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1.1.3 Exploratory Quiz: Malthus' Three Principles

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Ethan mentioned the three principles Thomas Malthus proposed to understand the growth of populations. Let's take a closer look at these.

> 1. The power of population is indefinitely greater than the power in the earth to produce subsistence for man.
>
> 2. Population, when unchecked*, increases in a geometrical ratio.
>
> 3. Subsistence increases only in an arithmetical ratio.

*"*Unchecked*" here means not affected by events like plagues and natural disasters, or by fertility controls like contraception

Question 1

1/1 point (graded)

Consider the third principle: “Subsistence increases only in an arithmetical ratio." Subsistence is food, so Malthus was talking about food production.

When he said it increases ‘in an arithmetical ratio’, this means subsistence increases like an arithmetic sequence where the *difference* between terms is constant. For example, the arithmetic sequence 1, 4, 7, 10, 13, ... has a constant difference of terms, namely 3. In more familiar language Malthus was saying that food production has linear growth: Production increases at a constant rate.

For example, let W be the amount of food (in bushels) produced in a year and t time in years. Suppose the food production grows linearly and the rate of increase in food production (in bushels per year) is the positive constant k. Which is a plausible differential equation for how food production changes with time?

(Hint: What does $\frac{dW}{dt}$ represent?)

- $\frac{dW}{dt} = k$ ✔
- $\frac{dW}{dt} = kt$
- $\frac{dW}{dt} = kW$
- $\frac{dW}{dt} = Wt$

Explanation

$\frac{dW}{dt}$ is the rate of change of W with time t. We are assuming that the rate of increase of W with time is constant — that W has linear growth. If this constant growth rate is k, then $dW/dt = k$ captures the fact that the amount of wheat produced each year increases at this constant rate.

Note that $\frac{dW}{dt} = kt$ is not correct. This says that the rate of change of W is linear, which is not the same as saying that W is linear. In other words, $\frac{dW}{dt} = kt$ says that the change in W increases (or decreases, if $k < 0$) each year, while $\frac{dW}{dt} = k$ says that the change in W is the same year to year.

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Question 2

1/1 point (graded)

According to Malthus, population increases 'in a geometrical ratio'. This means population increases like a geometric sequence where the *ratio* between terms is constant.

For example, the geometric sequence 2, 4, 8, 16, 32, ... has a constant ratio between terms, also known as a *constant of proportionality*. In this case, that ratio is 2. Another way to say this is that the numbers double at each step.

This type of growth is an example of **exponential growth**, which is growth at a rate proportional to the current size. Let's assume the population grows at a rate proportional to its current size. Let P be the size of the population and t time in years. Suppose the constant of proportionality is r. Which could be a differential equation for how population changes over time?

NOTE: Remember that P is NOT a constant, but a function $P(t)$ that can change with time t. It is standard to write it as P, for example, $\frac{dP}{dt} = rP$ means $\frac{dP}{dt} = rP(t)$, where the right-hand side is the product of r and the function $P(t)$.

- $\frac{dP}{dt} = r$
- $\frac{dP}{dt} = rt$
- $\frac{dP}{dt} = rP$ ✔
- $\frac{dP}{dt} = tP$

$\frac{dP}{dt}$ is the rate of change of the population P with time t. We assume this rate is proportional to the population itself, where the constant of proportionality is r. This is captured by the equation $dP/dt = rP$. As P increases, so does dP/dt.

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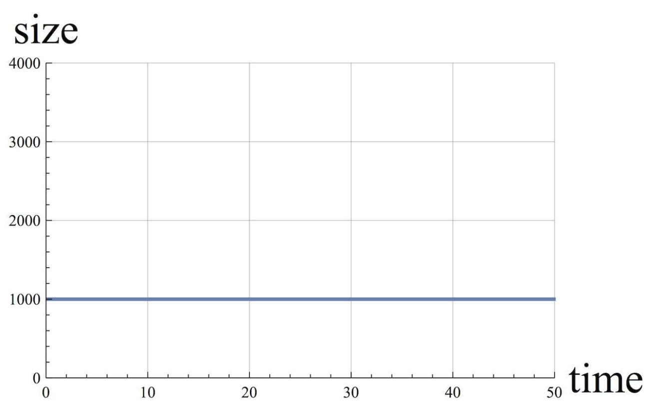
Question 3

2/2 points (graded)

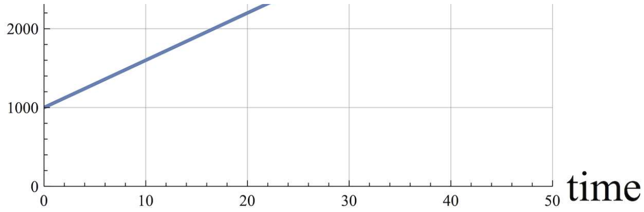
Malthus predicted that food production would increase arithmetically, that is, linearly. He also predicted the population would increase exponentially, doubling every 25 years.

Given this information, find the most appropriate graph to model the “size of the population” and the “size of food production”.

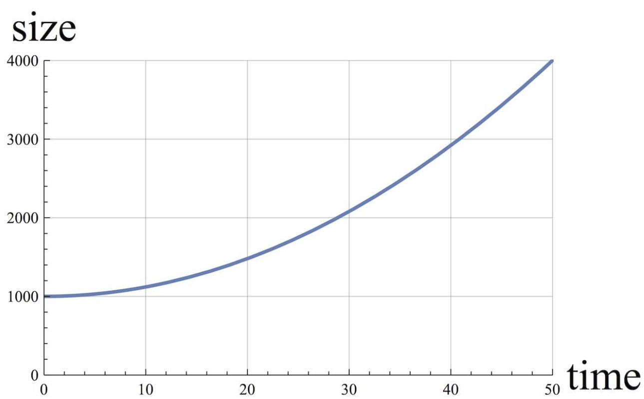
A.



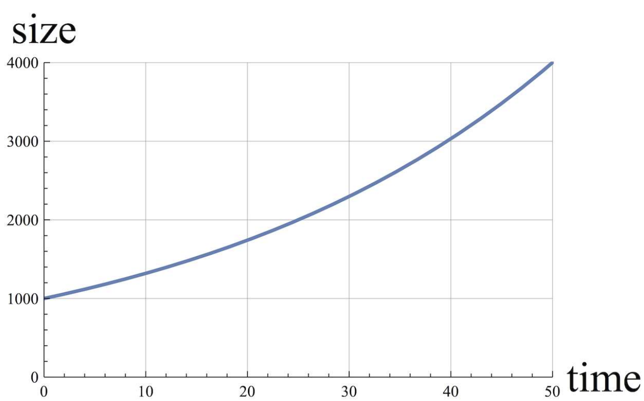
$\text{size}(t) = 1000$

B. 

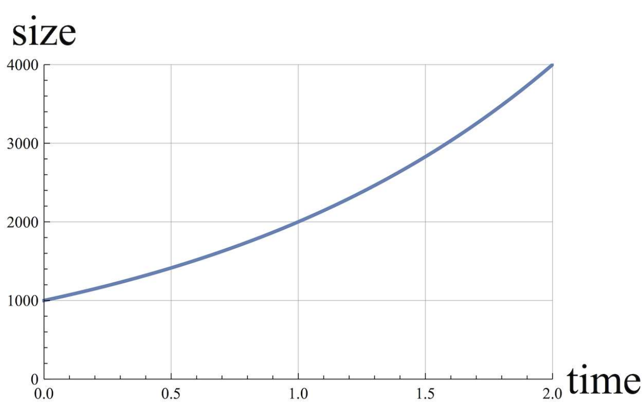
$$\text{size}(t) = 1000 + 1500\left(\frac{t}{25}\right)$$

C. 

$$\text{size}(t) = 1000 + 750\left(\frac{t}{25}\right)^2$$

D. 

$$\text{size}(t) = 1000 * 2^{(t/25)}$$

E. 

$$\text{size}(t) = 1000 * 2^t$$

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Size of Population:

Graph D ▼ ✔ **Answer:** Graph D

Size of Food Production:

Graph B ▼ ✔ **Answer:** Graph B

Explanation
According to Malthus' principles, population increases exponentially while food production increases linearly. Graph D shows an exponential function for which the size doubles every 25 years.
Graphs A and B show linear functions; Malthus assumed that food production would increase, so Graph B is the correct choice.

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Question 4: Think About It...

1/1 point (graded)
According to Malthus' principles, food production (subsistence) has a constant rate of change. In what ways do you think this is a reasonable model for food production? In what ways is this model not reasonable?

```
Reasonable since food growth does not always happen because
of reproduction.
```

✔
Thank you for your response.

Explanation
Malthus was writing in England at the end of the eighteenth century. In this context, it would have been difficult to increase food production by working more land; increases in food production must be due to increases in efficiency. Malthus thought that it was optimistic to hope for even arithmetic (constant) yearly increases in production due to efficiency.
Had Malthus lived in North America in 1798 he might instead have supposed that food production would increase geometrically along with the population, as more people can clear and work more land (which was readily available).
Reference: see pages 21-22. https://archive.org/details/essayonprincipl00malt An Essay on the Principle of Population As It Affects the Future Improvement of Society, with Remarks on the Speculations of Mr. Goodwin, Condorcet and Other Writers (1 ed.). London: J. Johnson in St Paul's Church-yard. 1798. Retrieved 12 May 201 via Internet Archive.

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Question 5: Think About It...

1/1 point (graded)
According to Malthus, population has a growth rate proportional to its size. In what ways do you think this is a reasonable model for population growth? In what ways is this growth model not reasonable?

```
Not reasonable for resource constraint.
```

Thank you for your response.

Explanation
It is reasonable to think that population grows proportionally to its current size if we think about reproduction: each new member of the population is the result of existing members mating. So the growth rate depends on the number of individuals mating, which should be proportional to the current size of the population. However, if we think about the broader environment in which a species lives, there may be limited resources to sustain the population, competition from other species, or other factors limiting growth.

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Question 6: Think About It...

1/1 point (graded)
Malthus' first principle was "The power of population is indefinitely greater than the power in the earth to produce subsistence for man." Is this consistent with the other two principles?

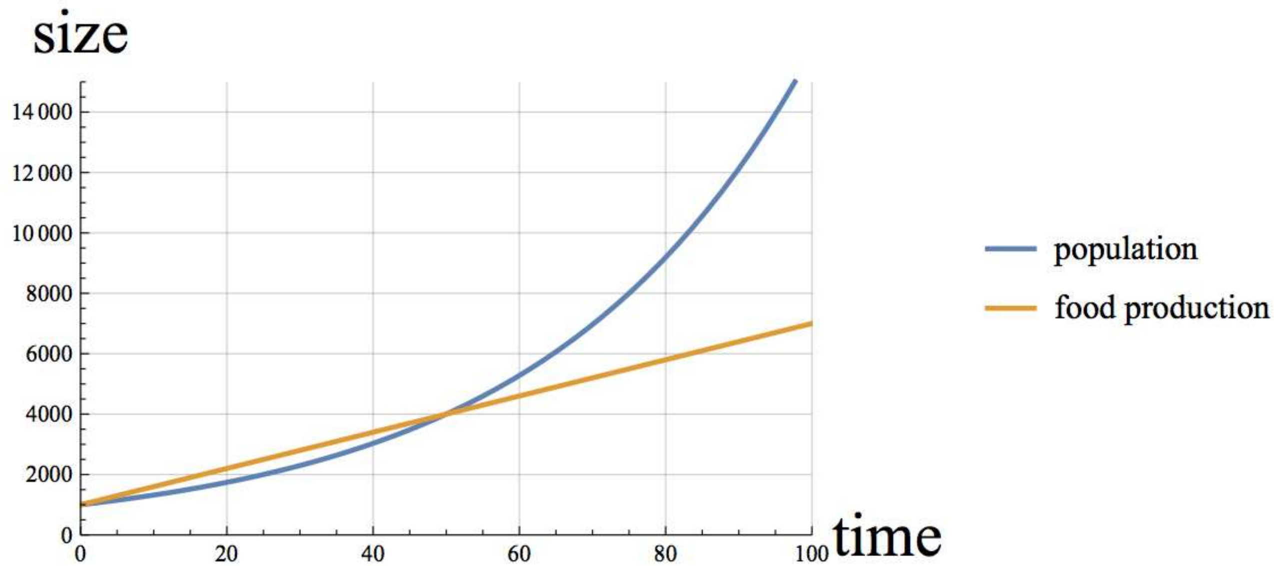
(Hint: According to Mathus' principles, how does a graph of food production over time compare to a graph of population over time? You explored these graphs in previous problems.)

```
Yes it is, since exponential function grows way faster than
linear function.
```

Thank you for your response.

Explanation

According to Malthus' principles, a graph of food production over time would be linear while a graph of population over time would be exponential. Any increasing exponential function is eventually larger than any linear function and the difference in the two functions increases with time, which is the idea behind Malthus' first principle.



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