•CHEMISTRY•
CHALLENGES AND SOLUTIONS

You will control a runner to earn the best possible time during a marathon (42.192 km). In this lab, the intensity of exercise **(Effort)** is measured on a scale of 0 to 10, with 0 being at rest and 10 corresponding to the maximum effort that your runner is capable of exerting. During training races, vary the level of intensity to improve performance. When you are ready to run, strategize during the race to set the level of effort that will achieve the best outcome.

Part 1: Experimentation and Goal Setting

1. Start the simulation. To get familiar with the simulation, run three races, writing your results below:

Race 1: Time _____ Distance _____   Outcome: Collapse _____ Stop _____ Finish _____
Race 2: Time _____ Distance _____   Outcome: Collapse _____ Stop _____ Finish _____
Race 3: Time _____ Distance _____   Outcome: Collapse _____ Stop _____ Finish _____

Now press "Reset" to clear the results and pick a new (or the same) avatar.

2. Choose an avatar and prepare a goal for the race.

There are four avatars, which have different running profiles. Elite athletes can complete a marathon in under three hours, with under four hours being considered good results. On the other hand, five to six hours is acceptable for moderately trained athletes. In this simulation, runners are stopped if they go over eight hours.

Write the name of the avatar you have chosen:

_____

Write your avatar's initial statistics:

OBLA: _____% of VO_2max

VO_2max: _____ mL/kg/min

What is their goal for completing the marathon? _____ hours _____ min

3. Run a test race with your chosen avatar. *You can control the runner's speed by clicking the arrows: Increase Effort or Decrease Effort. Note which factors change on the control panel when Effort goes up. Attempt to keep your runner's speed as high as possible, but avoid collapse caused by overexertion and/or reaching the critical limit on blood lactate. Record results:*

Run 1: Time _____ Distance _____ Outcome: Timed out _____ Finished _____

If your runner collapses, try again and record your best time without collapsing. If your runner cannot complete the race in less than the eight-hour time limit, don't be discouraged. Training will improve the total distance they can cover.

Part 2: Training and Testing

1. Initiate a training regime for your avatar. *Training is the same as a race, but with the goal of improving the runner's endurance and speed. In a training session, your avatar does not have to complete the full 42 km marathon. In training, your avatar will see improvements in Average Speed, and get closer to the goal you set in Part 1. After each training session, check the Results page to monitor Average Speed, OBLA, and VO$_2$max. Your avatar can enjoy Rest Days between each training session by pressing the "Rest Day" button. Now run three more training runs:*

Run 2: Avg. Effort _____   Avg. Speed _____m/min.   Distance covered _____

Run 3: Avg. Effort _____   Avg. Speed _____m/min.   Distance covered _____

Run 4: Avg. Effort _____   Avg. Speed _____m/min.   Distance covered _____

What is the maximum effort that your avatar can sustain without collapsing?   _____

Look at the results page. Do any parameters seem to be improving with exercise?

If so, which ones?

3. Look for improvements in VO$_2$max. *Try pushing your avatar as hard as you can without collapsing. (As you get close to collapse, Effort will go up by 0.5 but will bounce back down). Hint: If you don't see improvement, try adding more Rest Days between runs or pushing the avatar with a higher level of effort.*

Run 5: Avg. Effort _____   Avg. Speed _____m/min.   VO$_2$max _____

Run 6: Avg. Effort _____   Avg. Speed _____m/min.   VO$_2$max _____

Run 7: Avg. Effort _____   Avg. Speed _____m/min.   VO$_2$max _____

What is the relationship between VO$_2$max and speed and distance covered?

4. Explore the effect of slow and steady training vs. intermittent, high effort training. *The body reacts to stress by following Le Chatelier's Principle: a change in the state of equilibrium (i.e., periods of low oxygen in the muscles, or increased acidity) prompts changes in the body to return it to its original state. This can happen immediately (i.e. by increasing breathing to bring in more oxygen, or over time, by building more muscle fibers). Stressful exercise – like sprinting – can increase the rate at which the slow changes are implemented. Perform one training marathon with slow, steady effort and go to the Results page to look at the total Training Impulse. (Abbreviated TRIMP, Training Impulse is an arbitrary unit that is the product of the intensity of exercise by the amount of time it is carried out.)*

Run 8 - Slow, steady exercise:

Avg. Effort _____   Avg. Speed _____m/min.   W(T) Training Impulse (TRIMP)_____

Next, enter at least ten rest days. Perform another training marathon, but this time, alternate with bouts of intense effort that bring lactate close to the danger levels, but watch the warnings and pull back the effort to prevent collapse. Look on the Results page and record the total TRIMP:

Run 9: Alternating slow and fast

Avg. Effort_____   Avg. Speed _____m/min.   W(T) Training Impulse (TRIMP)_____

5. Run a timed race and complete the marathon. Now that your avatar has been trained, you can try to maximize his or her performance. Record results below:

     OBLA: _____% of VO$_2$max   Race: Time _____hr _____min

     VO$_2$max: _____mL/kg/min   Distance: 42.195km

How does this compare to the goal you set for the avatar in Step 2?

_____

If you did not reach your goal, how much improvement did you see?

_____

_____

How do current OBLA and VO$_2$max compare to pre-training values?

_____

_____

Part 3: Applying Kinetics Calculations to Running

In this section, you will calculate how many kilocalories your runner burned during the marathon. Oxygen consumption is the measure that is directly related to kilocalories burned during a race.

1. Look up how many liters of oxygen were consumed in the race.

Before you look up the answer, make a guess how many liters of oxygen your avatar might have consumed during a 42 km. marathon and write the answer below:

Estimate of how many liters of oxygen were used in the race: _____ (liters)

Now go to the current race on the **Results** page, and click **View Details**. Each line is one minute of the race. Identify the column **VO$_2$Total** (accumulated oxygen used) on the last line and write the amount below:

Actual results for liters of oxygen were used in the race: _____ (liters)

Was this less, more, or about what you expected?

_____

2. Convert liters of oxygen to moles.

According to the Ideal Gas Law, each liter of O$_2$ contains n moles of molecules where n = (P*V)/(R*T) Calculate how many moles of O$_2$ your avatar consumed during the race, where P = 1 atm, V = liters of oxygen consumed, R (the gas constant) = 0.08206, and T = 293 K (20°C).

Moles of O$_2$ consumed   _____

3. Convert moles of oxygen to kilocalories.

Each mole of O_2 combines with a mix of carbohydrates, fats, and proteins to release the energy needed during the race. While the ratio may vary, a good approximation is 117 kcal per mole of O_2. Use this average to calculate the number of kilocalories used during the race.

Kilocalories used during the race _____

4. Convert a runner's kilocalories consumed to a race to an automobile equivalent.

Given that 1 gallon (3.9 l) of gasoline contains about 31,000 kilocalories, and that some cars today might use one gallon to go 26 miles (42 km, the length of a marathon), how many runners would have to ride inside the car before the car could be as energy efficient as running?

_____

_____

5. Reflect on learning.

Please answer the questions below to summarize the results of this simulation:

Were you able to have your avatar reach his or her time goal for running the full marathon? Why or why not?

_____

_____

What factors in the simulation seemed to have the most effect on improving your avatar's performance during training?

_____

_____

Were there any factors that seemed to hurt your runner's performance in training?

_____

_____

Simulations like this are based on mathematical models, which are accurate for some aspects of the system under study, but are limited in the number of factors that can be realistically simulated when the system is as complex as a human runner. What factors seemed realistic to you about this simulation?

_____

_____

What factors did <u>not</u> seem realistic, compared to your or your friends' actual running experience?

_____

_____

6. Print out the main Results page and attach them to this page.