

Welwitschia mirabilis—A Dream Come True

Gillian A. Cooper-Driver

It's been said that if botanists were to invent the ideal plant for a desert environment, surely they would never come up with a monster like *Welwitschia*.

Welwitschia mirabilis has always inspired extreme responses. It was the Austrian botanist and physician Dr. Friedrich Welwitsch, one of the foremost collectors of African plants, who first discovered this extraordinary plant in 1859, in southern Angola near Cape Negro. When he saw it, "he could do nothing but kneel down on the burning soil and gaze at it, half in fear lest a touch should prove it a figment of the imagination" (Swinscow, 1972). In the first detailed scientific description of the plant, Joseph D. Hooker, Director of the Royal Botanic Gardens at Kew from 1866 to 1885, wrote, "it is out of the question the most wonderful plant ever brought to this country, and the very ugliest." Recent papers published on *Welwitschia* have used such titles as "*Welwitschia*—Paradox of a Parched Paradise"; "*Welwitschia*, the Wonderful"; "Voyage into the impossible—I meet *Welwitschia*"; and "The ugliest plant in the world—the story of *Welwitschia mirabilis*." I myself first heard of *Welwitschia mirabilis* about thirty years ago from a native of the Scottish isle of Iona, a long way from the deserts of southwest Africa where this strange plant grows. As we made our way in a small boat across the ocean, my companion told me of a strange plant, halfway between a flowering plant and a conifer, which Darwin had described as "the platypus of the plant kingdom." From that brief encounter, it had always been my ambition to see the miracle plant for myself.

Welwitschia mirabilis grows naturally in only one area in the world. Its distribution is restricted to an extremely arid strip of land about seven hundred fifty miles long along the west coast of southern Africa, from the Nicolau River in Angola to the Kuiseb River in the Namib Desert of Namibia. The amount of rain in the Namib Desert varies greatly from year to year and ranges from zero to a half inch near the coast and two to four inches inland, as compared to a temperate deciduous forest, which receives approximately thirty to one hundred inches of rain a year. *Welwitschia* is not restricted to desert. It occupies the northern and central part of the Namib, but may also occur in subtropical grassland to the east and even in the Mopane Savanna (von Willert, 1985).

Off the shores of southwest Africa is the Benguela Current, which flows from south to north and is extremely cold. Warm onshore winds flowing over the cold water create a belt of fog that forms on the coast at night and often remains well into the morning. This condensed moisture gives life to many lichens and to other specialized forms of insects, animals, and plants—including *Welwitschia mirabilis*.

One of the most accessible places to see *Welwitschia* is in the Namib-Naukluft Park in the *Welwitschia* Flats between the Khan and Swakop Rivers, about thirty miles east of Swakopmund. This plain of weathered granite, quartzite, shale, limestone, and marble is



Welwitschia mirabilis in the Namib Desert. Photo by the author.

home to what are probably the oldest and most dense communities of *Welwitschia*. As many as five to six thousand specimens have been counted in this area.

It was a bright clear day, the first day in June, when I set out with two friends to find *Welwitschia mirabilis*. Before starting on the Welwitschia Plains Drive, it is necessary to obtain a permit and a guide pamphlet from the Ritterberg Nature Conservation Office in Swakopmund. The drive starts about three miles outside Swakopmund, a few yards from an abandoned steam engine. (This engine was imported to Namibia in 1896 to carry freight across the Namib Desert. Unfortunately, it survived only a couple of trips before grinding

to a halt within sight of Swakopmund. It is named after the preacher Martin Luther, whose words, "Here I stand; God help me, I cannot do otherwise," are engraved on its pedestal.) At the engine you turn right and drive across the Swakop River to the entrance of Welwitschia Park.

The land around this part of the Swakop River is dry and at first glance entirely barren, resembling the spectacular images we have seen of the moonscape. However, closer inspection revealed several different plants. Among the more conspicuous were two drought-resistant shrubs, the dollar bush (*Zygophyllum stapfii*) with round succulent leaves similar to coins and the xerophytic

inkbush (*Arthroa leubnitziae*) with its tiny leaves reduced to mere scales. Others were "!"nara," or *Acanthosicyos horrida*, and "tsamma," or *Citrullis ecchirrosus*. Both of these plants provide a source of water for travelers in the desert. Parts of the moonscape are covered with a variety of lichens in colors of orange, black, and gray-green, the most conspicuous of which is *Xanthomaculina convoluta* with its bright yellow color and twisted filaments. These lichen fields, which are more extensive in the Namib than in any

other desert in the world, depend for their survival on the condensed moisture that moves in from the sea at night.

Several miles into the moonscape, a road turns off to the left to form a loop leading to Goanikontes, an old farm near the Swakop River. Here many different trees are found: the camel thorn (*Acacia erioloba*); anaboom or white thorn (*Acacia albida*), the largest acacia; Cape ebony (*Euclea pseudobenus*); tamarisk (*Tamarix usneoides*); and introduced species of *Eucalyptus* and *Casuarina*. These trees provide shade from the hot sun and offer a startling contrast to the vegetation of the desert area. On this day in June, the farm was completely deserted and silent.

We left this fertile green area and returned to the moonscape. Granite cliffs, intersected with bands of black dolerite, rose on either side of the road, and then suddenly there they were, three *Welwitschia* plants growing up the sides of the gravel cliffs. The first sight of *Welwitschia mirabilis* is so totally unexpected in this bleak desert environment that it is easy to understand why Friedrich Welwitsch fell down upon his knees. Farther along the drive, the land flattens out, and more and more plants become visible. They spread across the desert, often in densely massed groups or in long lines fading away into the distance; it is rare to find a single plant all by itself. Using carbon-14 dating botanists have estimated that many of the smaller plants are thirty or forty years old, medium-sized plants a few hundred years old, and some of the larger plants are as old as fifteen hundred or even two thousand years.

It is *Welwitschia's* leaves that give this plant its strange appearance. It has only two permanent leaves. These stiff, strap-like leaves grow from a thick, almost totally submerged, woody stem and can be as much as ten feet in length. Since the leaves grow from their base, the cells at the tips are older and in time begin to turn brown and die. In the desert the leaves grow very slowly, about four to six inches per year. As the years and ultimately the centuries pass, the wind and the scouring sand split the leaves



The natural distribution of Welwitschia mirabilis. Drawing by Clara Richardson courtesy of the Field Museum.



In their natural habitat Welwitschias occur in densely massed groups or in long lines fading away into the distance, as can be seen in this photo by the author.

longitudinally into ribbons, some ten inches or more wide, supporting Bornmann's description of the plant as looking "like a stranded octopus on a bare desert surface." Leaf-stripping also occurs when oryx antelopes feed at the leaf base (Brinckmann and von Willert, 1987) or when microarthropods graze on the undersurface of the leaves (Marsh, 1987).

These leaves are unusual not only in appearance but also in size. Nowhere else in the Namib Desert does one see plants with such large leaves. One way for desert plants to deal with the scarcity of water is to develop anatomical and morphological structures that minimize water loss. For example, succulents like lithops and aloes, as well as the dollar bush mentioned earlier, have in their leaves a special central tissue that stores water (Von

Willert *et al.*, 1992). Other plants, such as the inkbush, cope with the desert environment by having highly reduced, leather-like leaves, which minimize the loss of water vapor. Small leaves also reduce the high leaf temperatures that the intense solar radiation of a desert environment can cause. Therefore it is paradoxical to find a plant like *Welwitschia* with its very large leaves growing in the middle of a desert, especially since its leaves appear not to have special water storage tissues.

The leaves of *Welwitschia* are unusual not only in their structure, but also in their manner of development. The plant begins life as a winged seed. In a process similar to that of most broad-leaved flowering plants, the plant embryo first develops two primary leaves, or cotyledons. Above these and at right angles,



Welwitschia's taproot grows to massive proportions. It can extend downward for as much as three to five feet; the apex shown here is about four feet in diameter. Courtesy of the Field Museum (360395), Chicago.

the two permanent leaves arise, and the cotyledons wither away. Unlike all other land plants, no further leaves develop because the apical meristem (the cells from which leaves form) ceases all further activity and becomes nonfunctional. Only a pair of low crests representing primordia of a second leaf pair develop. Because it generally produces only two leaves, *Welwitschia* has been described by Martens as "a seedling arrested in development" or as "a plant without a head."

Plants use their leaves to manufacture sugars and other organic compounds from atmospheric carbon dioxide and water by the process known as photosynthesis. Carbon dioxide enters the cells of the leaf through special pores, or stomata, on the leaf surface. Water also enters and leaves the plant via stomata. Particularly important to plants growing in the desert is the ability to retain water and yet maintain a carbon dioxide balance so that photosynthesis can occur.

Welwitschia is again unusual for a desert plant in the way it obtains its carbon dioxide for photosynthesis. In most temperate plant species, stomata remain open during the day to take carbon dioxide from the atmosphere, then close at night. But in succulents and other desert plants, the process is reversed with stomata remaining closed during the day to reduce water loss and opening for water uptake at night (when atmospheric humidity is high and temperatures are low). Desert succulents also take in carbon dioxide from the atmosphere during the night, converting it into the organic acid malate by a process called crassulacean acid metabolism (CAM). During the day, when the stomata are closed, this malate provides a readily available source of carbon dioxide to allow photosynthesis to proceed in the normal way. Most succulents use CAM as a basis for their survival. It is therefore surprising to learn that *Welwitschia*, which lives in an environment that would favor CAM, behaves not like a succulent but like a temperate plant. Its stomata open in the morning and early evening, no organic acids accumulate during the night, and there is a marked daytime loss of water vapor from the leaves.

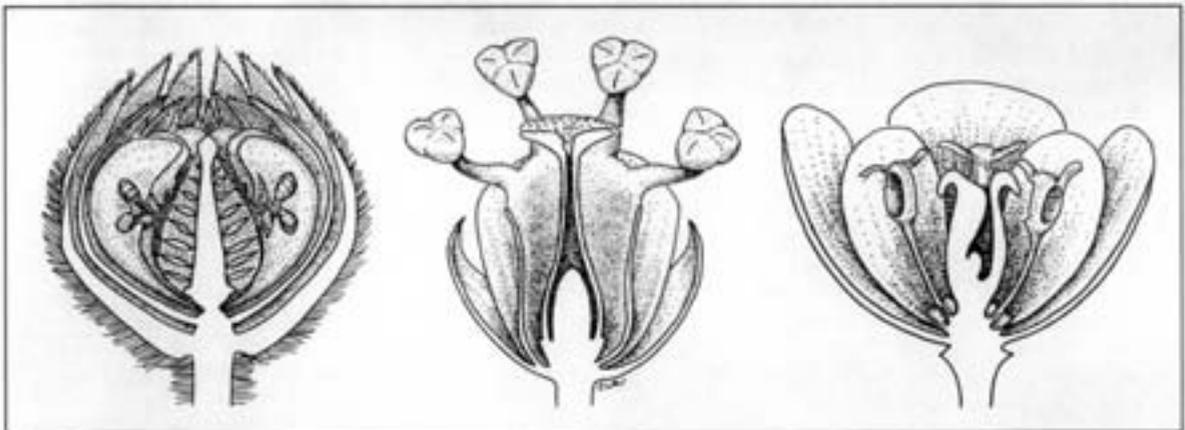
How then does *Welwitschia* obtain enough water to survive? One might suppose that *Welwitschia* acquires its water from the mist that settles over this part of the world. Some desert plants, such as members of the crassula family, have structures called hydathodes—specialized forms of stomata—that take in water from the air. However, *Welwitschia* leaves do not have these structures, and it appears that its leaves cannot absorb dew or mist water. A second possibility is that the water comes from the root. *Welwitschia* has a large taproot that extends downward for as much as three to five feet. Depending on the soil, lateral roots move out from the taproot at various depths, and multiple branches in the roots have been observed. It is possible that sufficient water is somehow available in the deepest soil layers and that *Welwitschia* taps into it through its deep-reaching root system.

While *Welwitschia*'s strangely shaped leaves apparently serve no water-gleaning function, they do help it cope with the problem of heat, which causes water evaporation. Von Willert, who has worked on *Welwitschia* in the Namib Desert for many years, has found that only 55% of the solar radiation is absorbed in *Welwitschia*'s leaves with as much as 40% being reflected away. (Compare this to most trees, from which about 25% of radiation is reflected.) Reflecting away the heat is probably the best strategy that a desert plant with large leaves can have for conserving water.

Other unusual features become apparent as one inspects *Welwitschia* more closely. The stem has a woody appearance and a large surface area. From the junction of the stem and the leaves arise branches on which the reproductive structures (the male and female cones) can be easily differentiated. By October most of these cones are fully developed. The cones indicate that *Welwitschia* is a gymnosperm, related to pines and other conifers. However, a closer look at the reproductive structures reveals several features that differentiate

Welwitschia completely from the conifers. A notable instance is the presence of distinct male and female "flowers." The flowers on the male plant have a single ovule, which is surrounded by a fused ring of "stamens" that produce the pollen. Unlike the "ovule" in the female flower (as can be seen in the drawing below) the apex of the ovule in the male is expanded into a prominent funnel. This ovule never develops a mature seed. Instead, this sexually nonfunctional ovule may play a role in attracting pollinators as the funnel secretes a large drop of fluid precisely at the time the pollen is shed.

Pollination occurs from about November to the end of March. It is still not completely clear how the pollen reaches the ovules in the female cones. One might think it was carried by the bright red and yellow insects (yellow bugs and their red larvae), *Probergrothius sexpunctatus* (Pyrrhocoridae), that presented a dramatic sight when we saw them in June. However, all experts agree that red beetles and their larvae are not responsible for pollination; it would appear that other insects are respon-



The pollen-producing (male) inflorescences of *Welwitschia mirabilis* have numerous small "flowers" borne in the cones. The reproductive organs resemble a tiny bisexual (or hermaphrodite) "flower" with a single sterile ovule (analogous to the female gynoecium in a female flower) surrounded by a fused ring of six structures (analogous to stamens). These latter structures produce the pollen. Although similar to a flowering plant, the ovule seems to be nonfunctional and never develops into a mature seed. The female "flower," on the other hand, has an ovule but contains no traces of stamens. Drawings by Clara Richardson courtesy of the Field Museum.

Cultivating *Welwitschia*

Welwitschia was first grown successfully from seed to seed in the Botanic Gardens of the University of Stellenbosch, and it is presently being grown with considerable success in the Montreal Botanic Gardens; the Royal Botanic Gardens at Kew; and the Huntington Gardens, San Marino. Because of the fragility of its root system, it is best cultivated from seed. Even then, however, it is notoriously difficult. Of the ten to twenty thousands of seeds produced by a female plant, only twenty to two hundred may be capable of germination (Bustard, 1990). The most critical stage is the first six months of life, as seeds collected from populations in the wild are often heavily infested with the fungus *Aspergillus niger* (van Jaarsveld, 1992).

As described by H. Teuscher of the Montreal Botanic Gardens, growing *Welwitschia* is an enormously complicated business. First the seeds must be sown in very well drained pans containing granitic sand, crushed brick, and a trace of leaf mold. To ensure drainage the bottom of the pans should be covered with broken bits of crockery. The pans should then be covered with glass and placed in filtered light at a minimum temperature of 50 degrees F.

The seedlings must be watered from below to avoid damping-off disease. Under these conditions, the seeds of *Welwitschia* usually germinate within two weeks.

At five months the seedlings will have developed five-to-six-inch long unbranched taproots and must be transferred to clay drainpipes or clay pots that will accommodate the long taproot—the trickiest part of the growing process. A layer of broken crockery an inch-and-a-half deep should be placed in a twelve-inch pot with a drainpipe approximately three inches in diameter inserted vertically. Then the seedling is to be carefully inserted into the drainpipe, making sure the roots are fully outstretched. The drain can then be slowly filled with seedpan soil to a height of approximately three inches, followed by a mixture of one part crushed limestone and one part granitic sand, topped by a thin layer of crushed limestone. At this stage,

the cotyledons should be lying flat along the top of the limestone. In the space between the pot and the drainpipe, two to three inches of topsoil and sand should be placed, followed by some leaf mold and a sprinkle of bonemeal and dehydrated sheep manure. Above this layer, crushed limestone and sand must be added, topped by a final layer of crushed limestone. Watering is done in the area between the drainpipe and pot. From April to September water should be enriched with a small amount of a complete liquid fertilizer, with plain water being used from the fall to the spring.

Teuscher, whose method represents the conservative end of *Welwitschia* culture, advises against repotting *Welwitschia* because of the serious hazard of damaging the root system. Instead, every three years after the plant is established, the stone and sand mixture along with the soil between the pot and drainpipe should be removed from around the roots. Fresh soil enriched with a small dose of fertilizer should then be added. In Teuscher's experience, it takes ten to twelve years for cones to develop.

Teuscher presents a daunting view of *Welwitschia* culture; however, others suggest that it may not be so difficult. For instance, Horwood goes so far as to say that it may not be necessary to cultivate the plants in drainpipes. Leo Song, Jr., maintains that these plants are not difficult to grow if certain basic conditions are given—full sunlight and abundant heat, protection from prolonged low temperatures, a fast draining growing medium, regular watering and fertilizing (preferably in a program of continuous feeding), and ample room for the root system. Song reports that he is growing *Welwitschia* in pumice in large pots with substantial success.

Van Jaarsveld also emphasizes the importance of allowing sufficient space for the taproot to develop. He attributes the success in cultivating *Welwitschia* at the Kirstenbosch Botanical Garden to bottom heat during the winter months, the rich, well-drained "Vanrhynsdorp" sand, and regular watering.



This model of a young *Welwitschia* plant shows the stout taproot and the two leathery leaves that the plant retains throughout its entire life. Courtesy of the Field Museum (B81801).

sible, possibly wasps, flies, or ants, and that the ovule's fluid may act as an attractant. Insects visit the drops of nectar secreted by the ovules in the female plants and in the process transfer pollen grains from the stamens of the male flowers.

After fertilization and following the sporadic February and March rains, the seeds fill out rapidly and the female cones spread their ripe seeds from about mid-June to mid-July. On the first of June, 1994, the seeds were just being released. By October, the mature cones will have shed virtually all their seeds and next season's cones will have appeared.

Welwitschia is generally classified as a gymnosperm in the division Gnetophyta. Within this division are three orders, Ephedrales, Gnetales, and Welwitschiales, each consisting of a single family and genus. Like *Welwitschia*, the two other members of this division are rather unusual. *Ephedra*, often called Mormon tea, is a shrub-like desert genus consisting of about thirty-five species and occurring in the United States in the deserts of California, Nevada, Utah, Arizona, and New Mexico.

Gnetum is a tropical genus of about thirty species found as a clinging vine in the rainforests of Asia, northern South America, the Pacific Islands, and Africa north of Namibia. But even within its own division *Welwitschia* is distinctive—unusual in its appearance, in its geographical restriction, and in occurring only as a single species.

Ephedra, *Gnetum*, and *Welwitschia*, as a group, are regarded as the closest living relatives of the flowering plants (Doyle and Donoghue, 1993). Unlike the other gymnosperms, the Gnetophyta resemble angiosperms in having special water-conducting cells, called vessels, for increased efficiency in transporting water. Whether this implies a direct evolutionary relationship or is an instance of convergent evolution resulting from adaptation to desert environments is still a subject of some debate (Muhammad and Sattler, 1982). A possible evolutionary relationship between the Gnetophyta and the angiosperms is also suggested by certain reproductive characteristics, such as the unusual male "flowers" and in fertilization techniques (Gifford and Foster, 1989; Friedman, 1990).

All in all *Welwitschia mirabilis* is an uncanny paradox. In its unique development and ambiguous relationship to the flowering plants, its very existence is a challenge to botanists. Certainly it was a privilege to see this living legend.

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References

- Bornmann, C. H. 1978. *Welwitschia—Paradox of a Parched Paradise*. Capetown and Johannesburg: C. Struik Publishers.
- Brinckmann, E., and D. J. von Willert. 1987. Injury and

- recovery of *Welwitschia mirabilis*. *Dinteria* 19: 69–76.
- Bustard, L. 1990. The ugliest plant in the world: the story of *Welwitschia mirabilis*. *Kew Magazine* 7: 85–90.
- Crane, P., and C. D. Hult. 1988. *Welwitschia* the Wonderful. Life as a Survivor in the Desert of Southwestern Africa. *Field Museum of Natural History Bulletin* (February), 22–29.
- Craven, P., and C. Marais. 1986. *Namib Flora—Swakopmund to the Giant Welwitschia via Goanikontes*. Goodwood, Cape: Gamsberg, National Book Printers.
- Doyle, J. A., and M. J. Donoghue. 1993. Phylogenies and angiosperm diversification. *Paleobiology* 19: 141–167.
- Friedman, W. E. 1990. Double fertilization in *Ephedra*, a nonflowering seed plant: its bearing on the origin of angiosperms. *Science* 247: 951–954.
- Gifford, E. M., and A. S. Foster. 1989. 3rd ed. *Morphology and Evolution of Vascular Plants*. New York: Freeman and Co.
- Hooker, J. D. 1863. On *Welwitschia*, a new genus of Gnetaceae. *Transactions of the Linnean Society of London* 24: 1–48.
- Horwood, F. K. 1974. Succulent Safari to Africa, Part 11. *Cactus and Succulent Journal* (U.S.) 46: 260–261.
- Marsh, B. A. 1987. Micro-arthropods associated with *Welwitschia mirabilis* in the Namib desert Southwest Africa. *South African Journal of Zoology* 22: 89–96.
- Martens, P. 1971. Les Gnetophytes. *Handbuch der Pflanzenanatomie* Band 12 Teil 2. Berlin: Gerbruder Borntraeger.
- Muhammad, A. F., and R. Sattler. 1982. Vessel structure of *Gnetum* and the origin of angiosperms. *American Journal of Botany* 69: 1004–1021.
- Rowley, G. 1972. Voyage into the impossible—I meet *Welwitschia*. *Journal of the Royal Horticultural Society* 97: 346–350.
- Song, L. C. 1980. Gross morphology of developing male and female strobili of *Welwitschia mirabilis* Hook. f. *Cactus and Succulent Journal* (U.S.) 52: 30–32.
- Swinscow, T. D. V. 1972. Friedrich Welwitsch, 1806–72: A centennial memoir. *Botany Journal of the Linnean Society* 4: 269–289.
- Teuscher, H. 1951. *Welwitschia mirabilis*. *The National Horticultural Magazine* 188–189.
- Van Jaarsveld, E. 1992. *Welwitschia mirabilis* in cultivation at Kirstenbosch. *Veld & Flora* (December), 119–120.
- Von Willert, D. J. 1985. *Welwitschia mirabilis*—New Aspects in the Biology of an Old Plant. *Advances in Botanical Research* 2: 157–191.
- Von Willert, D. J., B. M. Eller, M. J. A. Werger, E. Brinckmann, and H. H. Ihlenfeldt. 1992. *Life Strategies of Succulents in Deserts with Special Reference to the Namib Desert*. Cambridge: Cambridge University Press.
- Welwitsch, F. 1861. Extract from a Letter, addressed to Sir William J. Hooker, on the Botany of Benguela, Mossamedes Etc., in Western Africa. *Journal of the Proceedings of the Linnean Society Botany* 5: 182–187.

Gillian Cooper-Driver is an Associate Professor of Plant Biochemistry at Boston University. She has just returned from spending ten months at the National University of Lesotho on a Fulbright Award.