Ecology:

Ecology is the he study of how organisms interact with the environment and each other.

Ecology can often be subdivided into different types such as:

Population ecology - examines the causes of population growth and change.

Community ecology - addresses specifically how organisms interact with each other. Deals with such issues as competition, species diversity, and so on.

Ecosystems ecology - specifically examines the impact of the environment on organisms and vice versa. Also looks at such things as how energy move through a system, food webs, etc.

Conservation biology - deals with how we can best preserve organisms and their environment.

Population ecology:

First we need to define a population:

Usually it's defined as the number of individuals in a particular place. For example:

The deer population in Northern Virginia.

The mouse population at George Mason.

But we can also apply this to larger groups:

The population of black bears in the United States.

The population of humans on our planet.

Some characteristics of populations:

Density.

One of the first things we want to know is how many individuals are in the area we're looking at.

Population density is defined as the # of individuals / unit area.

For example, 100 people / square kilometer.

A real example:

Fairfax County has about 2,455 people / square mile (2010 figures).

Sometimes we want to figure out the population size or density for animals other than humans. It is often (almost always!) impossible to count every animal

We need to estimate population size using sampling techniques such as mark-recapture:

1) Catch as many individuals as possible. Mark them.

2) Repeat.

If most individuals caught the second time are unmarked, this indicates a large population (you caught only a small percentage of the population the first time).

If most individuals caught the second time are marked, this indicates a small population (you caught most of them the first night).

3) There are equations that can give you reasonably precise numbers.

Density or population size changes due to **[Fig., not in text]**:

Birth, death, immigration, and emigration.

(True for human populations as well!)

Dispersal patterns **[Fig. 36.2, p. 726]**.

This describes how the organisms are distributed. There are three main patterns:

Clumped - the organism occurs in clumps, with few organisms between the clumps.

An example might be wolf packs or other animals that travel in packs or herds.

Uniform - the organism occurs at a constant density (no matter where you look, there are about the same number).

Examples might be penguin colonies, where each “nest” is the same distance from every other nest.

Random - the organisms don't care where they are - there is no obvious “pattern”.

Examples might be wind dispersed plants like dandelions (they grow wherever they happen to land).

Population growth / change.

We often use mathematical models to describe how fast a population can grow.

Suppose we come up with the following hypothesis:

A single bacterium multiplies. Now we have two.

20 minutes later each of those divides, and so we have four.

40 minutes later, each of these four divides, so we have eight:

Basically what we have is 2^x, where x is the number of times they divide.

So, for example, we'd have the following:

At the end of 2 hours they've divided 6 times:

$2^6 = 64$

At the end of 36 hours, we would have:

$2^{108} = 324{,}518{,}553{,}658{,}426{,}726{,}783{,}156{,}020{,}576{,}256$

Or, as your book puts it, enough bacteria to cover the earth one foot deep.

This is an example of exponential growth. But this is obviously unrealistic:

Something stops this from happening!

The lack of food for our bacteria.

(Darwin realized this applies to organisms in general, and this helped him formulate his theory of evolution).

Here's a more precise formulation of the exponential growth model:

$$\frac{\text{change in population}}{\text{change in time}} = (\text{birth rate} - \text{death rate})N \qquad \text{where } N = \text{current population size}$$

Your text uses $G = rN$, which is the same thing, but with G and r substituted into the above equation.

Notice particularly that r = birth rate - death rate. r is used quite often in population ecology.

Note that if birth rate > death rate, r is positive and the population will grow.

Conversely, if birth rate < death rate, r is negative and the population will decline.

You can use this equation to model our bacteria and you'll get the same result.

For example, let's assume we have 4 bacteria and let $r = 1$. We have:

N = current population size so:

$G = 1 \times 4 = 4$

So the change in population is 4 (the population grows by 4 bacteria).

Now we have 4 + 4 (four original bacteria, plus the four new ones we got from growth). So we have:

$G = 1 \times 8 = 8$

Now we have a total of 16 bacteria (8 original, 8 from growth), and so on.

The exponential growth model makes what is happening a bit more obvious since it uses terms like birth rate, death rate, etc.

If you plot something with exponential growth you'll eventually get a steeply increasing curve (a J shaped curve **[Fig., similar to 36.4A, p. 728]**

But as mentioned, populations can't grow exponentially. Eventually they'll run out of food or resources (they might, however, be able to grow exponentially for a short period of time).

To fix (some of) the flaws in the exponential model we have the logistic growth model:

$$\frac{\text{change in population}}{\text{change in time}} = rN\,\frac{K - N}{K}$$

This is not a math class, so we won't go into to much detail.

But notice that if $K = N$, then the left hand side of the equation = 0.

There is no population growth if $K = N$.

On the other hand, if N is much smaller than K, then $(K - N)/K$ is close to 1

This allows for very rapid (almost exponential) growth.

K is often called the *carrying capacity*.

The environment simply can't support more organisms than K.

A lot of research is done to figure out what K is for a particular area, etc.

However, K can vary

In good years it might be higher, in bad years lower.

Plotting a logistic growth model gives us a curve like that in **[Fig. similar to 36.4B, p. 729]**.

Remember that even this is a model.

It's a very simple model, and real life may be quite different.

Let's assume for the moment that the logistic growth model does alright. What determines K?

Food (there is only so much food to go around).

Other resources - for example, water, nutrients, sunlight (for plants), etc.

Territory (e.g., many song birds don't like to be too close to each other)

Number of nesting or denning sites (similar to the previous one).

Predation (if there are too many organisms of one kind, a predator will start to eat more and more).

And remember that environmental factors like weather can influence *K* (and change many things on our list)

Dry, hot, or extremely cold conditions can all increase the number of deaths (and reduce *K*) **[Fig. 36.5B, p. 730]**.

Let's illustrate some of this with the moose population on Isle Royale (in lake Superior) **[Fig., not in text]**.

Moose are influenced by weather, predation, space, etc.

Some populations can even become cyclical (have up and down cycles) **[Fig. 36.5C, p. 731]**.

Lynx & hare (we're still trying to figure out exactly what's going).

Fact: when there are a lot of hares, there are a lot of lynx, and vice versa.

This could be caused by:

Hares increasing until they run out of food, then dying off.

In other words, they eat all the grass; once they die off, the grass recovers.

The lynx population just follows the hare population.

Lynx feeding on hares

As they feed on more and more hares, the hare population crashes

As a result the lynx population crashes.

The hares recover, and the cycle starts over.

Some combination of the above two could also be responsible.

Life tables & survivorship.

Insurance companies do a LOT of this. See **[Fig. (table) 36.3, p. 727]**.

Life tables calculate the number of individuals alive during a specific time interval and then use this to calculate things like death rate, survival probabilities and so on (for each time interval!)

Using live tables, we can also get survivorship curves **[Fig. 36.3, p. 727]**

These illustrate the percentage of organisms alive as age increases.

There are three types of survivorship curves, types I, II, & III (see figure).

Survivorship curves give rise to the concept of *r* & *K* selection.

(Not directly related to *r* and *K* used in the growth models above)

Organisms with *r* selection produce many offspring, and hope some survive.

They don't put a lot of resources into individual offspring

They have a very high potential rate of increase (their population could (potentially) increase very quickly).

Examples might be roaches, and weeds.

Organisms with *K* selection produce fewer offspring, and hope most survive.

They put a lot of resources into each offspring.

They have a lower potential for rapid population growth.

Examples might be humans or elephants.

Human population growth **[Fig., not in book & 36.9A, p. 735]**:

A very important (and somewhat political) issue.

The basic problem is that the human population has started to grow exponentially.

Health care has improved dramatically

This means the death rate has gone down (a good thing!)

Unfortunately in many parts of the world, birth rate has *not* gone down **[Fig. 36.9B, p. 734]**.

Currently (spring, 2015) we're at 7.2 billion, by 2050, we're expected to be over 9.3 billion.

The large human population puts an enormous strain on ecological resources:

We need increased food production

We need access to fresh water

We need higher amounts of other resources such as minerals, energy, raw materials, etc.

Simply put, this is not sustainable.

Our best estimates are that the carrying capacity for the earth (*K*) is somewhere between 10 and 15 billion people (some say we've already exceeded capacity).

However, this is not the only problem - we also have a large disparity in the amount of resources we consume.

In the U.S., for example, we use far more resources than other societies.

Comparing the U.S. with India, the average American uses **[Fig. 36.11, p. 737]**:

50 times more steel	170 times more rubber and newsprint
250 times more fuel	300 times more plastic

This gives us the concept of "ecological footprint"

How much area (of the earth's surface) does each of us use to keep us going in the lifestyle we're used to?

(We need x amount of area to grow our food, y amount to get the minerals/ores for our vehicles, z amount for the wood to build our houses, etc.)

[Fig., not in text]

It takes about 8.4 ha (1 ha = 2.47 acres) to support someone in the U.S..

Someone from India or Bangladesh can make do with 0.8 - 0.5 ha.

This raises two important ethical questions for conservation:

1) do we really have to use so much?

Note that other highly developed countries (e.g. Germany or Japan) have an ecological footprint about half the size of ours!

Notice also that our ecological footprint is bigger than the area of the United States - we're using other countries resources to keep us going!

2) is it fair? don't we want the rest of the world to catch up to our level of development?

There are NOT enough resources on the planet for every human to live the way we do!

We'll say more on this topic when we do conservation biology

Doubling times, growth pyramids, etc.

Using the above equations, we can calculate the approximate doubling time for human populations.

Doubling time - the time needed for the population to double.

This is highest in the poorer tropical countries:

Kenya doubles its population in about 20 years

The United States & Canada double their population in about 114 years.

We can also show growth using age pyramids:

This shows us (graphically) the distribution of ages within a population:

What % is between 0 and 5 years old, between 6 and 10 years old, etc.

We then arrange this data into "population pyramids" **[Fig., not in text]**

Only fast growing countries really have a "pyramid structure".

Stable populations will show a "pyramid" with parallel sides.

Declining populations will have an upside down pyramid.

Note that a population with a lot of children (e.g., Kenya or Afghanistan) will continue to increase in size even if 1 child/family rules are implemented (very controversial).

This is because **[Fig. 36.9C, p. 735]**:

All those children still get to have children (and there's so many more children!).

There is a time delay (population continues to grow until the current children begin to die).

China, with its 1 child / family rule is still growing, and won't decrease in size until about 2030.