viscosities determined by the method of Moness and Giesy at 100° F. These results were then compared with those obtained by the Saybolt Viscosimeter at the same temperature. See the accompanying table for results. The viscosities by the Moness and Giesy method were calculated using Bingham's equation and the Saybolt seconds corresponding to the absolute units were found in the U. S. P. X, p. 468.

	Moness and Giesy Viscosimeter.				Saybolt Viscosimeter.
	Time.	Poises.	Poises ÷ density.	Saybolt seconds.	Saybolt seconds.
1	566	0.524	0.596	272	276
2	576	0.535	0.607	277	277
3	652	0.539	0.611	278	277

Under 1, 2 and 3 each time of flow was checked several times and the average taken. The maximum variation observed was 4 seconds but usually the results checked within one or two seconds.

It would appear that the Moness and Giesy instrument is preferable to the Saybolt Viscosimeter because the liquid is under a constant pressure throughout the run due to a constant hydrostatic head and because it employs a capillary to which the laws of flow of liquids are applicable, making it possible to obtain absolute viscosity measurements. Another consideration is that, in the case of liquid petrolatum at 100° F., the oil does not flow out in a continuous stream but in separate drops toward the end of the run in the Saybolt instrument. This drawback is eliminated in the Moness and Giesy apparatus. The close agreement, however, of the results obtained by the Saybolt instrument and that of Moness and Giesy on liquid petrolatum shows that for this liquid the Saybolt results are correct.

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THE LIVING BELLADONNA.*

BY FRED B. KILMER.

The real story of a plant lies in the living structure. In every part of every cell there is graven the history of its being, the story of its inheritance, its purpose and its destiny. If we could interpret that which is recorded in the plant itself, we would have a greater knowledge than has ever been conceived or written down.

The herbalists of old, and the botanists who came after them, gained their real knowledge through their study of plants growing in the soil. In former centuries pharmacists knew drug plants from daily contact in their own gardens. Students in pharmacognosy must now be content to study plants either from a picture, a distorted specimen, or a market fragment. Our modern way is possibly the better one, but the older method had its attractiveness.

There is no more delightful course for the study of a drug plant than to place its seeds in the soil and note its development and growth until the seeds fall again.

* Scientific Section, A. Ph. A., Philadelphia meeting, 1926.

In the study of a living drug plant we come to appreciate how different is the market substance from the living thing. Observing in the fields the cutting of the leafy stalks, the picking by the gleaner, the heaps of leaves wilting in the carts, and following them to the drying house, one comprehends more fully and more clearly the many changes which follow in turn from the living structure to the finished drug, ready for the market.

Illustrative of the changes which take place in drug plants as they are removed from the soil, the author made some observations on witnessing a drug harvest in England:

The changes viewed in the mass are striking and impressive, seen as it were through a kaleidoscope of pharmacognostic figures. The progressive transformations most apparent to our physical senses are the changes in color, in odor and taste. Thus we observe that, dependent upon the conditions as to handling, leaves containing chlorophyl become spotted, darken and finally turn brown or black, while flowers lose their brightness, their hues change, disappear or turn dark.

Somewhat equally striking are the changes of aroma occurring in many plants. The herbaceous narcotic drugs living in the field have no distinctive odor, but the moment they are torn from the living stem, and during their manipulation, the odor becomes heavy, disagreeable and, to the novice, nauseating. Again, the process of drying results in giving them the comparatively tolerable mousy odor, such as we find in hyoscyamus, belladonna, etc. The development of odor in plants during the drying and curing process is well known.

The changes of taste are somewhat akin to the changes of odor. For example, aconite fresh from the earth might be taken for wild horseradish root, but as the drying proceeds it becomes the acrid drug which we know and dread. The first taste of any narcotic plants, when quite fresh, is not unlike that of any bitter weed, but by chewing, the taste peculiar to the prepared drug is developed.

The author's limited knowledge of drug plants has, in the main, been acquired from a study of plants growing in his back-yard garden, the cultivation of a few of them in a large way, and observation of drug plants in their habitat. Out of the many plants thus studied, belladonna has been selected for this paper.

Coming upon a belladonna plant as it grows, somewhere in a shady edge of the woods—one stops. Other plants in the thick undergrowth are more showy, but the belladonna arrests and impresses, seemingly by its presence, as "something unusual."

We see a shrubby plant that in its full glory may come to from two to five feet in height. Its stems, with purple tinged branches arranged in pairs, shoot out into a veritable bush. The numerous dark green leaves are oval, tapering and angular, with an unbroken border. There are many veined set-in pairs on short leaf stalks.

In misty weather the leaves give out a heavy odor. The taste of the leaves is insipid, increasing to bitter on chewing. Linnaeus classed belladonna as among plants having a "disgusting odor and taste."

Striking and noticeable in the belladonna is its bell-shaped flower. The lobes of the flower leaves of *Atropa belladonna* are a livid purple on their inner surface, and yellow below. (In the *belladonna lutea* the entire corolla is yellow.) The flowers lie pendant, except toward evening, when they tend upward. Five yellowish pollen-carrying stamens stand embedded in the lower part of the bell; these are curved shorter than the purple bordered corolla. The glands of the seed-bearing ovary carry a nectar-like stuff.

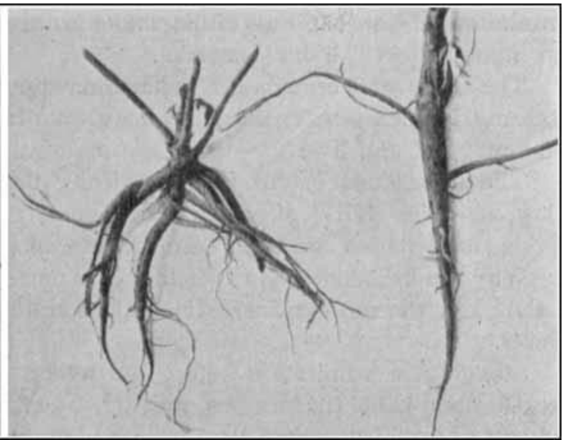
On a sunshiny day bees are constantly going into the bell, seeking the sweet fluid, and bearing away the pollen grains to fertilize the next flower visited.

The flowers have a mild nectar-like odor, a sweet taste that changes to mildly acrid when chewed. Often on the same plant one can find flowers in all stages—just budding, in full bloom, flowers with closed leaves, green fruit and ripe fruit.

The unripe berries are green in color, acid and acrid to the taste. The ripe berries resemble a flattened cherry, deep purple (almost black) in color, smooth-skinned, filled with purple juice, and crowded with hard shelled, minute, oval-shaped seeds.

The luscious ripe berries of belladonna, hanging in abundance through the branches, look "good enough to eat." To many who have ignorantly gathered them

Branch of *Atropa Belladonna* carrying flower and fruit.



Roots of *Atropa Belladonna* showing the root and branching formation.

they have proved disastrous. They are the "devil's berry" of the peasant, carrying wine-like juice containing poison in every drop.

Differentiation in plants gives groups, families, species and finally individuality. Important variations of the arrangement of the essential elements of structure arising from its manner of life, its place and its purpose in nature, finds a belladonna like and unlike other plant organisms.

The name "Nightshade," in a way, typifies the manner of growth. When compared with a plant standing out in the full glare of the sun, the belladonna is a shade plant.

Proportional to the living substance, the weight of the structural substance is small. There is no silicious framework. In the older plants woody fibre forms at the base of the stem. The skeleton of the plant is soft, elastic, with sufficient turgidity to carry on the work, assigned to it during the comparatively brief life of the part above ground.

The belladonna stem does not need to carry its branches and foliage above the other plants. It will catch the sunshine that it needs even in the forest.

The stem of the belladonna plant has a well-defined simple office to perform, and about eight months in which to carry it on. First it must raise the foliage with fruits and flowers above the surface of the ground so that the leaves may have access to rays of light, to air and carbon dioxide; the flowers and fruit must be accessible to insects and birds, or other fertilizing and distributing agents; the stem must receive, and conduct from the root to the growing parts of the plant, the water absorbed by the roots, with its contained food salts; the stem must carry away and distribute the varied products of plant life, from points where they are produced to places where they are to be utilized for the building up of the organism, as well as to the places where such materials are stored for future use. In belladonna this storage is mainly in the root.

Microscopic sections of the stem and branches of the belladonna plant exhibit an elaborate system of canals and vessels running direct from the absorbent root. Through these pipes and tubes there passes constantly an upward stream containing the raw materials of life, and a downward and outward stream of foods and manufactured living material.

The stems and branches of belladonna support a system of leaves of such a form and in such a way, that they may take in light, energy and air—that the plant may eat and live.

The belladonna leaves are botanically described as "numerous, alternate below, in pairs above, of unequal size, shortly stalked, broadly ovate or oval, tapering into a patiole, perfectly entire, membranous, downy-haired and glandulous."

Why the belladonna leaf is of this form and shape, why the leaves are placed as they are, the most enthusiastic student of adaptation could not undertake to answer.

Standing in admiration before the living, growing plant, we can only see that the stem holds the swaying, moving, trembling leaves up and out into the air and breezes; that light and shade, diffused and reflected rays of energy, fall alternately and unceasingly; that, enveloped in the mist and fog, or under the falling rain, the leaves distribute the falling moisture around and under the plant equally and unerringly.

Down underground, the root stalk from which the stem shoots upward, and the descending stem or root of the belladonna is not unlike, in appearance, that of many other plants.

The belladonna seeks a sheltered place, and thus does not need strong anchorage. The main tap root in large specimens extends two or more feet. As the plant grows and spreads, the root branches. In the open or on the hillside, there is an increased branching of the roots.

The young roots are spongy, tender and easily injured. As in other plants the tip of the root is the burrowing tool—"the brain of the plant." One can often find specimens where branching and side turns have been made to avoid stones, and to seek favorable soil. As the plants attain age, there is a hardening of the cortex of the root.

The life of the belladonna plant is not comparable to the decades, and sometimes centuries, attained by other plants and trees. The top of the plant dies down and is renewed annually. From the root stalk new stems sprout each year, and ordinarily this will continue for ten and, at times, for twenty years.

Roots of belladonna do not tend to produce lateral branches that would give new areas of soil; hence the particular soil constituents needed for growth become exhausted, and the plant dies, root and all. It may also be that in long growing in one spot, the plant gives to the soil some element that tends to shorten its life. As age comes on, the corms and tops of the roots become spongy, retaining an excess of water. In the freezing and thawing changes of cold climates the roots split and perish. But for the seed renewal, the plant would be liable to extermination through inherent weakness.

Through long ages of evolution the belladonna plant has become so molded in form and structure as to bring itself into advantageous relations with conditions

Belladonna plants self sown at the edge of a field in England.

Field of cultivated Belladonna, an enlarged branch shown in the foreground.

needed to carry on its functions, to maintain life, and to permit readjustment to special peculiarities of surroundings.

By, and through, its structure, the plant lives, thrives, grows and is—belladonna.

BELLADONNA AT WORK.

Tucked away in a corner, placid of mein, slow of growth, one would hardly associate a belladonna with work. But while it lives, the belladonna is ever at work.

If we could roughly measure the amount of air taken in, broken up, absorbed and respired, or measure the amount of water pumped from the tip of the root in the soil through to the apex of the leaf, we might in part visualize the work done by a plant.

Uprooted from the soil, weighed without drying, a fair-sized belladonna plant will weigh five pounds. Some work must have been performed to build up that structure from the elements of air, soil and water!

Every process of growth and maintenance of life calls forth an expenditure of energy. The life of the plant is one continuous round, involving the capture, the storage and the release of energy. It is stated that vegetable organisms are able to utilize less than one per cent of the energy rays of the sun which fall upon them.

The propensity of the belladonna plant for shade, would indicate that its intake of the sun's energy is small, when compared with plants growing in full sunshine.

The sun's rays are the source of heat. Interchanges of heat also take place between the plant and the surrounding air. Observations show that usually the temperature of the belladonna plant is lower than that of the surrounding air. Dew is found on the surface of the leaves, and sometimes in the early spring and in the fall there is a light frost.

A proportion of the radiant energy of the sun is absorbed and utilized by the chlorophyl apparatus in the elaboration of the green color and carbohydrate food materials. The belladonna is able to elaborate chlorophyl with a modicum of sunshine energy. Energy enters the plant in what is known as the kinetic form. It is accumulated and stored in a form known as potential energy.

The photosynthetic processes as carried out by the chlorophyl apparatus, involve the accumulation and storage of energy, which is subsequently distributed and utilized.

Destructive metabolism in the cell is carried on through the conversion of potential into kinetic energy. In this view the formation of alkaloids takes place through the transformation of potential into kinetic energy.

What is known as respiration in plant economy—the absorption of oxygen and the exhalation of carbon dioxide—is associated with the utilization of stored energy. Plants which grow in shady spots often manifest lower respiratory activity than similar ones growing in bright sunlight.

An all important and most intresting product of plant energy is the elaboration of the green coloring matter, chlorophyl. Chlorophyl is formed under special conditions: First, access of light; second, a particular temperature; third, access of oxygen; fourth, the presence of iron.

Under the action of light, through the agency of the chlorophyl grains, synthetic sugar (grape-sugar) is formed, which is commonly transformed into the basic plant food—starch. The chlorophyl apparatus is thus the focal point of all plant energy.

The belladonna plant shows a fine green color under a comparatively restricted light, or in shade, likewise in a moderate or low temperature. The plant takes on its most vivid green in the dawn of the morning, when emerging from darkness into a cold mist.

The purple color seen in the belladonna plant, anthocyan, is believed to be produced by the oxidation of some aromatic substance. It occurs frequently in plants growing in the shade.

The office of this purple color is not altogether apparent. In the flower it seems to attract insects. It is believed that it aids in the conversion of starch into sugar; hence its presence in the petioles may help in the production of honey. Likewise, in the fruit it may have to do with the production of sugar as the berry turns purple. It is also thought that its presence may, in some way, prevent the destruction of certain enzymes. The suggestion has also been offered that this color is protective against injury by intense light, that it has the power of converting light rays into heat rays, and that it is thus the belladonna stores its sunshine.

A conspicuous feature of a belladonna plant is its purple coloration, and we may therefore conclude that without question it is there for a purpose.

WATER.

Belladonna plants one hundred pounds in weight, standing in the soil, hold within their structure over eighty-five pounds of water. This water is different from H_2O. If it were purified and distilled water, the plant would die.

According to Laplace, the primordial seas contained hydrogen and oxygen in due proportion, and nothing else. In these seas there was no life.

Lloyd has tersely named the water flowing through organic cells "living water."

The water which is essential to sustain the living cell carries within it elements derived from earth and air—chemical life elements, elements essential to and "endowed with life."

Deprive the living cell of its contained water, and it droops and dies. In the act of giving up its water, the physical structure, the molecular arrangement, the combination of the chemical elements within the cell are transformed. The replacement of water to the dead cell will not bring it back to its original form.

Belladonna plant tissue retaining its "living water," seems quite different in taste, odor and appearance, in its physical and chemical make-up, from that which has given up its water. Water is not only a carrier of chemical elements essential to life—it is a carrier and a source of physiochemical energy.

"The most important property of water is its electric property, known as the dielectric constant. Although itself only to a slight degree disassociated into ions, it is the bearer of dissolved electrolytic substances, and thus possesses a high power of electric conductivity, properties of great importance in the development of the electric energy of the molecules and atoms in ionization.

"The union of the molecules of hydrogen, oxygen and water contribute to the living organism a series of properties which are the prime conditions of all physiological and functional activity.

"The great surface tension of water as manifested in capillary action is of the highest importance to plant growth; it is also an important force acting within the formed colloids, the protoplasmic substance of life."—Osborn.

Water is as essential to belladonna as to any other plant, but it is not an aquatic plant.

Belladonna and some of the related solanums will not thrive in dry climates. Seemingly they require that their store of water shall be regulated as to kind, quality, amount and uniformity of supply.

The machinery of a belladonna plant is slow-moving. While a stream of water enters at its root, passes through the stem into the leaves, and from thence is evaporated (transpired), the action is slow, especially so if its habitat is in a cool atmosphere. If the soil surrounding the roots of the plant is full of water, closing the interspaces between the particles, thus excluding the soil and air, the plant is choked—it is deprived of air, it cannot "breathe," it cannot carry away nor utilize the water, and the plant is drowned.

In its home, belladonna thrives best on a hillside in properly drained soil, which is sufficiently granular to afford interspaces filled with air, and where a delicate film of water adheres to the soil particles. It is the "hygroscopic" water that the plant needs in just the right amounts, and with constancy.

The point of water intake, of course, is the root system. In belladonna the absorptive organs of the roots are not as extensive as in many other plants. The root hairs, not ordinarily numerous, increase in seasons of dryness. It is the root hairs that take in the soil-laden moisture.

The root does the screening, sorting, sifting of the crude food supply from the earth. Its membranes are filters through which the watery solution passes onward. It is in the root hairs that the so-called root pressure begins. Each of these hairs is a pumping station in contact with the moist earth; the walls absorb water and allow it to flow inward, but closes to any backward flow.

Supplemental to the root pressure, as a means of raising and carrying water through the plant, is the action of what is known as transpiration—a modified evaporation.

The water-carrying mechanism of belladonna seems slow in action. When exposed to heat or strong sunlight the plant quickly wilts, and under these conditions it cannot maintain the flow of water to meet a rapid outgo.

It has been suggested that the moderate growth of the belladonna plant, coupled with the rather slow moving water supply has to do with the formation of the poisonous by-products—alkaloids. But this cannot be credited, because there are many slow-water moving, slow-growing plants that do not produce poisonous products.

When we reflect that in a large tree the equivalent of a good-sized pail of water is lifted ten feet every minute, we see that neither root pressure no transpiration will account for the energy by which a proportionate amount of water is carried through a belladonna plant. Botanists are not agreed either as to the source of this energy or the method of procedure.

To the two forces named, workers have added atmospheric pressure, capillarity, imbibition, propulsion and traction. But the end is not yet. Plants are continually giving off a tenuous cloud of vapor from the under side of their leaves, and in a lesser degree from other green parts. We are not altogether clear as to the meaning of this action in plant economy.

The amount of water passing from the plants in the form of vapor during periods of growth is quite large, averaging an ounce per hour day and night, per square yard of leaf surface.

Experiments in the study of belladonna have seemed to indicate that its water-carrying process, as noted by its transpiration, was low in comparison with some other varieties of plants.

The stomata openings of the belladonna plant, to which the water passes to the outer air, are comparatively few in number. The water supply of the plant must not only be sufficient to take care of the transpiration loss, but all working needs, physical and chemical, of the various tissues as well. These exist, live and work, floating in a watery fluid.

Water is as essential to the belladonna as to other plants. It furnishes only a small proportion of the food supply, but it is the substance which it absorbs in the greatest abundance, and by which it lives.

(*To be continued*)