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The Theory of Biomedical Knowledge Integration(Ⅲ)

——A Rediscussion on Background Space of Knowledge(BSK)

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Abstract This paper discussed the theory of background space of knowledge(BSK), which might be involved in a purely and entirely exploratory research of the Theory of Biomedical Knowledge Integration(BMKI). A set of basic concepts dependent on BSK were described. The necessary dimensions(NDs) of some abstract and particular BSKs have been presented and a principle for the functional integration of nerve-muscle synapse, for an instance, has been investigated.

Key words Medical Informatics, Biological Informatics, Biomedical Knowledge Integration, Virtual Patient, Artificial Intelligence of Medicine

1. The Roots of Knowledge

When we see a group of ants being very busy in a grassland, we are actually watching an inexhaustible world and can tell an endless story about it. “What are they busy with?”, “How they get food?”, “What enzymes are involved in the digestion of food?”, “How DNA expresses those enzymes?” “which molecular mechanisms control the expressing function of DNA”, “How the information system works in ant society?”,…I am sure that even the thousandth filial generation can’t finish this story. For the physical worlds, human being will never lose the curiosity. That means a human curiosity-created physical world is an endless one. And based on human curiosity, we can’t talk about completeness, certainty, clarity, understanding, etc of knowledge, reasoning and integration. But, in fact, each filial generation will nevertheless discuss his own recognized completeness, certainty, clarity, understanding, etc of knowledge, reasoning and integration, because each generation has his own mental or physical cognitive goals, basic objects and rules(self-evident truths or axioms), which altogether construct background space of knowledge(BSK) or the roots of the attributes or knowledge. It is the basic point of my theory of background space of knowledge for a goal-determined world. By this means, each generation makes, consciously or unconsciously, the endless physical world into a limited world or a story with perfect beginning and end.

Thus a BSK can be described as followings:

(1) It is determined by a mental(non-material) or physical(material) cognitive goal.

(2) It is based on a set of dimensions, ie the basic definitions(concepts, units, etc) and attributes, relations, rules etc. Each of dimensions has its valid domain of value.

(3) A complete BSK should have a set of necessary and sufficient(N-S) dimensions. The necessary dimensions(NDs) of a BSK are rather easy to be recognized, whereas the necessary and sufficient dimension set(NSDS) of it is more difficult to be met.

For automatic processing of biomedical knowledge, virtual patient engineering or data and knowledge integration[1-12,13-14] there are many problems needed to be investigated including so called the type Ⅱ theory in AI discussed by D.C. Marr[16]. And it is very important to increase robustness of the knowledge bases and reasoning mechanisms. That is one of the reasons why I have been doing my utmost to investigate the "soil" in which the knowledge exists and its reasoning carries out.

According to the theory of BSK, when we consider the attributes or descriptions of an object, we also need to think further the situations of their BSKs as much as possible, to confirm the completeness, certainty, clarity, etc of those expressed knowledge. The knowledge frame and structure of an object might be described as Fig.1 and 2.

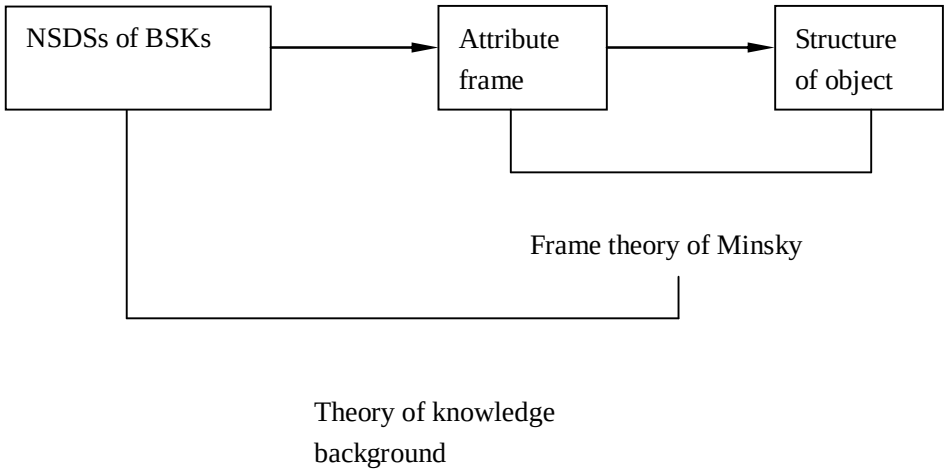

Fig. 1 The relation of the theory of BSK and the frame theory of Minsky. Any attribute of an object has its background space underlying. For the knowledge engineering such as biomedical knowledge integration, virtual patient, etc we need more robust knowledge representations and operations. For that purpose, it is sometimes necessary to know not only the attributes with or without their values at the level of phenomenon, but also the roots under them. The author believes that the clinical interpretations of a doctor involve, obviously or unobviously, the under-phenomenon situations or backgrounds of the attributes.

2. A Set of Definitions of the Basic Concepts

The author argues that the certainty, clarity and granularity, the completeness of concepts,

the sufficient and necessary conditions and the validity of reasoning, etc for which we are longing in various intelligent activities exist only in the definitely specified backgrounds or spaces. Therefore before doing any knowledge operations including integration of knowledge, we should ask what are underlying those knowledge. But first of all, the author prefers a discussion on a set of basic concepts relevant to this viewpoint.

Definition 1 The generalized dimension of BSK: The generalized dimensions include the those independent basic concepts, factors, elements, units and their definitions, attributes, relations, rules, forces, etc which altogether determine the behaviour of the object in the space.

Definition 2 The basic components of knowledge unit: In general, a knowledge unit is composed by four types of basic components: direct factors, indirect factors, direct rules and indirect rules. Concept "factor" is equal to "element", "operator", etc and "rule" is the synonym of "attributes", "relation", etc

Definition 3 The cognitive motive: That which causes one's efforts to get knowledge. There are two kinds of cognitive motives, one is driven by the instinctive or inherent longing or curiosity of human being for acquiring knowledge(ILAK or ICAK) about the world, creating the curiosity-driven knowledge systems, and another is by particular, physical or mental goals or "profits" (PPG or PMG) , creating the goal-driven knowledge systems.

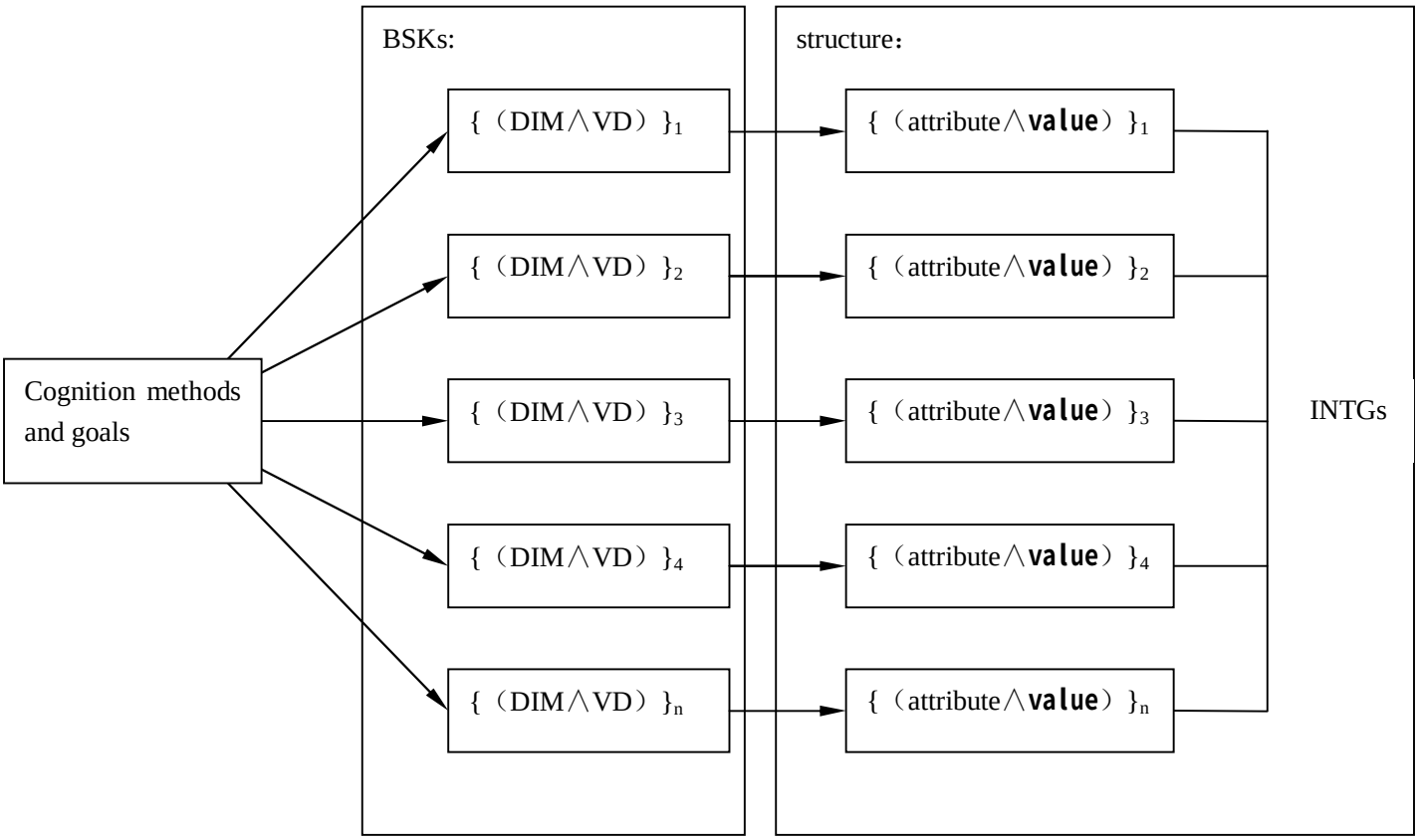

Fig. 2 A more detailed knowledge representation diagram: every thing relies on the cognitive methods and goals, which determine several background spaces. These different background spaces underlie those attributes of Minsky's frame. Where DIM: dimension, VD: valid domain of value, INTGs: integrators .

Definition 4 The cognitive goal: A set of things to be obtained driven by a certain cognitive motive. The goals determine the granularities of the rules, factors, interpretations, operations, etc involved.

Definition 5 The cognitive goal driven by ILAK: It is an endless goal, because human being can never exhaust the secrets of the world and fully meet his curiosity. Under this goal the granularities of rules, factors, interpretations, operations and BSKs are all infinite concepts. But at any historical stage, people can confine the endless goal to a rather definite one at that time, transforming it into a cognitive goal driven by PPG or PMG.

Definition 6 The cognitive goal driven by PPG or PMG: The specialized cognitive goal or things driven by PPG or PMG. That are sets of particular mental or physical objects and/or relations. Special mental goals include building a theory(eg Euclidian geometry), composing a poem, etc and physical goals may be those for eg diagnosing and treating a disease, growing a mu of rice, feeding a cow, and so on.

Definition 7 The cognitive quantum(CQ): So called cognitive quantum is the smallest factor(s) or rule(s) determined by a certain cognitive goal. They are the factor(s) or rule(s) which are unable to or don't need to be split further, for that cognitive goal.

Definition 8 CQ by ILAK is the stably and separately existing, smallest factor(s) or particle(s) or basic relation(s) or force(s) observed or measured by the scientific techniques in that age.

Definition 9 CQ by PPG or PMG is the smallest factor(s) or particle(s) or basic relation(s) or force(s) for a certain goal of PPG or PMG. For examples, hen and egg of a grandmother, point of Euclid, cell of pathology, Marie's dog, etc.

Definition 10 The cognitive granularity(CG) is the degree of the details of a thing for a certain cognitive goal. It may be theoretically calculated by the formula

CG = 1/d,

where d is the number of N-S details or items of a thing. The details of a knowledge unit may cover the aspects direct or indirect factors/operators and rules/relations.

Definition 11 CG for the cognitive goal driven by ILAK: The cognitive granularity for a certain cognitive goal driven by ILAK is a degree of the details of a thing for that goal.

Definition 12 CG for the cognitive goal driven by PPG or PMG: The cognitive granularity(CG) for a certain cognitive goal driven by PPG or PMG is a degree of the details of a thing for that goal.

Definition 13 The granularity of a cognitive quantum(GCQ): Because the detail of quantum is itself, ie d =1, therefore GCQ = 1.

Definition 14 The granularity of knowledge expression(GKE): The granularity of knowledge expression or description is the degree of the details of an expression of knowledge for a certain cognitive goal, ie the total granularity of the expressed details of the direct or indirect factors and/or rules of a piece of knowledge. It could be imagined as the granularities of "bird-views", eg the different sights of Shanghai for a person at levels of ground, building,

mountains, satellite, etc

Definition 15 The completeness of knowledge expression（CKE） is the ratio between the details expressed and N-S details of a thing for a certain cognitive goal.

Definition 16 The operational granularity of knowledge(OGK): The degree of the N-S details of the operational factors or rules of a knowledge for a certain cognitive goal(contrasted with CQ by ILAK). For a fruit seller , for example, it is needed only to know the quality and price of the fruit, without a necessity to investigate the details about how the fruit trees are growing in the garden.

Definition 17 The composition of BSKs: Several heterogeneous BSKs act jointly in a certain way. For instance, in AND-composition of BSKs, we can get the dimensional set of a compound BSK:

$D_c = D_1 \wedge D_2 \wedge D_3 \wedge \cdots\cdots$

Where $D_1, D_2, D_3, \ldots$are dimensional sets of the BSKs which take part in the composition.

Some kind of knowledge has "zero" BSK and unconditionally holds water. For example, a proposition "the life span of a person is limited" is unconditionally tenable knowledge. Even so, there is still some relativity in this proposition, because it is only unconditionally tenable for people who believe sciences, not for the first emperor of Qin Dynasty(221-207 B.C.) who believed that a person can never die. And in fact, here we only speak of people's physical bodies rather than of their mental activities, because the theories of people like Newton, Einstein, Euclid, etc for instances, will live for ever.

3. The Necessary Dimensions of Some Basic BSKs in Organism

Blood flows in blood vessel bed, following the laws of semi-hemodynamics; bone-muscle system is moving according to the lever-principle; rod cell in retina functions in terms of a chain: light—change of molecular configuration of rhodopsin—receptor potential, and hypothalamus—adenohypophysis—thyroid gland axis works through the HRP(hypothalamus regulatory peptide) — TRH（thyrotropin-releasing hormone）— thyroxine feedback loop;… Before talking about the integration of biomedical knowledge, we have already seen that thousands of biological mechanisms work in or are controlled by their own surroundings or spaces. In the following text I will only list out the necessary dimensions(NDs) of them, the researches on the more essential aspects of them is waiting for the efforts in the future.

NDs of The Limited Physical Descartes Space(LPDS) or Biological Room: The space is the container space for any other physical spaces or structures, including anatomical structures. The NDs include (1)The boundary which determines an efficient volume with a limited size. (2) The basic unit: evenly filled with the volume-replaceable Euclid points.

NDs of the Mechanical Force Linking Space(MFLS) or Mechanical Force Relation Semantic Network Space, or Spider Web Space: The space is one of the basic spaces of anatomy. The NDs are (1) The basic unit is any physical volumes with any shapes and hardness. (2)The boundary. (3) The relation between units: mechanical linking force through different shaped junctions (point-, line-, area-, anchor- and contain-shaped) and with different strength**.**

NDs of Physical Opening Communicating Spacs(POCS) or Anastomotic Relation Semantic Network Space or Kiss-Web Spac): The NDs are (1)The basic unit is any physical

volumes with any shapes and hardness. (2)The attribute of the basic unit: the boundary. (3) The attribute of the basic unit: the opening with its dameter. (4) the relation between units: the communication through the opening.

NDs of Static Compartment-Substance-Distribution Space(SCSDS) or the Space of Facial Makeup of Beijing Opera The space is the pattern of substance distribution in the comparted physical Descartes space at a time point. The NDs of it are (1)The basic unit: volume. (2) The attribute of the basic unit: the boundary. (3) The attribute of basic unit: concentration of a substance inside.

NDs of Dynamic Compartment-Substance-Distribution Space(DCSDS) DCSDS is a function of time. The NDs of it are (1), (2), (3) mentioned in SCSDS. (4) time arrow. Thus the space could be formulized as DCSDS = $\{(SCSDS)_i * T_i\}$, i= 1,2,3…...

NDs of the Basic Humor Space or the Lake of Life The space is a bath space of any life things. The NDs of it include (1) The basic unit: volume-unreplaceable particle. (2) The volume; (3) The attribute: isotropy, except the direction of the gravitational force. (4) The attribute: the viscosity. (5) The attribute: the resistance for movement in any Descartes-directions; (6) The solution-ablities.

NDs of the General Bio-Membrane Space(GBMS) or Even-Height Topology-like Space or Soft Thin Pancake Space: The space is one-direction space. The NDs of it include (1) The ability to combine or carry other molecules. (2) The boundary function(barrier-pathway function for both opposite directions); (3)Two heterogeneous faces which is different in functions.

NDs of the Myocyte Bio-membrane Space(MBMS) The NDs of it include (1), (2), (3) mentioned in GBMS. (4) The transmembrane electricity –distribution difference or resting potential. (5)action potential.

NDs of the Blood Hydrodynamics Bed Space or Hydrodynamic Hollow-Tree Space The NDs of it include (1) The basic unit: directional pipeline(P) segment with a limited-variable length. (2)The attribute of the basic unit: diameter(D). (3)The attribute the basic unit: permeability(PM) of wall. (4)The attribute of the basic unit: contraction(C) of wall. (5)The attribute of the basic unit: elasticity(E) of wall. (6)The attribute of relation between the basic unit: the communication through the opening(OC) with different diameter(see Fig. 3). This space is in fact a specialized one of POCS.

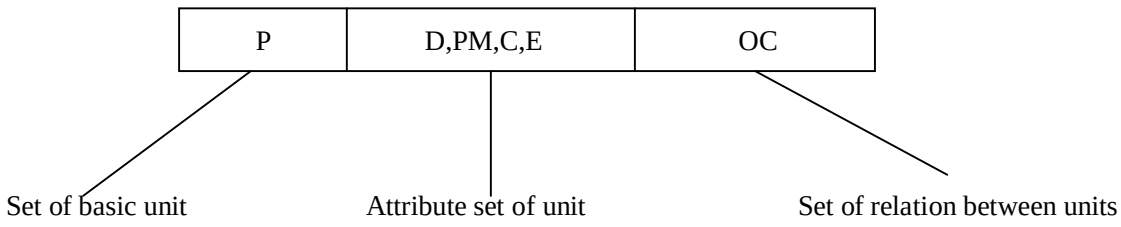

Fig.3 The components of Hydrodynamic Hollow-Tree Space of blood vessel.

4. The Example of Functional Integration

Let's look into the processes and mechanisms of the functional integration of nerve-muscle synapse[15]. In this example, the BSKs "neuron basic space" and MBMS are somewhat compound spaces which should be able to be decomposed into more basic spaces, though it has not been done in this paper. Fig. 4 and 5 demonstrate the structure and function of the nerve-muscle synapse. We can see that the attribute A_1 of Ach(acetylcholine) is determined by the dimension D_{14} (exocytosis) in neuron basic space and the attribute A_2 of Ach by D_{21}(diffusion function) in "the lake of life", and further, its attribute A_3 is dependent of D_{32}(path-protein combination function) in myocyte basic space. Thus, Ach presents the different attributes both in different dimensions ("the dimensional double-faced" element, DDFE) of the same space and of the different spaces ("the spatial double-faced" element, SDFE). And at least in this case, the DDFE and SDFE have carried out the functional integration of nerve-muscle synapse and act as the or "integrator" of the integration between the structures for different dimensions and spaces(see Fig.6). That is the "double-faces" principle for an integration.

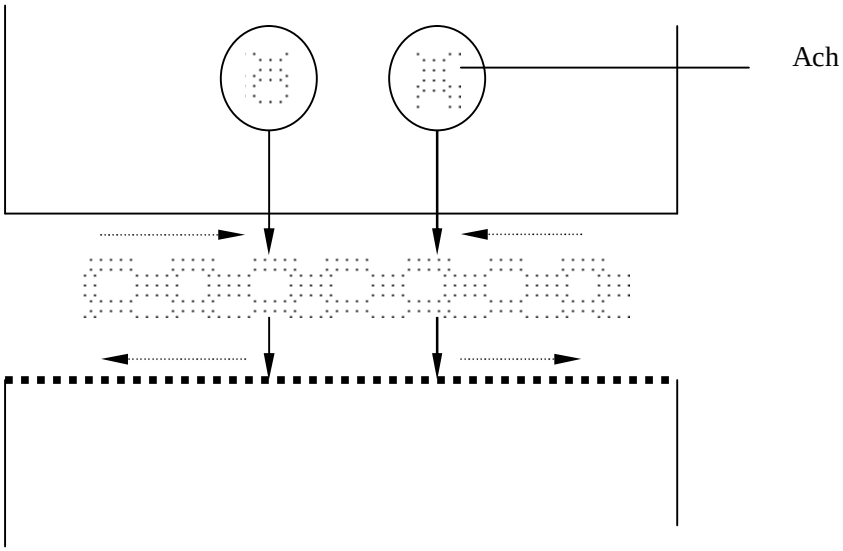

Fig. 4 The schematic diagram shows the structure and function of a nerve-muscle synapse.

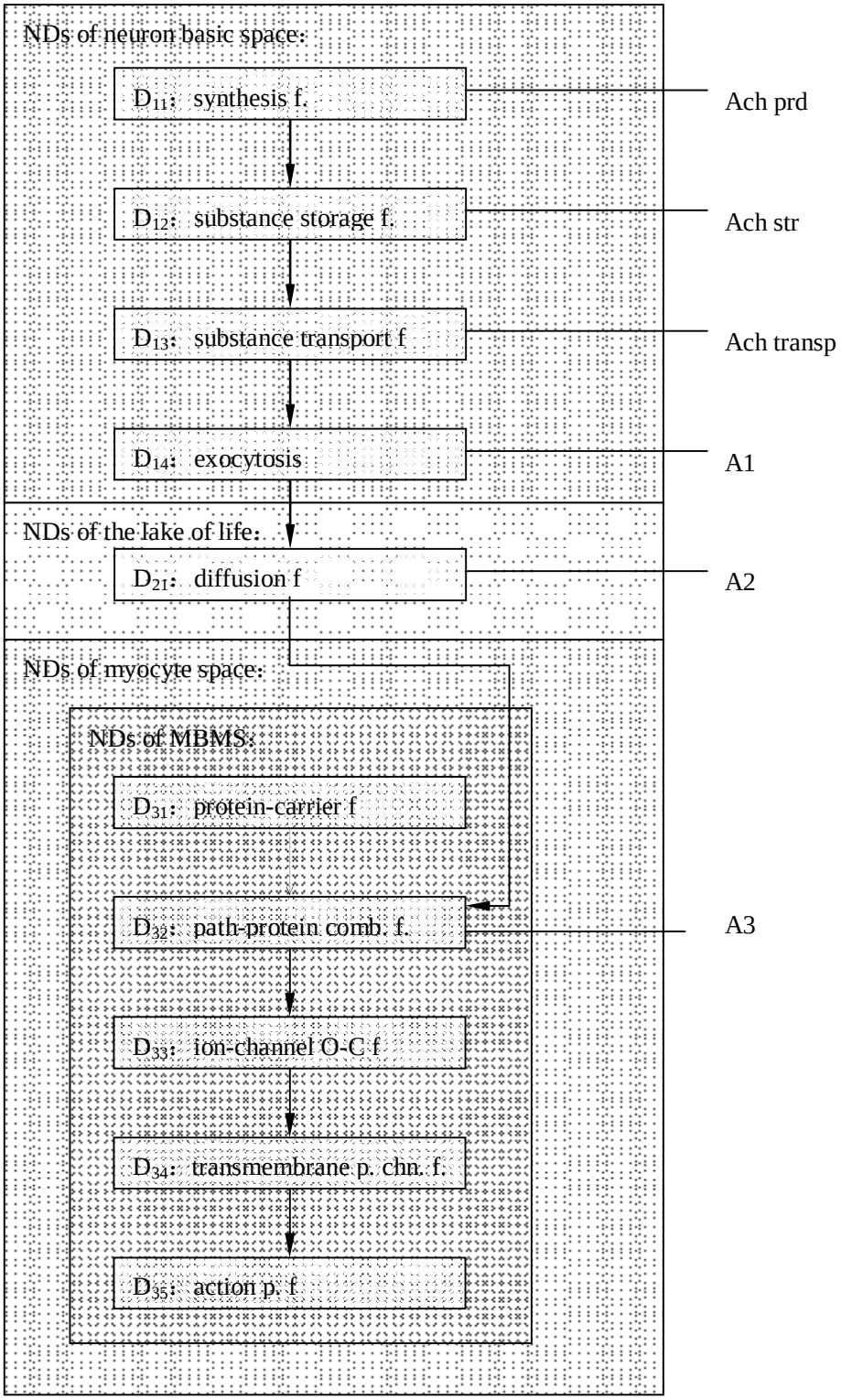

Fig. 5 a diagram to show the processes and mechanisms of the functional integration of nerve-muscle synapse. Arrows with solid line make the whole integration. The element which presents different attributes in different dimensions ("the dimensional double-faced" element(DDFE)) plays an integration operator between the two dimensions, whereas the element(Ach also) presents different attributes in different spaces ("the spatial double-faced" element(SDFE) acts as the operator between the two spaces. Abbr: f function; prd production; str storage; m membrane; comb combination; prt protein; O-C open-close; chn change; p petential; ND the necessary dimensions, A1 Ach out, A2 Ach to post m., A3 Comb of Ach and path-prt.

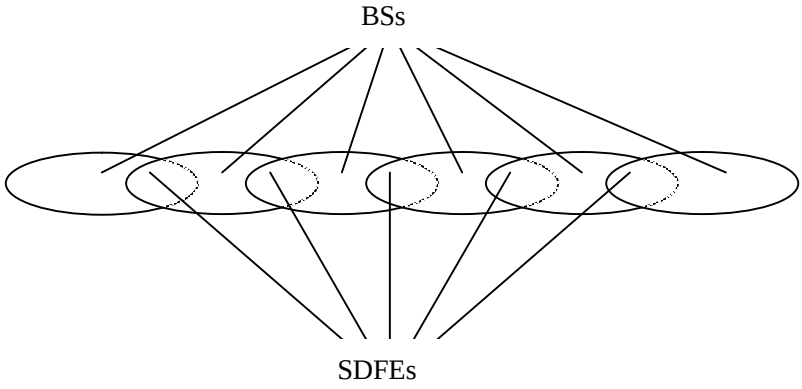

Fig. 6 So called "the spatial double-faced elements"(SDFEs) through the expression of its different attributes in different background spaces(BSs) integrate the functions in those spaces.

(to be continued)

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