only because of the results already achieved, but because of the possibility which they open up for determining which elements of the population will come to reproduce at the most rapid rate. How will the Germans use their means of population control? Here is a great and intelligent nation whose rulers are thoroughly alive to the trend of population growth, firmly persuaded of the innate superiority of the Nordic stock, alarmed over the natural increase of their Slavic rivals, strongly antagonistic to members of the Jewish race, who have been subjected to persecutions which one would scarcely believe possible in so highly civilized a country, bent on securing a homogeneous population of undivided loyalty, and believing in their divine mission to play a dominant rôle in the affairs of Europe and the world, in what ways will the Germans endeavor to control the growth of their population? Unless I am greatly mistaken, the German objectives of population control will come to be more clearly defined and pursued with a greater degree of effectiveness in the future. We may expect also that the example of Germany will in several respects at least be followed by other countries with similar imperialistic ambitions. The spectacle of a country consciously taking in hand the development of its human material, endeavoring to purge it of its undesirable elements and to increase its numbers and to improve its quality is a phenomenon which can not fail to arrest the attention of the whole world. It heralds the approaching end of the laissez-faire method of dealing with population growth and the beginning of an era of planned control. With the Germans the dominant and avowed motive of population control is to acquire greater wealth and power. And at the same time they like to enjoy the self-approbation derived from the thought that the interests of civilization for the world

in general are closely dependent upon the holy cause of Nordic supremacy. Despite the fanaticism and injustices of the present Nazi régime we may express the hope that the German efforts at population control, in so far as they are directed toward intelligently conceived and worthy ends, will meet with conspicuous success. Unfortunately they are now bound up with many indefensible notions about the race which receive little support from most qualified anthropologists.

What is of especial interest in the German experiment is the frank recognition of the principle that the perpetuation of life is a service to the state which is worthy of its reward. If this principle is carried out to its logical results it would mean that the wages of labor would be simply compensation for work done instead of being in part a contribution for family support. In many discussions of what should be the basic wage in industry the claim is made that this wage should be based on the amount that would support a man, his wife and three children on a fair standard of comfort. The price of labor, like that of other commodities, tends to be determined by the law of supply and demand. As stated by David Ricardo, "The natural price of labor is that price which is necessary to enable the laborers to subsist and perpetuate their race, without either increase or diminution." This so-called iron law of wages is based on the Malthusian theory of population. It represents the natural and inevitable outcome of unrestricted competition on the one hand and unrestricted fertility on the other. The logical and effective answer of the intelligent workmen to this situation is the *Geburtstrik*. And in Germany this answer was given to an extent that created widespread alarm. The working classes simply will not breed up to the point at which the drastic Malthusian checks become operative. It begins to look as if the alternative for most industrial countries having a fairly high standard of living and a wide diffusion of education among their inhabitants is either adequate family support or depopulation. At present, as the studies of Professor Paul Douglas have shown, "Industry cannot afford to pay all adult workers enough to support a family of five." In fact, probably less than half the adult workers have families of three or more adult children, and since wages are mainly determined by the law of supply and demand, large numbers of children suffer from inadequate support.

Two essentially unrelated considerations are involved in discussions of the basic wage: (1) The value of a man's labor to his employer, and (2) the needs of the laborer's family. As a rule, employers do not care a fig about the fertility of employees. Certainly an employer can not be expected to hand out an extra stipend every time the wife of an employee has another baby. Hence the proponents of the family allowance

system advocate that logically the state or the community should reward the functions of parenthood instead of throwing the entire burden upon the shoulders of the poor wage-earner often to the detriment of all his offspring. Many countries recognize the justice of the principle involved in the family allowance system by tax exemptions or small payments, graded as to the number of children, but they do this in an ineffective manner that has little influence upon the birth rate. Only in Germany has this system been carried out to an extent that has been productive of demonstrable results.

One thing is certain, namely, that in a country whose people are habituated to a high standard of living, the decline of natural increase will not be stayed by any amount of patriotic propaganda, moral appeal or fulminations against the wickedness of contraception. These measures have been tried and found wanting. Having been for several years more or less occupied with problems of eugenics, I have become more and more convinced that the most important problem of eugenics, that of increasing the birth rate of the better endowed elements who are now failing to perpetuate their kind, is practically hopeless under our present system of remuneration for services to society. It may be futile to speculate as to how long our dysgenic system of breeding will last. There is much to justify the prophecy of Mr. Bertrand Russell that for the next few hundred years "each generation will become stupider than its predecessors." But I believe that long before even one hundred years have passed a number of the nations under western civilization will be forced, as a matter of self-preservation, to inaugurate policies of population control which will be really effective in promoting an increase of numbers. When this comes about we may perhaps be justified in having some hopes for positive eugenics. This, for the reason that whatever measures are found effective in promoting numbers in general can be employed to stimulate the increase of any desired class within the nation.

The qualitative and quantitative aspects of population control are very intimately connected. Both should be regulated in such a way in every country as to maintain approximately the density of population most conducive to the general welfare and at the same time insuring that the population improves instead of deteriorates in quality. The endeavor to achieve these highly desirable ends inevitably involves a considerable degree of international cooperation. It is not a simple matter to alter the reproductive habits of a people in a short time. One of the most formidable difficulties in such a cooperative undertaking is the presence in the family of nations of countries with a determination to expand and increase in numbers and power regardless of how other nations may be affected.

Some of the populous nations have a very real case owing to their rapid rate of natural increase, although some of them are taking steps to increase their numbers instead of reducing them. A natural easing of internal pressure might of course be afforded through emigration. At present freedom of migration has become very much restricted and promises to become still more so. It is perhaps an encouraging symptom that the centralized control of migration has been discussed at two of the international congresses on population problems. Migration is no panacea for population difficulties, but it may afford a means of relief to over-populated countries until such time as measures to check undue multiplication have had time to become effective. How to regulate migration and

at the same time respect the sovereignty of peoples and their right to work out their destinies in their own way will afford many delicate problems for the statesmen of the future. The art of cooperative instead of competitive statecraft is, I fear, still in its infancy. Were the nations of the earth to unite in a population policy aimed to insure to each nation an optimum number it would go far toward removing occasions for war and would contribute greatly to the continued progress of mankind. At present this may seem to be a utopian ideal, but with a growing realization of the importance of regulating population growth in the interest of human welfare, we may at least hope that it may come to have more influence in shaping the policies of nations in their dealings one with the other.

NEWER BIOLOGICAL ASPECTS OF PROTEIN CHEMISTRY

By Dr. MAX BERGMANN and Dr. CARL NIEMANN

THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

For a long time it has been unquestioned that proteins are an indispensable requisite of the living organism. Serological investigations have apparently established the fact that each species possesses characteristic and specific proteins. The classical chemical experiments of Emil Fischer have demonstrated that protein molecules are, essentially, many-membered peptide chains. This investigator pointed out that such polypeptide chains allow an overwhelming number of different structures when one varies the number, the nature and the order of the constituent units. These observations appeared to offer an explanation for the vast number of different proteins found in nature but, on the other hand, with this variety of structure there appeared to be no prospect of ever being able to elucidate the exact structure of a single high molecular weight protein.

Fortunately, recent investigations have indicated that the above view can be modified, as it has been found that the natural proteins are not simply polypeptide chains of every conceivable length and configuration, but that their structures are defined by a general stoichiometrical law which greatly limits the number of possible formulae. The nature of this stoichiometrical law can be demonstrated by considering the composition of the four proteins presented in Table 1. These compounds were selected because of their widely different physiological significance.

The first value in each column of Table 1 is the total number of amino acids produced by the hydrolytic degradation of the protein molecule under consideration, and the subsequent values represent the amounts of the various individual amino acids. For

TABLE 1

THE NUMBER OF AMINO ACID RESIDUES IN THE MOLECULES OF CATTLE HEMOGLOBIN, CATTLE FIBRIN, CHICKEN EGG ALBUMIN AND SILK FIBROIN

Amino acid	Number of amino acid residues per molecule			
	Cattle hemo-globin	Cattle fibrin	Chicken egg albumin	Silk fibroin
All amino acids . . .	$2^6 \times 3^2$	$2^6 \times 3^2$	$2^5 \times 3^2$	$2^5 \times 3^4$
Arginine	$2^2 \times 3^1$	$2^5 \times 3^0$	$2^2 \times 3^1$	$2^2 \times 3^1$
Lysine	$2^2 \times 3^2$	$2^4 \times 3^1$	$2^2 \times 3^1$	$2^2 \times 3^0$
Histidine	$2^2 \times 3^0$	$2^2 \times 3^1$	$2^2 \times 3^0$	$2^0 \times 3^0$
Aspartic acid	$2^2 \times 3^0$	$2^2 \times 3^0$	$2^4 \times 3^0$	
Glutamic acid	$2^4 \times 3^0$	$2^2 \times 3^2$	$2^2 \times 3^2$	
Glycine				$2^4 \times 3^4$
Alanine				$2^2 \times 3^4$
Tyrosine	$2^2 \times 3^1$		$2^2 \times 3^0$	$2^1 \times 3^4$
Proline	$2^2 \times 3^1$	$2^2 \times 3^0$		
Tryptophane		$2^1 \times 3^2$		
Cysteine	$2^0 \times 3^1$	$2^0 \times 3^2$	$2^2 \times 3^0$	
Methionine		$2^2 \times 3^1$	$2^2 \times 3^1$	

example, in the case of cattle hemoglobin it was found that the molecule is composed of 576 or $2^6 \times 3^2$ amino acid residues, and of this total number there are 12 arginine residues, 32 histidine residues, 36 lysine residues, etc. The total number of amino acid residues (N_t), the number of the individual amino acid residues (N_i), and the frequencies of the individual amino acid residues ($F_i = \frac{N_i}{N_t}$) that are contained in a molecule of

protein can be expressed by the following equations:

(1) $N_t = 2^n \times 3^m$ where n and m are positive whole numbers.

(2) $N_i = 2^{n'} \times 3^{m'}$ where n' and m' are either zero or positive whole numbers.

(3) $F_i = 2^{n''} \times 3^{m''}$ where n'' and m'' are either zero or positive whole numbers.