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THEORETICAL APPROACH TO LIFE PROCESSES
Part III. Plant Processes and Aging

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Aging is suggested to involve dehydration as the preferred mechanism in the time-frame of biological reactions. It becomes dominant with time and inhibits life processes by gradually depositing the lyophobic metabolites in the microcapillaries. The flow of plant fluids is thus retarded and slows down the biological functions.

Small changes in the micro-environment of the plant e.g. introduction of ions like Ca in their biopolymer framework can initiate changes in the flexibility and conformation of DNA as well as the mode and extent of bonding of charged ligands including the gene regulating proteins. Such reactions lead to formation of an anionic terminal group by dehydration of the concerned portion of the biopolymer, giving rise, if not repaired through rehydration by the life propagating processes, to aging of the tissues.

Key words: Aging, Plant processes, Life processes, Dehydration, Hydrogen bondability.

INTRODUCTION

Aging is the slowing down of normal biological functions and processes of a living organism. It is severely resisted during the initial stages of the life cycle. That point of time is the active growth period since the driving force is the maximum and the forward reactions dominate. Youth or the blossom period is the stage when an organism is packed with activity, which is followed by an equilibrium position when the forward and reverse reactions are balanced. The growth rate slows down hereafter and reversal of life processes becomes apparent as aging. The biological functions are slow in the beginning but become well pronounced with passage of time. Whenever the normal body functions of a living being, plant or animal, are disturbed. there is an accompanying biochemical change which may manifest itself in functional or structural physiology or morphology. Among the higher animals the discharge of waste products through the kidney, for example, decreases progressively as one gets older. The spinal cord, as another example, first elongates and then shortens due to erosion of cartilaginous separations between the vertebrae [1].

The biochemical reactions which lead to aging among plants preferably comprise, according to the thesis presented here, dehydration processes. Accordingly dehydrated materials in the form lyophobic metabolities, produced during the dominant forward reactions in the previous history gradually deposit on microcapillaries, which retard the flow of plant fluids and slow down the biological functions.

Life processes in plants take their start from germination by hydration of seed which is followed by a thread-like root that travels down into the soil for extracting water and minerals and the would-be stem breaks through the surface looking for sunshine. The food stored in the seed produces the first leaves and for subsequent development photosynthesis provides the nutrients.

The plant has a closed circuit transport or vascular system wherein water, minerals and growth substances move up and down. Water and minerals are transported from the soil, up through the plant in xylem cells and the carbohydrates produced during photosynthesis travel to the living areas of the plants through phloem cells. New xylem and phloem cells are formed during the growth period and thus increase the diameter of the stem. The new cells which are formed get modified for specialised functions within the plant. The xylem cells gradually enlarge to their final shape by stretching the newly formed primary cell walls, losing water by dehydration in the meantime. The secondary layer of the cell wall is then deposited by the protoplams. Lignification is the final stage of cell development when the protoplams dehydrates and degenerates to form the warty layer and the cell dies [2]. Polysaccharides are formed in advance of lignification. It has been suggested that a superoxide generating enzyme outside the cell wall is responsible for lignification [3].

Dehydration and lyophobic substances Deposition. The biological processes such as enlargement cells, lignification and polysaccharide formation, accompanying phyisiological changes are ultimately connected to the slowing down of irreversible biochemical reactions in which water is gradually lost through dehydration. Body functions of all organisms, particularly plants, have to maintain a positive balance of water and with its help the equilibrium, instead of just being maintained, has to be shifted towards the product side so as to yield fruits and seeds. This is possible during the growth period when each part of the plant contains more water than when it starts aging. Useful work leading to growth is done with the investment of energy obtained from the sun and by absorption of carbon dioxide, water and nutrients by the plant. The wear and tear of functional parts of the living plant is mostly overcome at the expense of energy obtained in this manner. Since the reactions which take place in plants (and other living organisms) involve continuous transportation of fluids, the microcapillaries and since the tissues involved suffer wear and tear, some damage to the functional parts, dealing with the waste products as well as the main products, is inevitable. The more quickly these damages are repaired (and damaged parts removed) the better are the chances of continuing the life processes. Repair is possible only if damaged parts are appropriately rehydrated otherwise irreversible damage would be done and the concerned part of the plant (or living organism) may cease to be functional. A cut on a plant stem, for example, initiates a dehydration process which ages the tissues concerned. The cut is followed by a process called callus formation which is the plants defence mechanism. It separates the daughter cells by a plate of hemicellulosic material which forms the matrix where the primary cell wall is laid down subsequently. The matrix of the cell wall mainly comprises pectic substances which are polymers of galacturonic acid and lized by cross-linkages formed between adjacent carboxylic acids and divalent ions, mainly calcium. The cell walls form a microcapillary structure which remains permeable to water and hydrated ions during the secondary stage of development [4].

Metabolic energy is utilized exclusively for the transport of Na in fresh tissues as is indicated by ion uptake per unit of oxygen absorbed. This energy is directed towards transport of potassium ion as the tissue ages. The ion experiences difficulties during its transport when it has to leave the aqueous phase and enter the lipid phase on its passage across the membrane. The water of hydration surrounding the ion makes the ion bulky and hence transportation of fluids slows down. In the initial stages of plant growth size of ions is not so important but in the time-frame of biological reactions it becomes very significant. The hydrated ions of the polyvalent cations like calcium and magnesium are larger in bulk compared with monovalent ions like sodium, potassium and lithium.

The ions, on crossing a lipid membrane are either stripped of the water of hydration or else they get associated with a hydrophilic pathway which is large enough to accommodate the bulky ion. Such a pathway is indicated by the aqueous helical chains accompanying proteins. The activation energy for transportation of ions through membranes would be larger for dehydrated ions and therefore the operation is mediated through carriers comprising, as mentioned earlier, the coordination polymers which are casings of ligands that can discriminate between various species of closely related metallic ions [5a].

The cell wall permeability is reduced during the subsequent stages of secondary wall formation by either getting the microcapillaries blocked with lignin or by impregnating the matrix with hydrophobic glucosides, by the enzymic action of glucosidase. Lignins, from the point of view of the present hypothesis, are hydrogen bondable substances but of a lower order [6]. The lignified cell walls are, therefore, not completely impermeable to water and small solutes and permeation in lignified walls is known to occur through pits.

Different long chain hydroxy fatty acids constitute suberin, e.g., trihydroxyoctanoic acid. They are strongly hydrophobic in nature and their deposition on cell walls seriously retards the flow of water through the microcapillaries. The deposits are in the form of thin lamellae at the junction of the secondary and tertiary cellulosic walls [5b]. Lignification and suberisation are, it may be pointed out, different stages of dehydration in the life cycle of plant.

Electrolytic Balance and Energetics. The role of water has been discussed earlier as a chain propagating medium in life processes by way of hydrogen bond formation. The water molecule in its tetrahedral structure form, winds along the polypeptide helical chain and promotes interaction through the hydrogen bonds created between the keto-imide and HOH linkages. Hydrogen bond par excellence is the predominant feature of the biopolymers constituting all living species including plants. Radiation or thermal shock or introduction of ions in the biopolymer framework would initiate changes in DNA flexibility, conformation, secondary and tertiary structures as well as the mode and extent of bonding of charged ligands which include the gene regulating proteins. These reactions ultimately result in the denaturation of proteins and carbohydrates and bring about dehydration of the biopolymers.

It may be of interest to mention here that entry of calcium ion triggers structural changes *viz*, in the release of hormones and synaptic transmitters which constitute the major nerve transmission factors. Presence of Ca in the aging medium promotes development of K absorbing capacity as well as in increase in the rate of respiration but in the loss of capacity to absorb Na.

It is known from the analysis of biological systems that magnesium is preferentially bound to nitrogen bases and also to some anionic ligands while calcium is bound to multidentate and strong acid anions. The carriers of calcium therefore involve phosphorylated proteins e.g. there are four carboxylate residues in the terminal sequence of trypsinogen, an enzyme activated by calcium. Magnesium carriers on the other hand invariably have a nitrogen base e.g. imidazoles; and two anion groups like phosphate and carboxylate. The phosphorylated carrier proteins form an important link in the metabolism since the relative velocity of their formation determines the energetics of the reaction and processes involved.

$$\text{Protein} + \text{ATP} \rightarrow \text{Protein P} + \text{ADP}$$

Two energy producing reactions take place across the membrane and at the opposite side of the site of phosphorylation reaction. They are responsible for rejecting sodium and calcium and for acting as carriers of potassium and magnesium. Calcium is precipitated as the carbonate, oxalate, phosphate or fluoride and the process is facililated by are in-built mechanism which rejects this ion from the interior of the cells. Fibrous protein structures occurring outside the cells act as initiators of the crystallization of the sulphates or carboxylates attached to the outer side of the membranes. The pH changes in the concerned fluids of the membranes strike a balance between solution and precipitation of calcium thus dissolving bone and shell material, transferring it into the blood stream and depositing it at a new site. This type of activity is indicated by the growth of skeletons, egg, shells and other structures [7].

The electrolytic balance is perfectly equilibriated and pH, temperature, viscosity of the medium etc. are important parameters which determine the transport, deposition, dissolving and rejection processes of ions. Any adverse change in pH would create a disease situation. Small changes at sub-microscopic dimensions bring about a shift in the excellent equilibrium proceses and with advancing age lead to the formation of anionic polymers from the slow oxidation of proteins and polysaccharides. The formation of anionic terminal groups, would provide a site for the interaction of the rejected calcium and its deposition there. This may be the reason for the deposition of calcium in cataracts, stones, cartilages and for the hardening of arteries and soft tissues. Binding of calcium to the outer sequences of proteins and saccharides then is supposed to be responsible for the hardness of external and for changes in the internal structures.

Water acts as a source of energy since it provides electrons by its photolysis. Electrons and protons are temporarily separated from the hydrogen atoms in water:

$$H_2O \rightleftharpoons H^+ + HO^- \text{ and } OH^- \rightleftharpoons \tfrac{1}{2}O_2 + H^+ + 2e^-$$

The process then serves as a device to provide the free energy gradient to power the synthesis of ATP in the photosynthetic reactions [5c].

Uptake of nutrients and hydrogan bondability. Water acts as transportation medium; it carries ions and molecules degraded or upgraded during life processes. Substances which enter a living body have to be hydrogen bondable in order to be assimilated by the system otherwise they are degraded by enzymic action. Such substances help life processes which do not disturb the hydrogen bond super-structure. The reverse is also true i.e. substances which destroy the said structure are likely to prove toxic. Their toxicity would depend on how easily the toxicant and its metabolities are flushed out of the system. [4].

The mechanism of interaction being suggested here is similar to that proposed by this author for tannage of hide powder and gelatin. It was observed in the study that as the quantity of chromium increases, more cross linkages are introduced and the size of polymer units is reduced correspondingly. Chrome compound as presented to the pelt has chrome-ol bridges. For tannage the requirement is that the chrome-ol bridges should be hydrated and thus become hydrogen bondable. Water can induce the interaction of this type. The acidic conditions in which chrome tannage is carried out make the carboxyl groups available for reaction with the newly opened chrome-ol bridge. A chrome-polypeptide bond is thus obtained [8].

One could at this stage consider the process of assimilation/digestion of nutrients as an intelligent, selective hydration mechanism so as to make the food hydrogen-bondable. The living organisms have their own typical method of degrading the food comprising macromolecules. Some of them have an integrated system consisting of glands which are capable of changing the pH of the digestive fluids while others have glands which release digestive enzymes. The smallest unicellular organism amoeba presents an example of a hydrogen bonded material itself. It is a jelly-like mass of protoplasm which changes its shape constantly by putting out and withdrawing the small finger-like pseudopodia or false feet. It has no mouth and hence it digests from any point on the surface of the body. The initial process of digestion constitutes trapping the food particle by putting out pseudopodia around it. The concerned pseudopodia then fuse together which is easy for them because of their predominantly gelatinous nature. Water is taken along during the fusion process and the digestion process is initiated as soon as the food particle is engulfed.

The secretion of the digestive fluid by the endoplasm around the food particles constitutes the second stage of digestion whereby proteins and not fats, starch or sugars can be assimilated. The digestive fluid is contained in a space called food vacuole and the engulfed food particle ultimately forms part of it. The contents of the food vacuole are first acidic and thereafter become alkaline. The digested material then is absorbed into the cytoplasm where it is converted into protoplasm or is assimilated. The food vacuole contracts as the digestion process proceeds further and the undigested food particles are egested at any point On the surface of the organism. The undigested particles being heavier than the cytoplasm of amoeba are simply left behind as it moves forward.

The interaction of solids with liquids to attain hydrogen bondability is apparent in chewing, which is also a hydration process, common among all animal species starting from the unicellular amoeba to man. They have a well defined system of assimilation of food by which they first reduce the latter to fine particles and impart them a large surface area so that interaction with water is facilitated and their biodegradation becomes possible. Materials that already contain a lot of water are easily assimilated e.g. soups, fruit juices, fresh fruits and vegetables. Edible materials that are not easily digested without processing e.g. meat, dry vegetables, etc., have to be cooked, which again is a process of hydration.

In life processes tannage is analogous to attack by a toxin to produce disease, since it introduces cross linkages at a binding site. The toxin released by *E.coli,* for example, initiates a dehydration process in the stomach and consequently there is serious dysentry and loss of water due to flatulence. If the bond with the toxin and the cross linkage introduced by it can somehow be destabilized, detannage or detoxification would take place or, in other words, health would be restored. Water would be needed here to carry away the toxins from the bonding site. It is important that the water be of such quality as to help in the bonding process. For example, in case of chrome tannage, the aqueous solution should be acidic which condition is critical and if the same is altered, tannage would not take place. Similarly, several mineral waters having therapeutic value act by the introduction of small or large ions to displace and leach out the toxins and residues from certain tissues of the body. Detoxification is effected by the detannage mechanism using an appropriate aqueous solution or suspension of material of mineral or vegetable origin or a synthetic drug. An aqueous medium is necessary in all cases for making substances available in hydrogen bondable form to render them assimilable.

Once absorbed by a biological system, different toxic materials, hydrogen bondable or otherwise, act differently. They may either be distributed into specific tissues or through a series of metabolic steps, interact with multifunctional ligands such as proteins. The entering chemical may ultimately be bonded to one of the sites which has affinity for it or may be excreted through the roots of plants or by the kidney, respiratory tract or sweat glands of the animal system. The chemical could also be altered through a biotransformation mechanism by specific or nonspecific enzymes present in different organs.

Life processes in the plant system comprise reactions of simple compounds like carbon dioxide and water in an ionic environment of sodium, potassium, calcium and magnesium. Water is a reactant as well as a medium for the biochemical processes taking place in the system. It is responsible for translocation of ions from the roots to the various parts of the plant and by encasing coordination complexes into its superstructure it acts as a carrier of nutrients. With a slowing down of biological processes due to preference of dehydration reactions leading to deposition of lyophobics in the microcapiblaries, the vital exchange of protons, in water or in the hydrogen bondable substances, with the cations from the solid or nutrients is retarded. Biological function would therefore not able to proceed with the same vigour with aging as during the active growth period.

In conclusion it may be added that with progressive biological reactions the dehydration reactions which are less significant during infancy of the plant become dominant. The phenolic bodies gradually concentrate and lignificantion of the microcapillaries and cell wall proceeds unretarded. Hydrophobic glucosides formed by enzymic action impregnate and block the matrices of the cell walls comprising pectic substances mainly. What used to be hydrogen bondable substances initially, turn into hydrophobic deposits as a result of the dehydration processes taking place during the various stages of metabolism. The result is that the flow of water is retarded and the water holding capacity is reduced. The toxins which could be flushed out easily previously, tend to accumulate in the system. These processes being irreversible ultimately lead to the death of plants.

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