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Some Problems of the Theory of Phenology *

Niektóre problemy teorii fenologii

Некоторые проблемы теории фенологии

Major concepts on the theory of phenology are presented with suggestion of new terms. Some of them have already been discussed in my previous papers (1—16). The concepts are presented in the form of schematic illustrations with short comments.

The new terms that are introduced are without quotation marks; most have not yet been used in literature. They are introduced here in order to describe the essence of the subject in the most picturesque way.

THE UNITY OF LIFE PROCESS — TISSUE OF THE BIOSPHERE — ALL-EMBRACING WEB ** — GEOCOSMOCENOSIS (FIG. 1)

Mutual penetration and interlacement of all natural processes of organic and inorganic worlds, from the structure of primitive organisms to the cosmos, fully justify the use of terms mentioned above: tissue of the biosphere, all-embracing web, geocosmocenosis. A specific network of relationships, interwinds distinct fragments of the biosphere not only with each another, but also with the cosmosphere in an organic unity, justifies the introduction of such terms as biocosmosphere and biocosmocenosis or geocosmosphere and geocosmocenosis.

* This paper is with discussion appeal and it presents personal views of the author.

** Comes from the first chapter of Peter Farb's book, Ecology (translated: Popularnaja ekołogija. Izd. „Mir" Moskwa 1971).

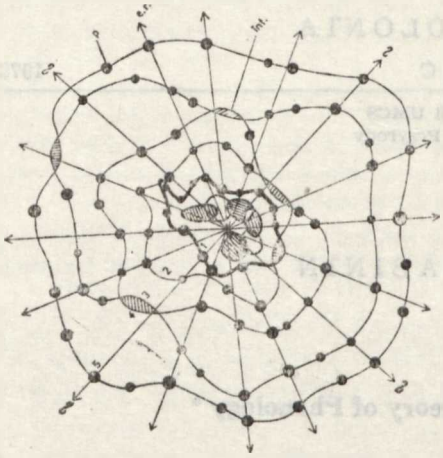

Fig. 1. 1 — organism and its internal anatomo-physiological ecosystem, 2 — biocenosis, 3 — landscape (physiocenosis), 4 — biosphere, 5 — cosmosphere, int. — integrating spheres of interactions of individual systems of geocosmocenosis (marked in the figure at random places), p. — pores (the walls of individual taxonomic units of the biocosmosphere are porous and permit mutual penetration of life processes), e.r. — electromagnetic rays penetrating the walls of the biocosmosphere

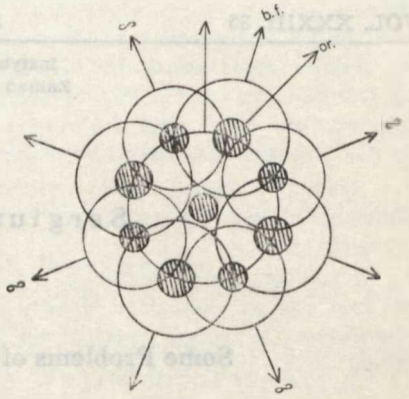

Fig. 2. or. — organisms as condensations of matter noticeable to man, b.f. — biological (electromagnetic) fields: contact between the organisms is possible by biological fields that are emitted into cosmic space (=sign of infinity)

Phenology, dealing with seasonal rhythmicity of the biosphere, has to consider the relationships between seasonal phenomena in the context of the geocosmosphere or, more specifically, in the context of geocosmocenosis. S m i r n o w proposed to call phenology the branch of the science which deals with the seasonal rhythmicity of our planet. Since the rhythm of our planet is related to the rhythm of the cosmos (the revolution of the earth round the sun), it could be said, that phenology deals with specific fragments of the geocosmosphere or — emphasizing their natural relationships — geocosmocenosis.

CONTACT BETWEEN ORGANISMS BY MEANS OF BIOLOGICAL FIELDS — NO BOUNDARIES EXIST BETWEEN ORGANISMS AND THE ENVIRONMENT (FIG. 2)

Data from biophysics about biological (electromagnetic) (17—20) fields extend and strengthen the issue of unity and interdependence of all pro-

cesses and phenomena. Thus, it is reasonable to suggest the extension of the term geobiocenosis so that it might include the notion of geocosmocenosis.

Thus the definition of phenology as a science of seasonal rhythmicity (pulsation) of geocosmocenosis should be the fullest and the broadest one.

NO UNISONS (SINGULAR SOUNDS) BUT ACCORDS — ANNUAL SUCCESSION OF ACCORDS (FIG. 3)

In nature every phenomenon occurs in a given context of other phenomena that vary in time and space; there are no unisons in nature but there are accords. Nature represents the annual succession of accords changing in an annual cycle: if one knows a leading note i.e. a characteristic phenomenon indicatory for the whole phenological complex, one can determine the composition of the whole accord.

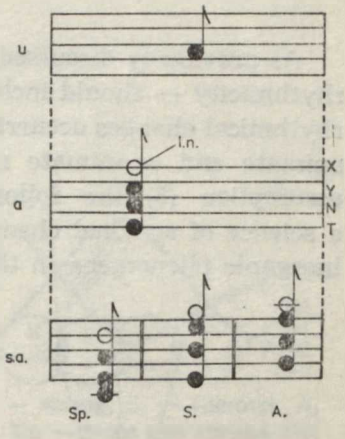

Fig. 3. u. — unison, a. — accord, s.a. — succession of accords, l.n. — leading note, X, Y, N, T — different phenological phenomena (e.g. X — among plants, Y — among birds, N — among insects, T — in inanimate nature), Sp. — spring, S. — summer, A. — autumn

SEASONAL RHYTHM OF THE ORGANISM INTEGRATED WITH THE SEASONAL RHYTHM OF BIOCOSMOSPHERE — SEASONAL UNDULATIONS OF BIOCOSMOSPHERE AS A WHOLE — UNDULATING CARPET OF LIFE (FIG. 4)

Organisms, as well as all taxonomic units of the biosphere, are ecosystems by themselves. One ecosystem is contained in a complex of others and, therefore, a change in the structure of one ecosystem causes seasonal changes in another ecosystem, as well as in the whole complex of them. On that basis one could say that the rhythmically undulating carpet of life is a subject of interest of phenology.

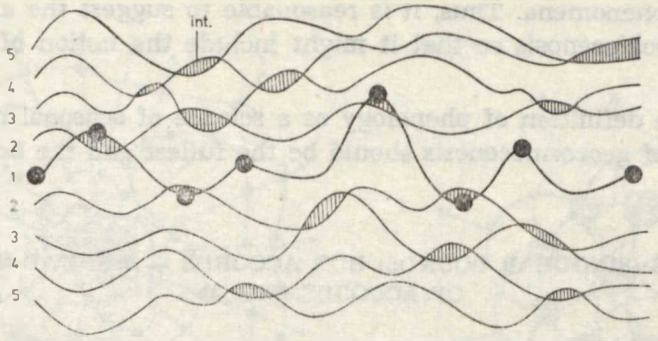

Fig. 4. 1 — organism, 2 — biocenosis, the organism being a component of it, 3 — landscape, biocenosis being a component of it, 4 — biosphere as a common denominator of a given complex of landscapes and biocenoses, 5 — cosmosphere, biosphere assumed to be immersed in it, int. — integrating spheres of interactions of individual system of geocosmocenosis

PHENOLOGY — SCIENCE OF SEASONAL CHANGES OCCURRING IN MATERIAL UNITY OF ORGANIC AND INORGANIC PHENOMENA DURING THE ANNUAL CYCLE (FIG. 5)

As previously discussed phenology — science concerned with seasonal rhythmicity — should include in its definition its main object of interest: rhythmical changes occurring in the organic complex of the phenomena of animate and unanimate nature in the annual cycle. Starting with the assumption (6) the following definition is suggested: "Phenology is a science of seasonal changes occurring in material unity of organic and inorganic phenomena in the annual cycle".

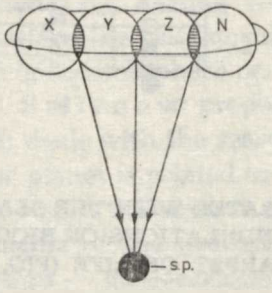

Fig. 5. X, Y, Z, N — overlapping, integrating phenologic phenomena: arrows indicate that, according to the above definition, phenology is concerned mainly with those integrating fragments, s.p. — synthetic point integrating the strikes of the pulse of the biosphere into an organic unity

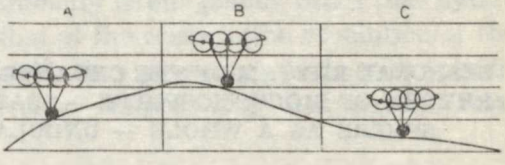

Fig. 6. Successive beats of nature: A, B, C

BEATS OF NATURE (FIG. 6)

Following the above premises, justifying such an understanding and such a definition of phenology — seasonal changes in the material unity of organic and inorganic phenomena may be considered a succession of the beats of nature in the annual cycle.

SYNCHRONIC PHENOMENA (FIG. 7)

Synchronic phenological phenomena may be divided as follows: 1) synchronous phenomena not linked biologically, 2) synchronous phenomena directly linked, 3) synchronous phenomena indirectly linked.

1. Synchronization of phenological phenomena not linked biologically results only from the community of meteoro-climatic conditions indispen-

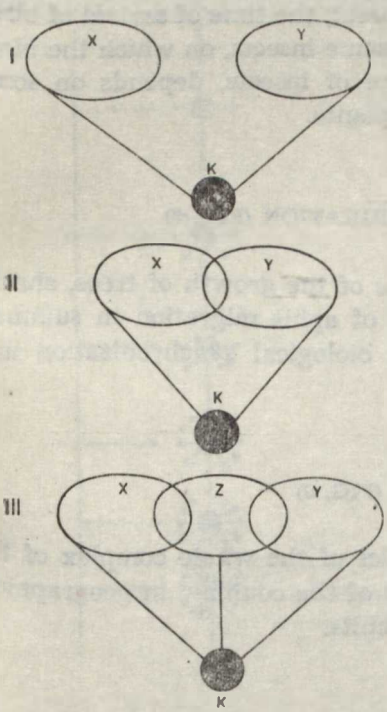

Fig. 7. I — synchronous phenomena not linked (biologically), II — synchronous phenomena directly linked, III — synchronous phenomena indirectly linked; X, Y, Z — phenological phenomena, k. — meteoro-climatic knot (e.g. thermal)

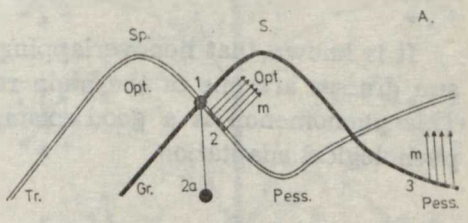

Fig. 8. Sp. — spring, S. — summer, A. — autumn, Tr. — trees and shrubs, Gr. — grasses, Opt. — optimum for aphis, Pess. — pessimum for aphis, 1 — critical moment for aphis with respect to feeding conditions on the grasses; 2, 2a — deterioration of aphis living conditions on trees: a majority of species migrated (2). The species that do not migrate fall into the state of anabiosis (diapause) (2a), 3 — deterioration of feeding conditions on the grasses and their improvement on the trees results in the appearance of winged individuals migrating back to trees (generation of "sexuparae"), m. — migration of aphis

sable for the occurrence of definite phenomena (for example, definite temperature); this community might be called the community of a meteoro-climatic knot. An example of such synchronization may be the appearances of a number of species of butterflies (e. g. *Gonepteryx rhamni* L., *Vanessa* sp.) early in spring.

2. Synchronization of phenological phenomena directly linked biologically involves — apart from the community of meteoro-climatic knot — direct biological links between the rhythm of life of organism X and that of organism Y; e. g. interrelations between insects and their host plants, dependence of phenology of a given developmental stage of insects on a given developmental stage (morpho-anatomical or physio-biochemical) of plants.

3. Synchronization of phenological phenomena indirectly linked biologically is a result of indirect relationship of phenological phenomena to definite biological phenomena; for example phenological phenomena in the complex: bird—insect—host plant of the insect; the time of arrival of birds depends on the time of the appearance of some insects, on which the birds feed. In turn, the time of the appearance of insects, depends on some appropriate phenological stages of host plants.

PHENOMENON OF APHIS MIGRATION (FIG. 8)

It is known that nonoverlapping waves of the growth of trees, shrubs and grasses are one of the main reasons of aphis migration in summer. This phenomenon is a good example of biological synchronization and phenological adaptation.

JOINT ISOPHENS (FIG. 9)

Joint isophens reflect seasonal dynamics of the whole complex of the elements of the biosphere in the territory of the country, in geographical regions and other ecologic-geographical units.

PHENOLOGICAL TREE WITH PHENOLOGICAL WHORLS (FIG. 10)

Particular meteoro-climatic stimuli (e. g. thermal) cause the formations of knots (developmental thresholds) branching in the form of whorls of synchronous phenomena: from spring to winter the length of internodes increases but the number of branches in the whorl decreases.

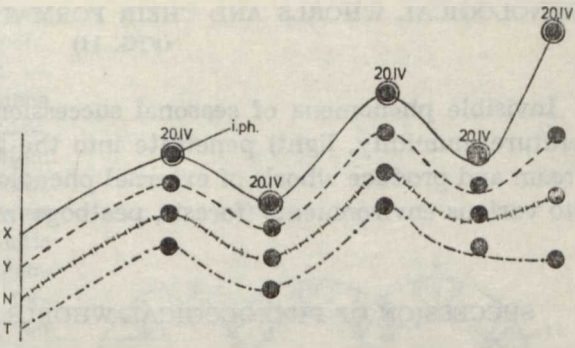

Fig. 9. X, Y, N, T — various phenological phenomena in agrocoenoses: e.g. X — indicatory events among plants characteristic of a given phenological season, Y — characteristic aspect phenomena among cereal weeds, N — characteristic aspect phenomena among cereals, T — characteristic phenomena among some insect pests in cultivated plants, i.ph. — indicatory phenomenon for the whole phenological complex

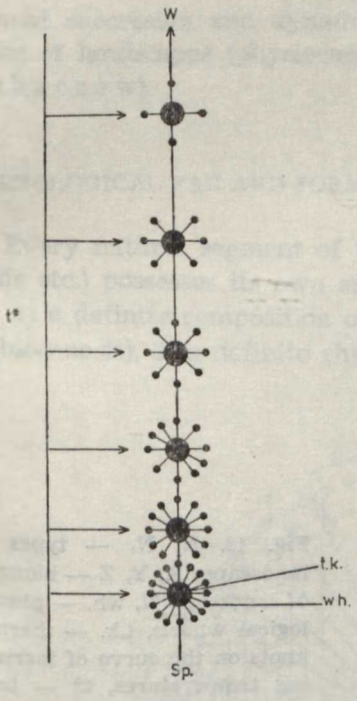

Fig. 10. W. — winter, Sp. — spring, wh. — whorls, t.k. — thermal knots

Fig. 11. T.L. — tree of life; X, Y, Z, N, T — phenological whorls branching into different environments (forests, meadows, peatbogs etc.); 1, 2 — disappearance of old branches of phenological whorls, 3 — formation of the new ones, t° — temperature, l. — light, h. — humidity

PHENOLOGICAL WHORLS AND THEIR FORMATION ON THE TREE OF LIFE (FIG. 11)

Invisible phenomena of seasonal succession of inorganic nature (temperature, humidity, light) penetrate into the tree of life, merge into one stream and produce whorls of external phenological phenomena branching into various environments (forests, peatbogs, meadows etc.).

SUCCESSION OF PHENOLOGICAL WHORLS IN BIOSPHERE (FIG. 12)

Each natural, historically conditioned and, at the same time, different sector of biosphere, i. e. each taxonomic geographic-ecological unit, has in its annual cycle a characteristic set of successive phenological whorls and, accordingly, one can speak about specific succession of phenological whorls in each specific sector of biosphere.

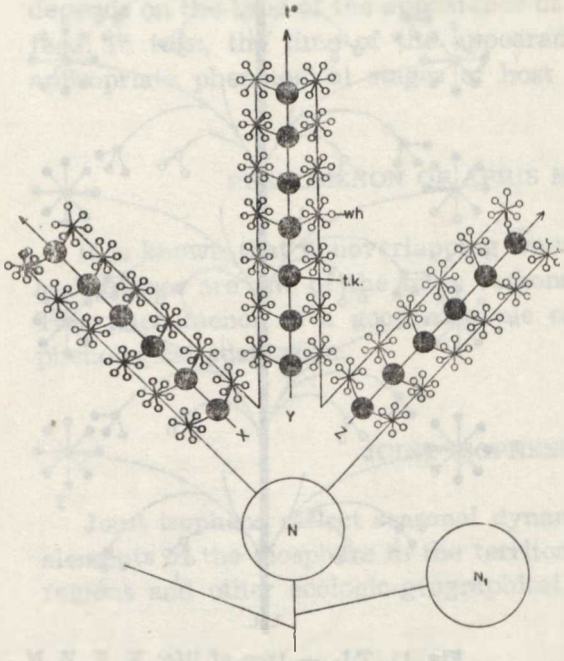

Fig. 12. N, N_1 — types of landscape; X, Y, Z — biotopes of landscape N, wh. — phenological whorls, t.k. — thermal knots on the curve of increasing temperatures, t° — temperature

ANNUAL SUCCESSION OF PHENOLOGICAL WHORLS (FIG. 13)

Every type of biotope in every type of landscape possesses specific annual dynamics of ecological-climatical conditions reflected in specific

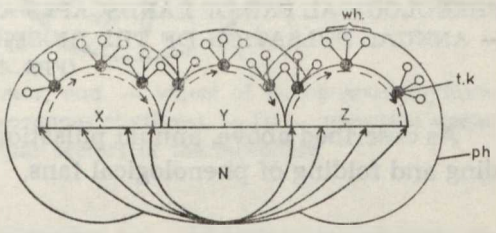

Fig. 13. N — landscape N with biotopes X, Y, Z; t.k. — thermal knots, wh. — phenological whorls, ph. — circle of phenological phenomena within a particular physiocenosis, arrows: solid arrow at the bottom shows penetration of microclimatic elements into biotopes, broken arrow — dynamics of microclimatic (ecological-climatical) and phenological phenomena. Thus the following general picture emerges: "on the surface" there are visible phenological whorls and their annual succession that result in an „invisible" succession and dynamics of microclimatic phenomena

annual succession and dynamics of phenological phenomena in natural units of landscapes (physiocenoses — W o d z i c z k o, geobiocenoses — S u k a c z e w).

PHENOLOGICAL FAN AND FORMATION OF PHENOLOGICAL WHORLS (FIG. 14)

Every natural segment of the environment (region, landscape, biocenosis etc.) possesses its own specific phenological fan: it is characterized by: 1) a definite composition of animal and plant species (a definite type of biocenosis), 2) a definite rhythm of phenological events (their order as

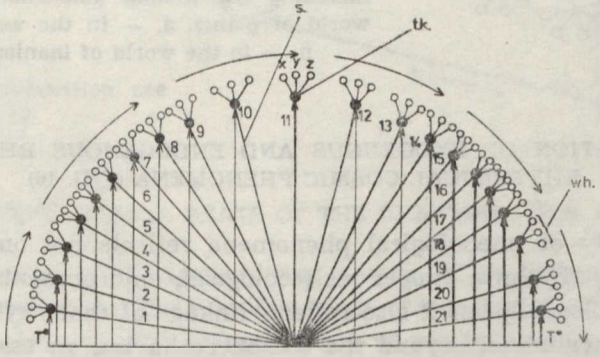

Fig. 14. 1—11 successive stages of unfolding of the fan, 11—21 — successive stages of folding of the fan, s. — segments of the fan corresponding to particular phenological events, T° — rise and fall of temperature, t.k. — thermal knot, wh. — whorls of synchronous phenological phenomena produced by a given knot, x — phenomena in the world of plants, y — phenomena in the world of animals, z — phenomena of inanimate nature

well as their duration), 3) a definite dynamics of unfolding and folding of the fan depending on a given climatic influence. The same fan, of fixed structure, changes with regard to time and speed of unfolding and folding, depending on meteoro-climatical conditions in respective years and on the character of a given environment.

PHENOLOGICAL FAN OF LANDSCAPES AND ECOLOGICAL ENVIRONMENTS — — ANNUAL PULSATION OF THE BIOSPHERE IN ITS DIFFERENT BRANCHES (FIG. 15)

As described above, annual pulsation of the biosphere reflects an unfolding and folding of phenological fans.

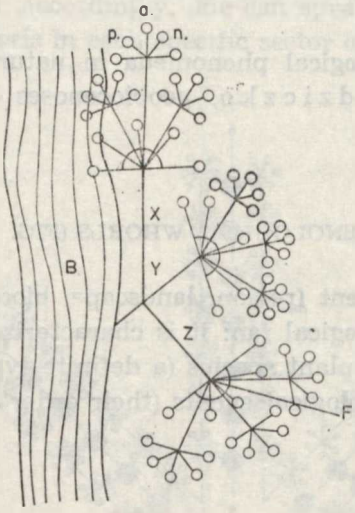

Fig. 15. — B — biosphere, F — phenological fan of various environments: e.g.X — beech forests, Y — peatbogs, Z — meadows; p., a., n. — whorls including synchronous phenomena: p. — in the world of plants, a. — in the world of animals, n. — in the world of inanimate nature

SYNCHRONIZATION OF EXOGENOUS AND ENDOGENOUS RHYTHMS WITH RHYTHMICAL COSMIC PHENOMENA (FIG. 16)

Rhythmicity of phenological phenomena reflects not only two kinds of overlapping rhythms: exogenous (ecological, environmental) and endogenous (physiological) but it also reflects linkage of that rhythmicity with some other phenomena beyond the biosphere having an essential impact on it (as, e.g., with the revolution of the earth round the sun). In this way a complex of interrelated rhythms of the biosphere with cosmosphere is in the formation process. Thus one can speak about phenology of the biocosmosphere or about the phenology of geocosmosphere or geocosmocenosis (see page 2).

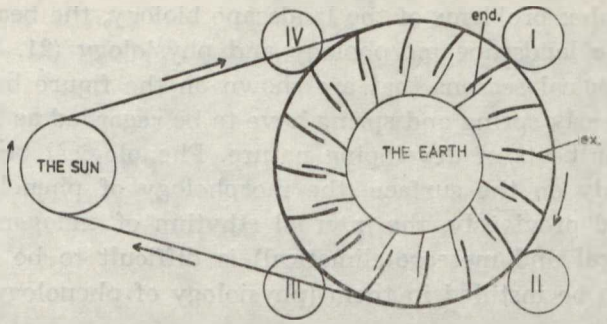

Fig. 16. ex. — wheel of exogenous rhythms, end. — wheel of endogenous rhythms (meshing of wheels of endogenous and exogenous rhythms), I—IV — succesive stages of phenophases of particular sectors of the biosphere

THE PRESENT RHYTHM OF THE BIOSPHERE AS A PRESERVED RHYTHM OF THE PAST AGES (FIG. 17)

Phenological phenomena reflect not only present processes and phenomena taking place in the biosphere but also represent some preserved echo of the rhythmicity of the past epochs (this is one of the reasons why it is so difficult to explain the essence of phenological phenomena).

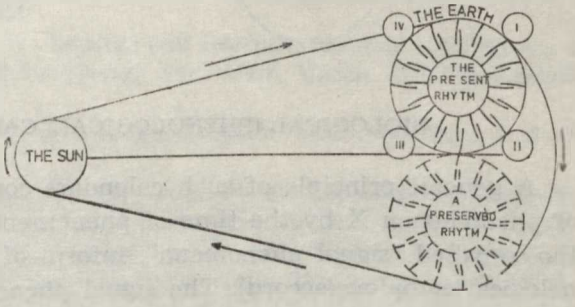

Fig. 17. For explanation see Fig. 16

PHENOLOGICAL BEATS OF THE BIOSPHERE (FIG. 18)

With reference to the transmitting wheels of an endogenous rhythm with an exogenous one, the manifestations of seasonal rhythmicity of the biosphere may be regarded as instillations of successive internal processes of inorganic geographic-natural environment into phenological pictures of phenological seasons, phenological complexes etc. (see Fig. 13).

The manifestations of this seasonal rhythmicity of the biosphere, reflecting themselves — among others — in particular successive phenological seasons, may be viewed as specific beats of nature. Within the scope

of some complex problems of the landscape biology, the beats have to be related to the landscape morphology and physiology (21, 22). The first three phenological seasons that are shown on the figure below, namely: ante-spring, early spring and spring have to be regarded as the first three specific major beats of developing nature. Phenological beats are easily noticeable only on the surface (the morphology of phenology) because, as it was said previously, the internal rthythm of endogenous processes (biogeochemical and meteoro-climatical) is difficult to be observed and is assumed to be instilled in them (physiology of phenology).

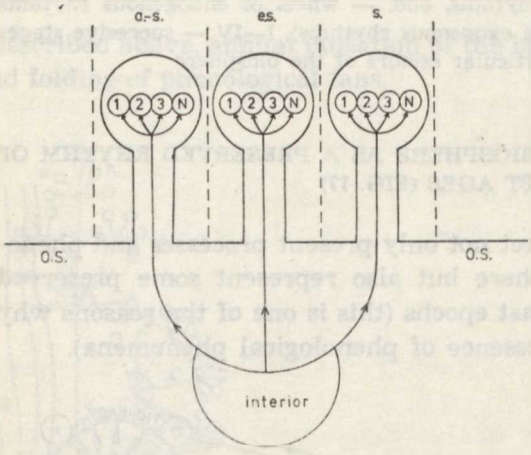

Fig. 18. 1, 2, 3, N — a number of successive minor beats making up a major beat of phenological season, a.s. — ante-spring, e.s. — early spring, s. — spring, O.S. — on the surface

BIOLOGICAL (PHENOLOGICAL) CALENDARS (FIG. 19)

A general principle of such calendars consists in measuring the time of phenomenon X by the time of phenomenon Y; the latter phenomena, the so-called "signal phenomena", inform of the state of the whole phenological complex (accord). The signal phenomena have to be very common and easily noteceable but also characteristic of a given fragment of time and space.

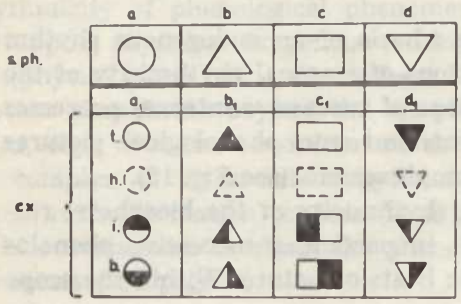

Fig. 19. s.ph. — signal phenomena (a, b, c, d) for a complex (cx) of phenological phenomena (a_1, b_1, c_1, d_1); t. — trees and shrubs, h. — herbaceous plants, i. — insects, b. — birds

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STRESZCZENIE

W pracy przedstawiono ważniejsze koncepcje autora w zakresie teorii i metodyki fenologii (sezonowego rytmu) krajobrazu i jego komponentów. Praca integruje problematykę biologii (zwłaszcza ekologii) i geografii. Zaproponowano szereg nowych pojęć i terminów. Omawiane zagadnienia ilustrują schematyczne ryciny (ryc. 1—19) stanowiące istotną część pracy.

РЕЗЮМЕ

Работа касается главным образом исследований в области фенологии (сезонного ритма) ландшафтов и их компонентов. Тем самым органически связана она с вопросами биологии (в особенности экологии) и географии.

Автор представляет здесь свои важнейшие концепции теоретические и методологические, а также некоторые предложения терминологические.

Для более ясного представления сложной часто проблематики, каждый из поставленных вопросов иллюстрирован схематическим рисунком (фиг. 1—19) с кратким к нему комментарием.

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