Cambridge University
Botanic Garden

Amazing Adaptations:

journey through the glasshouses

Notes to assist you on your visit to the Garden

Cambridge University Botanic Garden

LESSON PLAN: Amazing Adaptations: glasshouses
DURATION: Typically 30 minutes

Learning Objectives

Explore the different environments within the glasshouses, including deserts, mountains and rainforests.

Develop observational skills by using all the senses.

Understand adaptations for life in extreme environments including deserts, rainforests and mountains.

Overview

Taking a tour of different glasshouses within the Glasshouse range allows you to visit plants from many different growing regions of the world. There is a glasshouse devoted to Mountain plants, and one for Desert plants, and an interconnected series of three glasshouses devoted to Tropical plants. The different plant adaptations are revealed in the different climatic conditions of the houses.

Introduction

Gather in the courtyard area at the entrance to the glasshouses and explain to your group that you will be exploring the different environments within the glasshouses. Ask them to use their eyes to observe all the different shapes of the plants' leaves and stems etc, but to also use their ears, noses, even their skin to fully appreciate the environments they are in. Imagine that you are about to embark upon a journey around the world.

Main Task

Enter each of the three key houses in turn:Mountains House, Tropical House and Arid Lands House. Once inside each house consider how the environment feels (temperature, humidity), how much light is in there and generally how much vegetation there is around you. Look at the plants and focus on their size and structure. Look for specialisations that help them to be well adapted to the environments in which they grow and use the accompanying teachers' notes to generate further discussion. Consider making drawings of the plants and their specialisations. Seek out the plants of economic importance in the Tropical House and talk about their products.

Plenary

Regroup outside the glasshouses and go over what you saw in each house. Discuss some of the specialisations you have seen and consider why, for example, a plant from the Arid Lands House wouldn't survive for long in the Tropical House.

Resources

Laminated A3 world map, teachers' notes on tropical rainforests, plants of economic importance, plants of the desert, mountain plants.

Vocabulary

Temperature, humidity, adaptation, specialisation, survival, arid, exposed, competition, environment, conservation, rainfall, waxy, drip-tips, epiphyte, succulent, hairy, cushion.

Plants of the Mountains

Cambridge University Botanic Garden

Where is the Mountain House? Enter the corridor and take the third door on the right.

Alpine habitats occur in mountain ranges throughout the world - not just in the central European mountains we call The Alps. These mountain areas are **ice- and snow-covered for more than half the year**, then **sun-baked** and lashed by **fierce storms** in summer.

They are amongst the most inhospitable habitats in which plants grow.

Alpine habitat in the Picos de Europa, north Spain. Photo by Jo Joyce

Alpine habitat in the Picos de Europa, north Spain. Photo by Jo Joyce

The environment becomes increasingly harsh as one climbs a mountain. Above a certain altitude, it is so cold, wind-swept and snow-covered that **trees cannot survive**. This level is the 'tree line'. Above it the terrain is **rocky and craggy** (as above).

There is **hardly any soil to provide minerals and anchorage** for plants. Only tiny species, such as cushion plants, survive there. They have adapted to cope over millennia.

Crevices in the rock, gullies and side-valleys (left) provide protection for plants. Here, taller species such as shrubs or lilies grow amongst rocks and grass. In early summer the meadows are a **riot of colourful flowers**, as the plants advertise to **attract insect pollinators**.

Many alpine species are **miniature cousins** of familiar garden plants. **How can you recognise their adaptations? Look for some of these features:**

Cushion plants: Many species have evolved a roughly **hemispherical form**. This is a strong shape to withstand heavy snow. Cushion plants often grow in small hollows in the rock. Their **roots penetrate cracks in the rock**, to find water and to anchor the plant. **Tightly-crowded shoots** support and insulate each other. In summer, the cushion acts like a sponge, helping to retain moisture. Over the cushion surface, tiny leaves photosynthesise to make energy for the plant. The small surface area of each leaf reduces wind damage and water loss.

A typical cushion plant

Sun-blocking waxes & hairy coats: Look for leaves with a **silver-grey colour**. At high altitude exposure to the sun's rays can burn delicate leaves. Waxes and fine hairs coating the leaf surface **deflect harmful rays, such as ultra-violet**, away from the leaf. Fine hairs also help **insulate plants** against frost damage.

Edelweiss - hairy all over!

Herbaceous life-style: Species with larger, delicate **leaves and shoots die down** once they have flowered and dispersed their seeds. In winter, **only underground parts of the plant survive**. For instance, daffodil or crocus store energy for next year in underground **bulbs or corms**. New leaves and flowers grow after winter snows melt.

A tiny cousin of daffodils

Alternative approach

The concept of Adaptations to the environment in which a plant grows can cause some conceptual problems for young children. A method of addressing this can be to use analogy. Comparing what the plant 'needs' to what a human would need in the same circumstances.

In the context of mountain plants this process of making comparisons can be done using rucksack. Fill a rucksack with items that you might want to take on a trip to the top of a mountain. Each item in the sack represents something you would need or find useful on your trip. This helps illustrate the survival mechanisms the plants make in this hostile environment

Mountains have **exposed, cold often windy climates** you would take ajjacket with a hood and perhaps a survival blanket if it was a long trip. Plants have thick skin or hairy surfaces to prevent heat loss. They also grow low down to the ground in compact cushions to stay out of the wind. Think of what happens to trees on mountains and the wind pruning that takes place.

Extremes of temperature perhaps you would have many layers of clothing so that you could take layers off when the sun is high and the temperature warm. The plant has to find ways of coping with warm temperatures during the day and extremes of cold at night. Sometimes the hairy surface of a leaf can help trap warmth, this would be a bit like you wearing a fleece. The thick waxy layer is also a way the plant protects itself from temperature extremes. Where it is too snowy and cold plants do not grow.

There is **not necessarily a lot of water** on a mountain top, possibly it is frozen as ice. You would take a water bottle, the plant develops long roots to reach down between the cracks to look for moisture and also develops ways of holding on to water, in much the same way as cacti do such as developing a succulent growth form.

Very bright sunlight, you might take sunglasses and wear suncream, plants have to find ways to stay out of the sun under rocks, in cracks, or else develop thick outer layers to prevent them being burned by the sun.

Food, you would take supplies with you plants use the sunlight to make sugars but have to get other nutrients from the soil. On mountains soil often has poor nutrient quality. This can be helped by manure from grazing animals such as goats or rabbits putting organic matter back in to the ground.

Mountain plants have **bright coloured flowers**, you might wear bright outer clothes on your expedition so that in case of needing to be rescued from the mountain you would be easily seen. The bright flower colour helps them to be seen by their insect pollinators which is important for the survival of the plants they must set seed for the next generation of plants.

Plants of the Tropical Rainforests

Cambridge University Botanic Garden

Tropical rainforest species are displayed in the Tropical Houses in the glasshouse range. Species from 'New World' tropics - the Americas and Australia - are reached through the door marked Western Tropics. Those from 'Old World' tropics – Africa and Asia – are through the door marked Eastern Tropics. The Palm House (the tallest glasshouse - in the centre of the range) displays tree species from all tropical rainforest regions. The planting is designed to give a good impression of the structure and diveristy of rainforest.

Rainforest covers 6-7% of the Earth's land surface and is distributed between the Tropic of Cancer and the Tropic of Capricorn.

There are 3 main rainforest areas - Central & South America, West Africa, Asia & Austrailia.

Environment

Susbstrate characteristics

- soil is usually composed of a relatively thin layer of reddish clay with low fertility
- soil fertility depends mainly on rapid release of minerals from decomposing organic matter
- leaf-fall occurs throughout the year. Decomposition is rapid due to high temperatures and humidity, so relatively little leaf litter accumulates
- vacant ground space is rapidly re-colonised

Other characteristics

- Climate – hot and humid throughout the year, with no distinct seasons
- Annual rainfall – typically between 2m (80ins) and 4m (160 ins) but may reach 20m (800ins)
- Temperatures – fairly constant - between 20-28°C.
- Humidity – always high at approximately 80%.

Plant responses to environment

The conditions outlined above favour rapid growth and fast reproductive cycles. Rainforests support more species (all Kingdoms) than all other climatic regions (biomes) combined. About 70% of species in tropical rainforest are trees, most being evergreen, as there is no cold season.

Forest Structure and biodiversity

Rainforest supports a high diversity of tree species per hectare. Typically, there may be only a single representative of each species in an area. This contrasts with UK native woodland, in which high numbers of a few species are usually found, as for example in a beech wood. The diversity of plant species in rainforest makes for habitat diversity and a wide range of potential food sources. This, in turn, supports correspondingly high animal diversity.

Rainforest Structure

The plants in rainforest compete mainly for light, 4 distinct layers of vegetation being identifiable.

- **The emergent layer** - the tallest trees up to about 50-70m high and extending above the majority of other trees. These are too tall to be represented in the Palm House.

- **The canopy layer** - trees between 40 and 50 metres tall which dominate the rainforest environment. They have long, straight trunks with few side branches and smooth bark. The crowns of trees are tightly crowded and, as their leaves absorb much of the sunlight, the forest floor below is deeply shaded and relatively cool.

- **Shrub or understorey layer** - scattered shrubs, saplings, ferns etc. extending to about 5m tall. As light intensity is low, they often have very large leaves to intercept enough light to energise photosynthesis.

- **Ground layer or herb layer** - herbaceous perennials and non-woody plants at ground level. less than 1% of the total rainforest plants grow at this level. They often have dramatically coloured and patterned leaves. This pigmentation assists them to utilise a wider spectrum of light for photosynthesis. IIn some species light is reflected back through the leaf from its lower surface to give a second chance for harvesting energy.

Other specialist plant Groups

Lianas - woody climbers, rooted in the forest floor, then usually reaching the upper canopy. By developing a climbing habit and relying on trees for support, lianas are able to produce their leaves in well-illuminated positions, high in the canopy, without investing the energy required for growing a thick trunk.

Epiphytes – e.g bromeliads, orchids, ferns - are not rooted in the forest floor but use tree trunks and branches as anchorage. Epiphytes make their own food by photosynthesis, so are not parasites. By growing well above the forest floor, they benefit from higher light levels than would be available amongst herbaceous plants of similar size that are restricted to life on the forest floor. The seeds of epiphytic orchids are extremely small and distributed by the air currents. When they land in a moist crevice they germinate to produce a new generation of epiphytes.

Epiphytes' roots cling to the surface of the bark, but do not penetrate it. As there is minimal substrate material to provide water and minerals, the stiff leaves of epiphytes, such as bromeliads and Stag's Horn fern create 'urn'-like structures, which trap water and act as a reservoir, prolonging water availability. Organic material tends to fall into the 'urns' and when decomposed, the resulting minerals are taken up and re-used by the epiphyte.

Epiphytes such as air plants (*Tillandsia* spp.) have no water-seeking roots but their long, scale-covered leaves take in water directly from the atmosphere.

Leaf characteristics

Leaves that shed water effectively

The high relative humidity of the rainforest atmosphere presents the danger that leaves may become infested by algae or fungi, reducing their ability to intercept light. Leaves may even 'drown' if the stomata remain waterlogged for long, preventing gaseous exchange. The leaves of many species show adaptations, which help them to dry out rapidly after rainstorms. They may have **waxy cuticles** for example such leaves look very shiny and feel as if they have a waterproof coating. The leaf cuticle is protected by **water-repellent waxes** which shed water rapidly. Another adaptation if for leaves to have **drip tips** – exaggerated points at the leaf tip act like the spout of jug, directing water off the leaf.

Leaves that channel water

Leaves are often arranged on the plant so that rainwater is directed from the leaf surface towards the plant's roots. Bananas are an example of this. See also the note above about the ability of some epiphytes to trap water and minerals in 'urns' formed by their leaves.

Adaptations in the leaves of shade adapted plants on the rainforest floor

Some plants adapted to life below the canopy have leaves that **appear disproportionately large** for the overall size of the plant, their increased surface area maximising light interception for photosynthesis. Some plants adapted to grow in the herb or ground layer, where it is most shaded, have **strongly patterned leaf laminas**. Their striking appearance reflects the presence or absence of different pigments. Each pigment enables the leaf to use a specific wavelength of light for photosynthesis. Examples e.g. the leaves of begonia and of the herringbone plant (Maranta leuconeura erythroneura) have red undersides. The pigment reflects back any light transmitted through the leaf lamina so it can be used a second time to energise photosynthesis.

Tropical Economic Plants

Not only do tropical rainforest plants present very high diversity, they are also very productive as growth and reproductive cycles are fast. Tropical plants provide people with many valuable resources - foods, raw materials for industry and construction, medicines, cosmetics etc. A few that can be seen in the glasshouses are: -

Food crops - rice, bananas, cocoa, coffee, sugar, vanilla, pepper.

Plants that provide materials - cotton, rubber, mahogany, bamboo, fibres, lubricants, paints, soap, shampoos, perfumes, lipsticks etc.

Plants that provide materials to make drugs and health-promoting products - Quinine (anti-malarial), Rosy Periwinkle (for treating childhood leukaemia) and others. Annatto (E160b) - a food colouring which replaced tartratine, the artificial food colouring believed to aggravate hyperactivity.


Arctic Ocean
Arctic Ocean
GREENLAND
NORTH AMERICA
EUROPE
ASIA
North Pacific Ocean
North Atlantic Ocean
AFRICA
North Pacific Ocean
Indian Ocean
SOUTH AMERICA
AUSTRALIA
South Pacific Ocean
South Atlantic Ocean
2500 km
mi
Distribution of tropical rain forests

Plants of the Deserts

Cambridge University Botanic Garden

Plants of the world's deserts can be seen in the Arid Lands house at the eastern end of the glasshouse range

Succulents and Cacti

Due to the extreme environment of deserts, their vegetation includes some of the most highly specialised (and bizarre) plants in the world.

The term succulent is used to describe plants that are adapted to survive in arid environments, due to their ability to store water. Succulent plants grow in deserts throughout the world.

Cacti are succulents that belong to a single plant family, the Cactaceae. Although cacti are now grown throughout the world, all members of this family originated in the deserts of the Americas.

Threats to desert habitats

Desertification

Overgrazing and trampling by domestic livestock damages desert environments, whilst also enlarging their area. Such pressures de-stabilise the fragile ecosystem of transitional zones bounding the deserts. Windblown dust and sand from overgrazed areas bury land that was once productive. In this way, the Sahara Desert is extending all along its southern edge.

As much as one third of the Earth's land surface, in 110 countries, is now threatened by desertification.

Further threats to deserts and their flora are **introduced species, spreading cities, and poachers**.

Convention on International Trade in Endangered Species (CITES) protection has been extended to many succulents, including cacti, aloes, agaves, euphorbias, and pachyopodiums.

Deserts cover about one fifth of the Earth's land surface.

Most are located at latitudes roughly 30° north and south, in zones of high atmospheric pressure that flank the tropics and extend polewards in the interiors of the continents.

The Sahara Desert in Africa is the largest, followed by Australia's Great Western Desert.

Environment

Minimal rainfall

Desert regions have **less than 25cm of rain per year**. In some years, no rain may fall. When rain arrives, storms are often brief and torrential.

Dry atmosphere and extreme temperatures

As there is little water vapour in the air to moderate temperature fluctuation, nights are often extremely cold - sometimes as much as 30°C colder than daytime temperatures. (This contrasts strongly with the humid tropics, which usually only experience variation of a few degrees between night and day.)

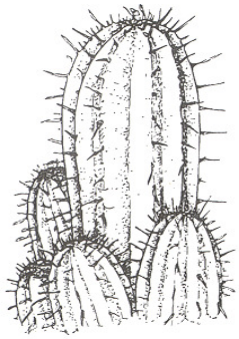
Strong, dry winds cause dust and sandstorms

Loose, light particles such as sand, grit and decomposing organic matter are driven through the air at high speed. Flying material abrades and erodes exposed bedrock and dunes are formed, where sand is eventually deposited.

Poor soil

The heavier and more stable substrate is coarse gravel, stones and rock, with low fertility. Where the ground is baked by the sun and abraded by winds or impacted by trampling, rainfall cannot penetrate and rapid run-off typically causes flash flooding.

Plant responses to environment



Cacti are **stem** succulents

Agave is a **leaf** succulent

Adaptations

Ability to store water

Many desert plants from around the world are classified as succulents due to their **ability to store water inside their stems or leaves**. Such reserves are used very economically, enabling the plant to survive long periods of drought. The storage organs are covered by an extremely **thick, waxy cuticle**, which greatly reduces water loss. Because leaves lose water rapidly (by transpiration), many desert plants have evolved to cope without leaves. They are called **stem succulents**, and photosynthesis is carried out in their chlorophyll-rich stem tissues. Species in the Cactus family are stem succulents. Other species, such as those in the Agave family, store water in their succulent leaves and are known as **leaf succulents**.

Spines protect against predators

Many long-lived desert plants have sharp spines or pointed leaves to protect them from predation by desert animals.

Fibrous roots

Cactus species typically grow a mass of fibrous roots close beneath the surface. These capture water from the lightest rainfall, as well as moisture in the form of dew or fog, which collects on stems at night and trickles to the ground.

Growth Rates and Life Cycles

Deserts have **low soil fertility** and **sparse vegetation**. Overall productivity is low. **Long-lived succulents**, such as cacti, euphorbias and pachypodium grow slowly. The seeds of **ephemeral species** remain viable in the ground through long periods of drought, only germinating in response to rainfall. The life cycle is then completed rapidly - some species producing flowers within days of rainfall, resulting in the so-called 'blooming of the desert'. New seeds are set before drought resumes. **Small perennial species**, such as members of the lily family, also have a life cycle with a short growing season. After setting seed, they survive extreme drought as a **dormant bulb** below the surface.

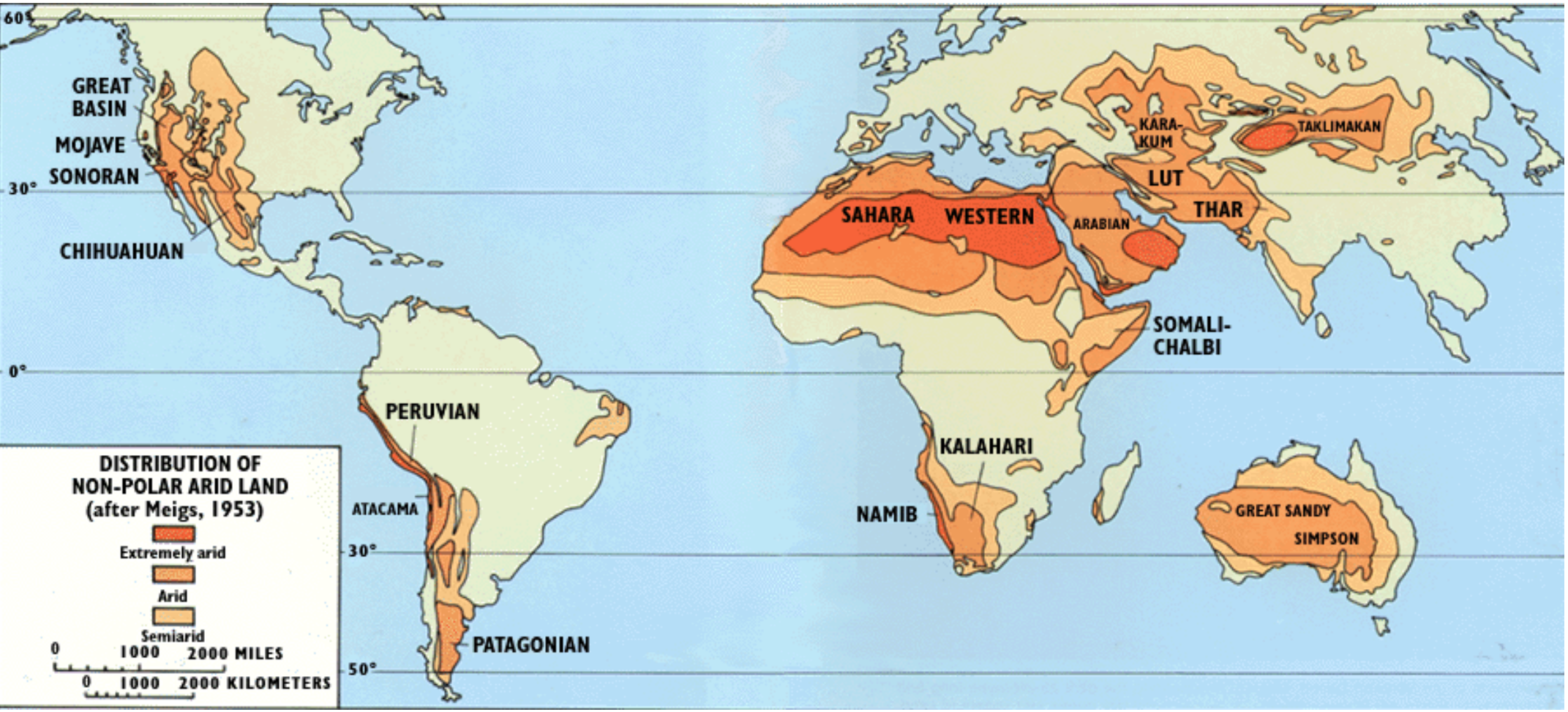
CAM and C4 pathway photosynthesis

In cacti and many other succulents, the method of photosynthesis is either by **CAM or C4 pathway**. Both processes conserve the plant's water resources.

Slow growing Saguaro cacti and thorny scrub are the main components of the relatively diverse vegetation of the Sonoran Desert, Arizona, USA.

Long-lived desert shrubs and trees, including **palms**, often have **very long roots**. These reach water deep underground as well as helping to **anchor the plant** during hurricane-force winds.

Unlike the trunks of temperate climate trees, in which new wood is laid down in growth rings, the wood of **palms** comprises many **bundles of fibrous, tube-like vessels**. This construction gives the palm trunk the flexibility required to bend with and withstand the wind.


60°
30°
0°
30°
50°
GREAT BASIN
MOJAVE
SONORAN
CHIHUAHUAN
PERUVIAN
ATACAMA
PATAGONIAN
SAHARA
WESTERN
ARABIAN
KARA-KUM
TAKLIMAKAN
LUT
THAR
SOMALI-CHALBI
KALAHARI
NAMIB
GREAT SANDY
SIMPSON
DISTRIBUTION OF NON-POLAR ARID LAND
(after Meigs, 1953)
Extremely arid
Arid
Semiarid
0 1000 2000 MILES
0 1000 2000 KILOMETERS