# Towards Understanding Biological, Psychological and Cultural Mechanisms of Anticipation

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**Abstract.** Foresight or anticipation is an inevitable characteristic of life. Instead of asking whether this or that organism reveals some form of anticipation as it is often done in biology and psychology today, it is more fruitful to ask, in which ways different organisms anticipate future. In this chapter Anokhin's theory of the basic architecture of a functional system is taken as a starting point to proceed with the analysis of how psychological and cultural mechanisms of foresight have evolved over the history of mind. Grounded also on Vygotsky's and Lotman's theories, it is concluded that there are nine different developmentally ordered mechanisms of thought. Knowing the basic mechanisms of thinking, it becomes possible to evaluate research in anticipation from a new perspective. Limitations of less developed forms of anticipation can be recognized and replaced with more efficient hierarchically higher-order forms of anticipatory thinking.

**Keywords:** biotic anticipation, psychic anticipation, semiotically mediated anticipation

## 1 Introduction

Anticipation is one of the essential characteristics of life. All organisms are able to anticipate certain changes of their environment. Anticipation is everywhere – it is common in our everyday lives. When we plan (sic!) to take a bus, we predict that bus is going to be in a certain place at a certain time and after we sit in it, it travels to a predictable place. We put clothes on predicting that our body temperature is going to increase after that. And so on and so forth. Even thought often not called in this way, all science is also a form of anticipation. Medicine, for instance, is constantly looking for better ways to diagnose different disorders. Every diagnosis is in essence a form of anticipation: the diagnosis predicts the forms of effective treatments and also the state of a patient in the future. Economy, political science, chemistry, physics – all areas of human knowledge from natural sciences to human involve predictions of future states as well. If not otherwise, every scientific experiment is conducted to learn whether expected event is going to take place as predicted or not.

Thus it is safe to conclude that human activities aimed at making sense of the world and adjust to it are essentially forms of anticipation studies. Most of the time the studies aim to discover how to anticipate certain events. Humans, especially scholars among them, are interested in finding more and more information about the phenomena under study in order to use it for predicting future events. What is not so often realized is that anticipation is a two-sided phenomenon. On the one hand, indeed, knowledge about the phenomenon to be predicted is relevant. On the other hand, however, there is a living and sense-making organism who learns the ways to predict future. In order to learn the most efficient ways to anticipate, we should know how we – humans who anticipate – do it. We need to know, how our mind works and what kinds of possible obstacles we may encounter while trying to see the future before it arrives. In short, we need a psychological theory of anticipation.

In this chapter I am going to outline this theory as I see it. This theory is rooted, among others, in the works of two outstanding Russian scientists, neurophysiologist Piotr Anokhin and psychologist Lev Vygotsky. We are going to see that theories of these two scholars allow not only to understand anticipation processes better but – what is even more important – they also suggest direction for the development of new theories. Before going to the theory, I would like to mention that the theory described is quite complex. In the limits of one chapter it is not possible to discuss all the relevant background in sufficient details. So several fundamental concepts, among them life and psyche, are defined but not discussed.

## 2 Anticipation as a Characteristic of Life

First we need to understand how, in principle, living organisms anticipate. This might seem a little out of place – why to bother us with biology, if the aim is to understand psychology of anticipation? Yet understanding life is not just useful, it is essential for developing a coherent theory of any mental activity, including anticipation. The problem is that there are different ways how anticipation is achieved; in order to understand psychic forms of anticipation we must be able to distinguish them from biotic forms.

Before describing the basic form of anticipation in living organisms, it is necessary to define life. Today hundreds of different definitions can be found (e.g. [1]). These are not interesting for us as we need a definition that can be coherently incorporated into our theoretical framework. So we do not need to bother ourselves with questions whether life is defined by metabolism, reproduction or several other characteristics of life forms. Our subject is anticipation – which is always about environment or, more exactly, about the change of the relationships between an organism and its environment. Thus our definition of life should define it not as a list of characteristics of an organism as if isolated from its environment but make the unity of organisms and their environments explicit. In the following I rely on Anokhin's works, which did not give to the very best of my knowledge the definition of life necessary for the comprehensive theory of anticipation but nevertheless provided all the ingredients for that (see also [2] for a short survey of Anokhin's ideas).

Anokhin suggested that the decisive and primary characteristic of life processes is stability on the basis of self-regulation principles [3]. Here 'self-regulation' refers to systems, which equilibrium is maintained by the internally generated goal-oriented activity of the system. All nonliving nature may preserve their stability over considerable length of time without any activity. So we need to ask, why goal-oriented activities are necessary for living organisms. I think the answer to this question leads to qualitative distinction of life from nonliving matter: living organisms preserve their integrity not just in changing environments but in environments, which changes would be destructive to an organism unless organism does something purposefully. Organisms change either themselves or their environments in order to cope with environmental changes that potentially go over tolerance limits of their structural stability. Trees is northern countries, for instance, would just explode in minutes if in summer temperature would fall in short time, say a minute, considerably below freezing point of water. Water in a tree would freeze and expansion of it would destroy the tree. Yet nothing like that happens in ordinary situations, where changes from warm to cold are relatively slow. In that case trees can anticipate the change of the temperature beyond critical level and they would change themselves either by decreasing their water content or by binding water with chemical substances so that water will not freeze in winter temperatures. Making things short, we arrive at the following definition of life: *Life is a form of organization of matter, which, on the basis of the anticipatory reflection of the environment and corresponding goal-oriented activities leading either to change of itself or its environment, is able to sustain its integrity despite potentially destructive effects of its environment.*

This definition explains, among other things, why anticipation is absolutely essential to life – effects of potentially destructive changes of the environment can be prevented only before these changes take place. Another important ingredient in this definition is that of environment; life is defined not as a set of characteristics of an isolated organism but rather as unity of an organism and its environment. Each and every organism is adapted to its environment, including the changes of it, in certain limits that characterize the organism. Thus in a certain sense organism can be defined by characterizing the environment it is adapted to.

Now our question is, how living organisms anticipate future changes of their environments. Anokhin proposed the following idea [4][1]: in the beginning of the formation of living systems, every distinguishable event in the sequence of events in the environment became connected with a different chemical reaction in the system: environmental event *A* became connected with a chemical reaction *a* in the system; event *B* with a reaction *b*, *C* with *c*, etc. Chemical reactions *a*, *b*, and *c* begin to reflect the whole sequence of corresponding environmental changes when internal connections *a* → *b* → *c* emerge. This sequence becomes anticipatory, if the chain of chemical reactions in the organism, triggered by the environmental event *A*, is faster than corresponding sequence of environmental events. It is noteworthy that recent studies seem to confirm Anokhin's theory – though not mentioning his contribution – and open ways to understand biotic anticipation at the molecular level (e.g., [6-8]).

## 3 Anticipation in Living Systems: Far More Complex Than it Seems

[1] This idea was rediscovered by Robert Rosen (cf. [5], p. 8). Even though he was familiar with some of the Anokhin's works, he does not mention Anokhin's contribution in that particular context.

At the moment it might seem that we have understood anticipation, at least in living organisms. Next we see that we are far from that yet. There is a fundamental issue we must take into account. Namely, Anokhin followed the way of scientific thinking, I have called structural-systemic (cf., e.g., [9-12]). Shortly, according to this view, every distinguishable from others material object, including all forms of life, is a whole composed of distinguishable but not separable elements. It is important that the properties of elements, when they are included into a higher order whole, change. Anokhin, who also relied on this understanding, conjectured logically from this principle that no analytic study of the objects of studies can be conducted without exact identification of this object as a component of a big system [13]. This principle applies also to chemical chains of anticipatory reflection of reality that are not isolated from the organism as whole – therefore understanding of anticipation requires understanding of the whole where this molecular chain-system is an element.

## 4 Anticipation in the Structure of Goal-oriented Behavior

According to Anokhin's theory, the living system must be able to answer four questions about the future result of its behavior ([13], p. 70): (1). What result must be achieved? (2). When exactly this result must be achieved? (3). With what mechanisms this result must be achieved? and (4). How the system ensures the sufficiency of the result? Every living organism, in order to be able to answer these four questions and execute on the basis of answers to these questions actions with the expected results must be organized in a certain way. This organization was defined by Anokhin in his Theory of Functional Systems (TFS; [13-17]). Functional system was defined as follows: Functional system as a unit of integration is a strictly delimited group of processes and structures that are united for realization of a certain qualitatively specific function or act of behavior of an organism ([14], p. 128).

Next I will outline very shortly the basic architecture of a Functional System, which is described in Figure 1.

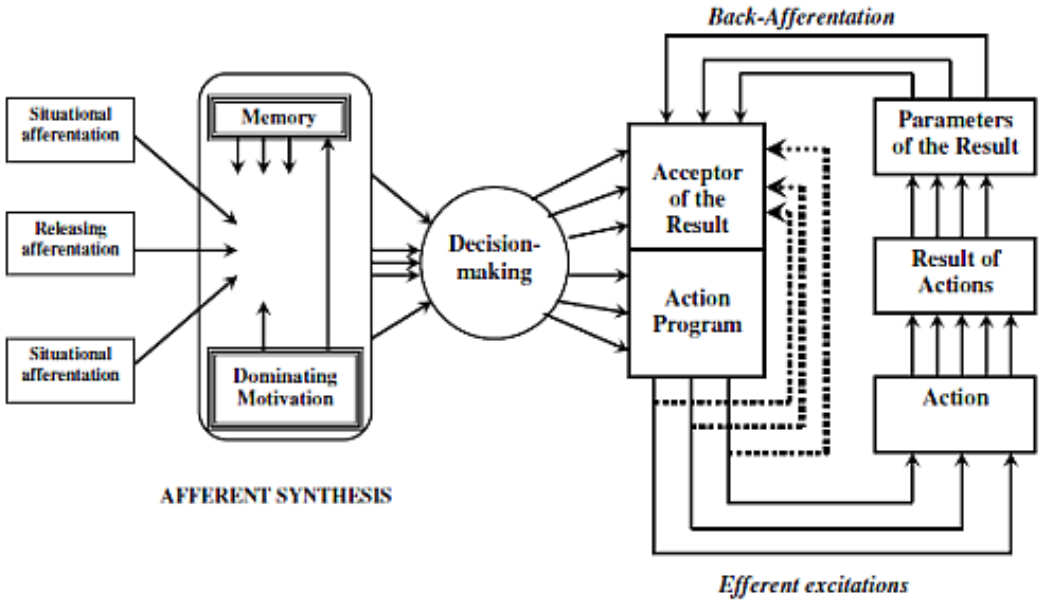


**Fig. 1.** The basic architecture of a functional system. Adapted from Anokhin ([13], p. 87; [16], p. 372)

Behavioral act begins with *afferent synthesis*. A behavior emerges on the basis of dominating at a given moment *motivation*. Motivational impulses activate in *memory* all information that has been connected to satisfying a given need in the previous experience of an organism. *Situational afferent* information is needed for further selection of memory information: this is information about what resources in the environment are available for an organism at a given moment as well as what environmental factors may hinder using the needed resources. In afferent synthesis all sources of information are integrated into a unitary whole on the basis of which *Decision* is made about what, how, and when should be done. Decision-making involves formation of two complementary dynamic structures: *Acceptor of the Result* and *Action Program*. Acceptor of the result includes all information about the physiological parameters

that characterize the expected result. When the *releasing afferentation* informs organism that it is time to release the action program, the *Actions* will be performed. Actions lead to some *results*, either in the organism itself or in the environment. Release of action program also is connected to the Acceptor of the Result which receives feedback from performed behaviors and therefore allows deciding whether behaviors correspond to the plan that is executed. Actions lead to changes either of the organism or its environment; these changes, sensed through sensory organs, comprise *back-afferentation*. Back-afferentation is compared with the expected pattern of inputs encoded by the acceptor of the result. If these two flows of information match, an organism is informed that expected result was achieved. In that case behavior is either stopped or, in case of a sequence of behaviors, a next behavior in the sequence is released until the final expected result is achieved. If there is a mismatch between the acceptor of the result and back-afferentation, new functional system is organized to achieve the motivated result.

As far as I know, Anokhin did not locate anticipatory processes coherently into the architecture of the functional system. In his TFS he discussed the role of anticipation in the acceptor of the result. Indeed, purposeful result-aimed action is impossible without anticipation of the specific result. This, however, cannot be the only process of anticipation in the system for two reasons. First, acceptor of the result is too specific – it is created as expectation of the result of very specific actions in very specific environmental circumstances. And second, this kind of anticipation is about changes of the environment or environment-organism relationships introduced by the organism. But life, as we defined it, is about survival despite potentially harming changes of the environment independently of the actions of the organism. Actions of the organism, on the contrary, are aimed at removing the potential danger.

So we actually need another kind of anticipation – that, which allows to anticipate the changes of the environment independent of the organism. No purposeful action can be planned unless it is not known, what kind of effect of environmental change needs to be prevented. If the question is put in this way, the answer becomes, I believe, obvious: another form of anticipation we are looking for must be located in the afferent synthesis; more specifically it must be located in the *motivation*. It is so indeed; dominating motivation, according to Anokhin, informs the organism about the *need* that must be satisfied. 'Need', however, refers to emerging mismatch between integrity of the organism and environmental conditions. So need is essentially the result of anticipation. Now we can be even more specific in locating this kind of anticipation in the structure of the functional system – the chemical chain-reaction that corresponds to certain chain of environmental events must be one element in the structure of a need.

## 5 Limits of Anticipation

Now we have distinguished two kinds of anticipation, one about the results of goal-oriented activity and the other about the possible mismatch between the changing conditions of the environment and the condition of the organism. Let us call them for sake of brevity action anticipation and mismatch anticipation, respectively. Next we analyze the limitations of anticipation. Some limitations are obvious. Organism cannot anticipate environmental events for which there is no corresponding intraorganismic anticipatory chain of chemical reactions. There is also no way to anticipate events, for which there is no sensory organs of the organism. This applies to both kinds of anticipation we distinguished above, action and mismatch anticipations. Anokhin's TFS allows us to go further and discover other mechanisms that limit anticipation and its usefulness. We can do it by just following the flow of decision-making and action in the TFS.

First, decision-making begins with the activation of a need, with a *dominant* motivation – which, as we discovered, contains mismatch anticipation. Here also lies the first limitation of anticipation: organisms cannot act to all mismatch anticipations; only one or, perhaps, a few, can be chosen at any given moment. The rest, thus, has to be suppressed or ignored. So organisms cannot anticipate actually everything they potentially could. Also, there must be some mechanism by which anticipations are ranked according to the importance for the organism. Every new anticipation acquired, requires comparison of it with all the rest of anticipatory reaction-chains to decide where the new anticipation should be posited in respect of importance. This introduces further complexity into anticipation.

Second, anticipation by itself is useless; it must be matched with actions in order to be useful for the organism. There are, however, potentially many different ways to prevent harmful effects of anticipated environmental changes. Organisms are limited in the ways of actions they have in memory. These ways, in addition, may not be the best to adjust to the environmental changes. Especially in the context of the third limitation – that of available environmental resources estimated on the basis of sensations. So the potential benefit that may emerge on the basis of anticipation can become useless if memorized actions are not matched with available resources. In that case there is no difference whether organism has anticipated a certain mismatch with its environment or not.

Fourth, the more complex is the organism, the more there are ways to construct an action program. Choice among numerous possible ways to react on mismatch anticipation introduces further potential instability into the system as a whole. We already saw before that without efficient actions anticipation has no use for the organism. Here, thus, lies another limitation on the utility of mismatch anticipation.

Fifth, with performing actions and achieving results a new instability is brought into organism-environment relationships. By changing environment in one way many unexpected consequences may emerge together with expected results. Thus anticipating one sequence of events and acting on the basis of that anticipation may actually lead to unexpected environmental changes that may be even more harmful than the anticipated one. If this turns out to be the case, anticipation has actually failed from the survival perspective.

Finally, interesting consequences may follow from back-afferentation, i.e. from perception of the results of actions. If actions have led to expected results which, however, in that particular environment have activated a chain of events with harmful to the organism consequences, the organism receives contradictory feedback – expected result turns out to harmful. Meaning of mismatch anticipation that underlies the actions with unexpected side-effects becomes contradictory for the organism.

All this said, it might seem now that there can be no use to anticipation at all. This conclusion would be obviously wrong. The fact that life has existed on earth for about four billion years is proof to that. Nevertheless, the consideration just discussed should not be ignored also – anticipation that is useful in most cases may utterly fail in certain situations for many reasons, as we just saw. If we are to learn how to mismatch anticipate the world better, potential sources of failure need to be kept in mind. It might be said now that what has been discussed so far concerns just relatively "blind" biotic mechanisms that are not relevant for humans. The opposite is true, humans are living organisms as all the others in this respect. Therefore humans may fail in anticipation similarly to all other organisms. In fact, the consequences of failures might be far more devastating for humans because we have learned ways to act on environment with massive consequences on the whole ecosystem on earth. One "small" error in anticipation may lead to devastating results for the whole race.

## 6 Psychic Forms of Anticipation

Biotic form of anticipation is not the only one available to organisms. Among living organisms there is a subgroup that is able to anticipate in two ways, biotic and psychic. To understand how these two forms of anticipation are different we need to define mind or psyche.[2] I think there is one central qualitative difference between biotic and psychic forms of being; this difference lies exactly in the mechanism of anticipation. All living organisms anticipate on the basis of the experiences of the *species*; this is biotic form of anticipation. Some of them anticipate also on the basis of *individual* experiences – this is where psyche is born. I define psyche as follows: *Psyche is a form of organization of living matter that is characterized by active, purposeful aimed at self-preservation relation to its changing environment on the basis of individual experiences* (see for earlier versions of the definition, [20], pp. 10-11; [21]).

Through individual experiences new forms of anticipation become possible. Central difference between biotic and psychic forms of anticipation lies in the units of information that are organized in experiences. In biotic anticipation, it is chemical reactions, which are connected to environmental events. In psychic anticipation the biotic mechanism is the same – biochemical-biophysiological. Yet in psychic experiences there are structurally complex units that can be understood at hierarchically higher level of analysis. What are organized in psychic experiences are sensory attributes, which correspond to qualitatively distinct units of biotic structures.

Psychic forms of anticipation are based on learning novel relationships between sensory attributes. Without going into details, three developmentally ordered ways of forming associations between sensory attributes can be distinguished (see for background, [22]). First just relevant for the organism *associations between sensory attributes* can be learned. Classical example of that kind of learning is Pavlovian conditioning, where an animal learns an association between some sensory attributes of food and regularly co-occurring to them events in the physical world;

[2] I prefer to use the term 'psyche', because the term 'mind' is in modern mainstream psychology usually used as an attribute of an organism as if isolated from the environment. Historically the term 'psyche' is also contaminated – by questionable theories of psychoanalysis. Yet the term 'psyche', psychoanalytic speculations left aside, is free of fragmented and both ontologically and epistemologically problematic meanings that characterize modern mainstream psychology (see, e.g., [10-11], [18-19], for the discussion of these fundamental problems). So I stick to 'psyche', even though 'mind' can be taken as synonym of it.

ring of a bell, for instance. In this way an organism learns to react on novel anticipatory events of the environment. Yet no novel ways of action can develop at that stage. The reasons for this limit become clear with the next stage. At the second stage of psychic development, the learned associations of sensory attributes differentiate; certain learned structures form higher order wholes that correspond to *things* in the organism's environment. Now an organism can also change the structure of its actions – novel actions can be created and executed. At the first stage, associated attributes could belong to many different things in the environment and there is no way to act towards all of them in one act. If things are distinguished, the organism changes qualitatively;[3] now it can act towards them. Entirely novel patterns of actions become available in this process. Most primitive forms of tool-use emerge at this stage. Acting towards things also grounds the next stage in psychic development. While manipulating things, an organism can learn relationships between them; it can develop representation of *situations* at this stage. Actions also change; an organism becomes able to plan actions that relate things into novel structures. Now more complex tools can be created by synthesizing several things into one tool with novel qualities.

Psychic anticipation, as we saw, is related to qualitative changes of the organism – entirely novel ways to relate to the environment emerge in psychic development. Yet there is a very fundamental limit to even the most developed forms of anticipation; all anticipation is limited to environmental events that can be sensed. The senses, however, are activated only in the interaction with very limited number of physical events of the far more complex environment. Things too large, too small, too distant, too close cannot be sensed as well as many other physical phenomena for which there are no senses at all. We know that humans are able to represent this world that goes beyond senses and also anticipate events in this extrasensory world. Entirely new kind of psychic operations must emerge for experiencing extrasensory world.

## 7 Specifically Human Forms of Anticipation: Semiotically Mediated Thought

Theory to explain the mechanisms by which humans have acquired an ability to represent the world beyond senses is quite complex (see [23-26, for elaboration). In principle, following Yuri Lotman's theory (e.g., [27-30]), for creation of novel kind of information, at least two different mechanisms of information processing must interact. Novelty emerges in the process of "translation" between those two mechanisms that by their nature have achieved different understanding of the same phenomenon. I have shown that one of these two mechanisms in humans is sensory based thinking just described above and the other is language. Language is not just to reflect sensory-based experiences. In language information is processed according to another set of principles – those of social interaction. As the rules of connecting language units are qualitatively different from the rules by which sensory experiences are connected, the same experiences are processed in two different ways and therefore also with two different results. Novelty, including representation of the world beyond senses, emerges when these two results are synthesized into a higher order psychic whole.

Let us take just one example to understand this. When we are looking some numbers on a display, we can just see the light emanating from the display. In sensory-based thinking we can associate these numbers – if they regularly co-vary with other observable events – with other sensory experiences. But a scientist, who has formulated a scientific theory – which is always with no exceptions in some form of language – the same numbers on a display can be interpreted as concordant or discordant with the theoretically expected numbers. Thus sensorily the "same" numbers can acquire very different meanings depending on whether they are or are not interpreted in the context of some theory formulated in language. In scientific interpretation, these numbers may reliably and validly refer to extrasensory world.

## 8 Stages of Word Meaning Development

It was Lev Vygotsky, who not only put language in the center of human cognition – that was done by many much before him (see, e.g., [31-32]) – but also grounded a developmental theory of language that could explain qualitative

[3] Here more than before the definition of 'quality' becomes essential. Quality, as I have defined it, *is the potential of a structure to become into relationship with another structure* ([12], p. 283). Thus qualitative change is essentially a process of emergence of novel ways to relate to the environment.

differences in cognition. Vygotsky distinguished three stages in word[4] meaning development – syncretic concepts,[5] complexes or everyday concepts, and scientific concepts (e.g., [33-34]). This most innovative theory of the time had some fundamental deficiencies. First, there is no understanding how language evolves from nonlinguistic processes and how every next stage of word meaning structure develops from the previous stage. Second, he did not provide arguments as to why the stages evolve in that particular order. And third, he also did not describe in sufficient details what exactly distinguishes word meanings at different stages. I have tried to answer these questions. Answers to these questions forced to look at word meaning structure development in novel ways. Among other things it turned out that not three but five stages in word meaning development should be distinguished [26], [35].

Next I describe these five stages shortly. It should be noted that I am going to use terms to name every of the stages, which only partly overlap with those I proposed earlier. These older terms just feel a little clumsy to me now. I also add short remarks as to the forms of anticipation available at each of the stages of word meaning development. So the stages, as I see them are characterized as follows. Word meaning development begins with *syncrets* or *syncretic concepts*. Their relation to referent is not fixed in any way; the same word form, depending on the context, can be used to refer to different aspects of the situation. The basis of extension of the word meaning changes also; different sensory and functional qualities of the situation are selected for extending word meaning. Therefore semiotically mediated thought, i.e. thought, which structure involves a word as one element, is not focused as well. Nevertheless, words can be used for anticipation at that stage in ways not possible in biotic or sensory-based psychic anticipation. Perhaps the most important qualitative change that takes place with the emergence of syncretic words in comparison to earlier sensory based forms of thinking is that words, due to their flexibility, allow to expand the ways different events are connected into anticipatory thought. Word meaning connects together things and phenomena in novel ways, determined not by the environmental circumstances but by the principles of thought. Thus entirely novel ways to relate experiences emerge with syncretic signs.

Next *object concepts* develop. These words are distinguished into two classes by their reference. One class of object words refer to objects and another class to object-specific attributes, both sensory and functional. At this stage, it is not possible yet to express relationships between things in language; situations are thought in not mediated semiotically sensory-based units. Categories of objects referred to by objects concepts do not have clear boundaries; object-words refer to prototypical categories (see on prototypes, [36-37]). Object concepts allow to anticipate new properties and functions of objects not obvious from direct encounters with them in the environment. Every time a different word referring to some novel attribute is associated with the word referring to an object, the object in the environment is thought in a novel way.

Third stage of word meaning development is that of *everyday concepts* – I am using the term proposed by Vygotsky here. At this stage it becomes possible to describe situations in the sensory world. Words that refer to objects can distinguish, differently from the previous stage, exemplars from one another. Both within-object and between-object attributes of situations can be referred to. As combining of the words is not constrained by directly observable situations, imaginary worlds not available for senses – such as fairy-tales or religion – can be created. Yet there is no cognitive mechanism by which to distinguish imaginary extrasensory worlds from realistic ones. This mechanism develops only with the next stage.

As to anticipation, concepts at this stage open entirely new possibilities. Words allow to extend anticipation quantitatively both in time and space; predictions can be made over life-time and further as well as over distances not personally experienced. Though this extension can be expressed in terms of quantity of time and space-distance, respectively, the change is actually qualitative. I think agriculture is one of the activities that emerged on the basis of everyday conceptual thinking. Here we see anticipation over considerable amount of time: seeds to be used in spring are preserved from the crop collected in autumn; the same seeds sowed in spring are anticipated to give crop in the next autumn. Planning of sowing requires purposefully "throwing" food away in order to get more of it many months later. Humans have done it in many occasions even when very hungry. Complexity of planning goes further; the soil is prepared, fertilizers are used, etc. All this requires planning where things are purposefully organized beyond what can be experienced in spontaneous natural environment.

In the next stage, I call *logical concepts*, the main limitation of the previous stage is overcome: it becomes possible to distinguish intralinguistically created imaginary extrasensory worlds from potentially realistic representations of the world beyond senses. Two parallel changes in the word meaning structure underlie that

[4] Vygotsky usually used the term 'word' in a wide sense referring to all kinds of linguistic signs, not only oral speech. I am using the term 'word' in this chapter in the same wide sense.

[5] 'Concept' is another term, which Vygotsky often used as synonymous to 'word' or linguistic sign. I am also going to use the term 'concept' as referring to linguistic signs exclusively.

potential. First, categories referred to by logical concepts are organized intralinguistically; this allows to create categories of referred aspects of the world with sharp yes-or-no boundaries. Verbal thought becomes precise at this stage. Second, logical concepts are used as a system where description of the external world is combined with metacognition. In addition to describing the world, it is thought how the thoughts about that external world are organized. This is most obvious in all sciences, where theories of the world are always checked in terms of thought itself – it is asked, whether the conclusions follow from premises logically or not. Illogical conclusions are rejected independently of their subjective appeal. In this way it becomes in principle possible to distinguish between myths, fairy-tales, religion, etc. on the one hand and rational empirically based sense-making of the (extrasensory) world on the other.

Anticipation acquires now qualitatively novel dimensions; foresight can be rationally based on knowledge about extrasensory attributes of the world. In addition, as logical concepts rely on metacognition, it becomes possible to formalize predictions; forms of mathematical anticipation become possible, for instance. Another formal form of anticipation is based on creation of lists of individually necessary and collectively sufficient attributes of phenomena. If all the attributes are present, predictions can be made. This kind of prediction is common in modern medicine, for instance. In medicine diagnoses are made. Diagnosis is a form of prediction: it predicts the effects of possible treatments and also the future states of a patient.

Here we can also distinguish predictions based on logical concepts from predictions based on everyday concepts. In everyday concepts also lists of predictive attributes can be made. But everyday conceptual thought does not have possibilities to select the attributes rationally. Health and future states of it can be predicted on the basis of many "signs", such as the color of the skin, patterns of pulse, presence of pain, difficulties in breathing, etc. But such predictions may occasionally turn out to be useless if not harmful. One problem is related to theories of the causes of the sicknesses. Modern medicine creates and constantly revises attributes necessary for a diagnosis on the basis of increasing understanding of the mechanisms of the sickness. In traditional cultures where thought is based on everyday conceptual thinking, causes of some diseases can be attributed to supernatural forces. "Cure" in that case is supposed to be found in communication with that supernatural world through dances, offerings, etc.

Another problem is related to the selection of treatments. Some problems of the lungs, for instance, could be "cured" in Europe just a few centuries ago with a "Lohock", certain form of a linctus, a drug "to be licked up" ([38], p. 135), made of the fox lungs (*ibid.* p. 137). And how was use of such drugs justified? It is not hard to guess by just reading the title page of the book, where we find that the author Nich. Culpeper was "Gent. Student in Physick and Astrology" – yes, Astrology. The reasons for using substances with quite questionable today health effects was justified then by astrological considerations. No wonder that these drugs are mostly gone from modern pharmacopoeias.

Logical concepts, however, are still constrained. Formal logic is a powerful tool – illogical chains of thought can be rejected without any further analysis. Yet, logically correct conclusion is not necessarily correct about the world. Logical conclusion about the world is correct, when the premises of it are correct. Thought in logical concepts does not question the sources of premises; these are just accepted. Modern mainstream psychology,[6] for instance, relies almost exclusively on statistical data analysis methods in interpreting the data. On the basis of such analyses conclusions are made about the mental processes that supposedly underlie observable behaviors. One fundamental question, however, is not even asked – why to assume that quantitative methods are actually appropriate for achieving such conclusions? Here we see that certain premises of scientific thought are not questioned; they are accepted with no ground. As a matter of fact, after asking the question, one would find that it is impossible to infer hidden from direct observation psychic processes on the basis of observed behaviors by any kind of mathematical data interpretation procedure [9], [39-42].

This limitation can be overcome at the next stage of development, that of *systemic concepts*. In this form of semiotically mediated thought, the whole process of sense-making is made conscious; in addition to the chain of conclusions, the premises of the chain are explicitly analyzed and their sources studied. Systemic semiotically mediated thought can be characterized from another perspective as well.

Here it becomes crucial to define what 'system' is. It is important to realize that 'system' has been defined in several different ways. So the definition that characterizes systemic thought must be rationally chosen – I have done it elsewhere [9-12]. On the basis of theoretical considerations – I already mentioned above that this theory I have called structural-systemic – I suggest that system must be defined as a qualitatively novel whole that emerges in the synthesis of elements in specific relationships. This definition is not original, in psychology, for example, it was

[6] See for a definition of 'mainstream psychology', [11].

adopted already by Wilhelm Wundt [43] and followed by many scholars, among them Anokhin, Vygotsky, and Luria.

When element is incorporated into a higher-order whole, its qualities change according to which exactly whole it belongs to. These principles apply to thought as much as to the rest of the material world. Thus in systemic conceptual thought it is explicitly understood that every act of thought – including every act of anticipation – is part of the more complex whole of psyche. It follows that results of thinking depend on the context where the act of thought is situated – this context contains, among other components, the premises. Thought becomes systemic only when the context of it is explicitly defined. In addition to its premises, several other aspects need to be taken into account. First of all, a systemic thinker must – not should or would! – be able to understand the principles of his or her own thought.

Anticipation as a special form of thought also changes qualitatively at this stage of development of word meaning structure. All of the changes cannot be described here. First and foremost not because of space limitations – which are obviously important – but because I am not able to analyze them in sufficient details (yet?). But I think one important aspect of systemic anticipation must be stressed. In systemic thought all kinds of anticipation, including those based on lower levels of thought organization, can be accepted – if this acceptance is based on a theoretically grounded justification. For example, quantitative mathematical prediction can be accepted if it is understood that systemic prediction is not yet available because of the lack of relevant knowledge (cf. [41]). But what is unacceptable is to believe that mathematics is the best possible form of prediction. According the structural-systemic approach, the best possible anticipation is achieved with explaining the thing or phenomenon under study. Explanation is here defined unequivocally as knowledge about what elements in which specific relationships form the qualitatively novel whole that is studied. Prediction in that case is not quantitative-probabilistic but rather qualitative: knowing which elements are available and into which relationships they can enter in a particular context, it is possible to anticipate exactly which kind of a higher-order whole emerges.

I add here a last remark. I am not saying that systemic thought allows predict systemically every possible state of affairs in the universe. This is impossible for several reasons. Among them the most important limitation lies in the impossibility to understand unique aspects of events; only repeated aspects of them can be understood in principle [40]. Another reason lies in the fact that qualities of a whole emerging first time cannot be predicted. As novel wholes with unique qualities emerge constantly, it is not possible in principle to anticipate consequences of such emergence. So anticipatory thought will always be limited. And yet there are ways to improve our anticipation qualitatively and through this to become able to know possible futures in far more details than it can be done today.

## 9 Summary and Conclusions

In this chapter I followed the path grounded by Piotr Anokhin, Lev Vygotsky and Yuri Lotman among others. Following their theories, I concluded that anticipation characterizes all forms of life. What is often not taken into account is that more than one mechanism of anticipation can be distinguished. These mechanisms can be developmentally ordered. In order to formulate a coherent theory of thinking development in general and anticipation in particular, some fundamental phenomena were defined – life and psyche in the first place. Three qualitatively different basic mechanisms of thought were distinguished: biotic, psychic, and semiotically mediated. On the basis of Anokhin's Theory of Functional Systems I demonstrated that two forms of biotic anticipation must exist; one for anticipating changes in the environment-organism relationships and the other for anticipating results of goal-oriented activity. The same theory allowed to understand better the obstacles on the way of anticipation. Anticipation is just one component in a general functional system and therefore the state of the other components in the same system constrain the ways and efficiency of anticipation. I suggested next that psychic anticipation can take three developmentally ordered qualitatively different forms and semiotically mediated thought, in turn, exists in five hierarchically ordered forms.

Anticipation is always a two-sided phenomenon. On the one hand, efficient anticipation requires information about the anticipated phenomena. On the other hand, however, efficiency of anticipation is bounded by the mechanism of thought that underlies anticipation. Theoretically, the more developed is the mechanism of though, the more efficient anticipation can be achieved. Every time we aim to find better ways for anticipation, we should explicitly take into account the form of anticipatory thought we are relying on. This allows us to search for the most informative kinds of information available and construct the best models for anticipation. Perhaps one of the most radical in today's context of science conclusions that emerge from the theory concerns the use of mathematical tools

for anticipation. It turns out that mathematical prediction is not and can not in principle be the most efficient way for anticipation. Theoretically the most efficient anticipation is qualitative or, as I have called it, structural-systemic.

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