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|  | Roots, as defined by Funk and Wagnalls 1961 edition dictionary, are an underground portion or descending axis of a plant which absorbs moisture, obtains or stores nourishment, and provides support (Roots: Miracles Below, 4). This definition is acceptable for many. For some, it's the extent of their knowledge about roots. There is so much information and agricultural potential for roots out there that many don't know about. For example, roots are an underground support system as well as the beginnings of plants, our primary producers, on this planet. Roots can definitely be described as the miracles below the ground.  In 1420, to help the average person better understand roots, Fra Tomas De Berlarga proposed that vegetation is simply animal life turned inside out. He stated that the leaves represent the lungs, the sunlight represents the heart, and the roots represent the digestive track (Roots, 8). This was an interesting analogy and helped many to better understand the function of roots. Berlarga also hypothesized that God saw fit to create roots even before he created man (Roots: Miracles Below, 2). He also stated that man still lives by the grace and integrity of roots (2). The root is distinguished from its stem by its physical structure, by the way in which it is formed, and also by the lack of appendages such as buds and leaves (Root(Botany)). Though the root is different from the stem, is not usually seen, and is not thought of as the important part of the plant, roots carry out the important job of obtaining nutrients from the soil for the plant to grow. Plants, being immobile, rely on their roots to branch out to obtain minerals for them.  The type of roots that carry out this main branching function are called true roots. They anchor the plant in the soil, absorb the minerals, and conduct the minerals into the stem (Roots, 9). There are two types of true roots: primary roots, and adventitious roots. The first root of the plant, known as the radicle, elongates during germination of the seed, forming the primary root (Root(Botany)). Both tap roots and fibrous roots are types of primary roots. A tap root has one central root with other smaller roots radiating around it (Roots, 10). It is often fleshy and thick. Beets and carrots are examples of plants with very large taproots (Root(Botany)). Fibrous roots on the other hand, are primary roots that divide at once into a cluster of many thick roots. Grass is an example of a plant with a fibrous roots system (Roots-WBE, 473). Another type of root is the adventitious root, which is not derived from the primary seed root. Also associated with roots are rootstocks, which are underground stems that produce leaves and true roots (Roots, 10). They serve as organs of storage and also absorb nutrients, conduct them into the plant, and anchor the plant in the ground (10). There are many forms of rootstocks. The first, a rhizome, is a horizontal creeping stem that produces roots from nodes and buds in the leaf axis. Next, tubers are swollen tips of stems. Also, corms are the enlarged bases of the stem. Lastly, bulbs are storage organs made of scales which are actually thickened leaves(10).  With these given characteristics as well as preconceived notions one may hold, one may think that roots can only grow underground. This statement is far from the truth. In fact, some plants live only in water. Plants living in water have special porous passageways that supply the roots with air. Examples of such plants are the Limnobium and Lemna, otherwise known as Frogs bit and duckweed (11). Other plants that grow outside of the soil are ones containing parasitic roots. These grow high in the air and live off the sap streams of other plants. Examples of this are mistletoe and broomrape (phoradndron and orobanchae) (Roots: Miracles Below, 5). Yet other roots live and multiply without having any true roots. These plants, like the Spanish moss (tillandsia usneoides), are often smaller than most (5).  Each of these plants, despite the fact that they grow in various mediums, are all formed through plant propagation, which is the art and science of replacing plants that are used in daily life (Plant propagation). Plant propagation can fall into two categories, sexual and asexual propagation. Sexual propagation is usually performed through seeds, and it involves two individuals, usually a male and a female. Among the plants that reproduce sexually are plants in the grain family, vegetables, and many horticultural and floral plants (Plant Propagation). In addition to this, most forest trees are also formed sexually. Sexual reproduction is wonderful because it created the possibility of endless genotypes in individuals (Plant Propagation). It also contributed to the development of new plant forms and species, as well as protecting species from disease, insect epidemics, or gradual changes in the environment (Plant Propagation).  On the other hand, asexual propagation is quite useful when identical genotypes of a plant must be reproduced. There are several forms of asexual reproduction, most of which I won't go into detail. These include grafting, vegetative reproduction, budding, and marcottage. However, two that are of particular interest to us are asexual reproduction through root cuttings and also through tissue culture.  In root cuttings, some plant species can be produced from a single twig or leaf. However, it is notable that most cuttings are taken from woody or semi-woody plants. When the stems are taken from these plants and placed directly in soil, vermiculite, or a sand mixture, along with proper heat and humidity, miniature roots called stem roots appear (Plant Propagation). The stem roots develop from microscopic cells called root primordia. From here, the plant can eventually grow roots and a stem, which then gives it the ability to survive on its own. Some plants that take root easily are the willow and the geranium. Others, however, such as the conifer, will rarely root unless given special outside treatment. Root formation on some cuttings may be stimulated by the application of "root hormones", which are actually substances found naturally in the plant when new roots are formed (Plant Propagation). Many commercial preparations of root hormones contain indoleacetic acid, which is the most common root-stimulating substance (Plant Propagation). Sometimes, roots may actually be formed from the leaves of plants. Such is the case of the African violet, which can be propagated by rooting the cut end of the leaf base in water (Plant Propagation). Growing cuttings in this manner upholds the species characteristics much better than growing plants from seeds would. Another advantage to cuttings is that they provide a much hardier plant stock.  The main reason that one will grow plants from cuttings is because more of them can be grown in a shorter amount of time. Also, the more desirable traits of the plant are able to be bred in future generations. One such desirable characteristic is a large root structure. However, the size of the root structure doesn't necessarily decide the plants strength or vitality (Roots: Miracles Below, 9). One deciding factor of the length of a plants life is the roots ability to resist disease. This factor is the reason that conifers have been around for so long. Their root systems are not only disease resistant, but also very hardy. For reasons not completely understood, they collect inorganic nitrogen from the soil and convert it into useable organic nitrogen (15). This reason, along with others, is why conifers are so valuable to humans. They make up most of the trees in the forest, and are used as the primary source of lumber and paper products. There are over 550 species of conifers, many of which have been flourishing for tens of millions of years(15).  Conifers are on a long list of plants classified as dicots. Others include agricultural crops, forest and shade trees, flowers and flowering shrubs, waterlillys, legumes, poppies, etc (16). A notable characteristic of dicots is that their stems develop concentric rings through which dissolved nutrients that were gathered from the roots are distributed to the leaves and other parts of the plant. The roots of dicots have a central column of primary xylem with radiating arms (Biology, 719). Around the vascular tissue in their roots are layers of cells. The region with the largest cells is called the cortex; it is here that large quantities of starch are often stored (Biological Science, 12). On the outside of the cortex is the epidermis (Biology, 719). Outward cell division on the epidermis forms a thimble-like mass of unorganized cells called the root cap. The root cap covers the apical meristem, where the plant cells on the root tips divide rapidly and continually form new cells (Roots-WBE, 474). On the root cap are root hairs. These root hairs are tiny extensions off of the tip of the root. They secrete a chemical that "eats" the soil around the root, which then allows it to push through the ground (Roots, 12). The root hairs also increase the surface area and absorptive powers of the root (12). The innermost layer of the cortex is called the endodermis (Biology, 719). It is here that the plant determines which minerals and nutrients enter the vascular tissue and move up the shoot system. The cells of the endodermis are surrounded by a thick waxy band called the casparian strip (719). Inside the endodermis is a specialized layer of cells called the pericycle. From here, branches or lateral roots are formed. The pericycle forms the outer layers of the core, or the center of the root. Just inside the core are two tissues, the xylem and the phloem. The xylem conducts water and minerals up to the stem and the leaves, while the phloem transports food down from the leaves and into the roots for storage (Roots-WBE 474).  Conifers, as already mentioned, are dicots. Therefore, along with the primary growth that occurred in all of the tissues just mentioned, secondary growth occurs as well. The primary growth adds length to the root, while secondary growth adds thickness to the root (474). Secondary tissues develop from two meristems. The first, cork cambium, originated beneath the epidermis in the pericycle (474). The cork expands outwards to cover the root. The second meristem, the cambium, which lies between the primary xylem and the primary phloem, produces secondary xylem cells around the center of the root and secondary phloem cells around the outside (474). This process of root formation is truly amazing.  The form of asexual reproduction yet to be discussed is tissue culture. It is the newest and the most technical method of propagation and it involves cloning (Plant Propagation). One reason that this form of asexual reproduction so wonderful is because of the fact that any plant tissue with cells that can divide can be used for tissue culture. Cultures have been started from the fruit, endosperm, pollen and embryos of various plants. However, tissue taken from the vascular area has proven to be the most successful (Plant Propagation). In tissue culture, sections of the tissue are cut in pathogen-free environments and placed on the surface of a nutrient medium (Plant Propagation). This is then put into a closed, temperature and humidity controlled environment (Plant Propagation). When the callus proliferates, it is cut into small pieces and then transferred into an auxin or kinetin rich environment. These two plant chemicals promote root formation and root initiation, respectively. Once roots begin to form, they are again moved, but this time into a greenhouse where they are controlled further.  An exciting process that roots engage in naturally is to protect and strengthen themselves with chemicals they release. A plants growth is regulated by its vegetative hormones, which include gibberellins, kinins, and auxins (Roots: Miracles Below, 149). These hormones are also currently being manufactured and used by humans. Gibberlinn is being made as a spray to help plants grow better; when sprayed on the plants roots, it causes spectacular stem and leaf growth (149). Another hormone, kinins, is being used as a circulation stimulant, a capillary opener, and as a plant freshener (it keeps green vegetables crisp and unwilted) (149). The third hormone that regulates plant growth is called Auxin. When sprayed on leaves, it can prolong the fruit season by retarding leaf shedding or seed ripening. Doing so can lengthen harvest by several days to several weeks, and can give us sturdier, healthier plants with finer products (150).  Many may not realize it, but the roots of these healthy, hormone induced plants are edible and contain considerable quantities of food materials, such as starch. Some well known root crops in agriculture include the sweet potato, beet, turnip, carrot, parsnip, and cassava (Root(Botany)). The wild forms of these plants have much smaller roots than are normally seen, but because of development of these products in laboratories and through selective breeding, agricultural persons have been able to improve their size, texture, food value, and flavor(Root(Botany)).  The process of finding ways to use plants to our advantage and finding out as much as possible about them has gone back to the beginning of time. It wasn't until 1902 that a German botanist, Gottleib Haberlandt proposed that all plants were totipotent (Biology 746). This meant that every plant possesses full genetic potential. He stated that one ought to be able to develop a whole mature plant from isolated plant cells if one could devise the correct medium to support growth. He discovered that there were nutritional requirements for some of these plants in a defined media; some couldn't grow on their own. Some plants required coconut milk, the liquid endosperm that forms within coconuts (746). Doing so would supply cells with substances obtained from dividing cells.  Then, in 1958, FC Steward isolated small bits of secondary phoem tissue from carrot roots and put them into a liquid growth flask (746). This flask contained minerals essential for growth, sucrose, and vitamins, which were organic molecules that some of the plants could not manufacture themselves (748). This environment encouraged many new cell clumps (each from a single phloem cell), differentiated roots, and developed shoots. These cell clumps eventually grew into whole plants. By doing this experiment, Steward confirmed Haberlandt's hypothesis that under appropriate circumstances, and provided that they still have a living protoplast and nucleus, individual plant cells could resume growth and differentiation (748).  Despite the exciting new discovery, a general understanding that we hold on the factors that lead to the production of roots and shoots in masses of callus tissue is limited. The results on whether or not the cells will grow, and in what condition they will grow in differs from species to species. Various firms are now working on how these biotechnological discoveries can apply to the agricultural industry. One application is called micropropigation. It can take slow-breeding trees such as coconuts, Douglas firs, elms, and redwoods, and help them grow faster (749). With the rapid rate that these trees are being used and cut down, the fact that we can now grow them faster is important. Not only can we grow them faster, but we can also choose the desirable traits in them. What we have found out from all of this is that differentiated plant tissue is capable of expressing its hidden genetic complement when suitable environment signals are provided (749).  As was mentioned before, coconut milk has been found to be rich in reduced nitrogen compounds such as amino acids, and cytokinins. These two growth hormones are necessary for differentiation to occur. Coconut milk may not be the only substance that could be added to cells to encourage them to differentiate; there are others out there. After all, each plant is found to be different in its nutritional requirements for proper growth. What can be concluded from this is that the environment determines the outcome of the plant by triggering the expression of one particular development pattern from among several determined possibilities. |

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