



Natural Selection Engineering Internship: Fighting Drug-Resistant Malaria

**Engineering Notebook
with Article Compilation**



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Natural Selection Engineering Internship: Fighting Drug-Resistant Malaria

Engineering Notebook

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Name: _____ Date: _____

Natural Selection Engineering Internship: Fighting Drug-Resistant Malaria Unit Overview

Which medications are best for treating malaria? Which combinations of antimalarial drugs will keep the malaria parasite population from developing resistance to specific drugs?

That's what you will figure out as you and your classmates take on the role of biomedical engineering interns with Futura Engineering, a company that specializes in designing solutions for the world's problems. As an intern, you'll be helping doctors work to fight malaria by designing a set of drugs used as a treatment for patients with malaria. Using a digital tool called MalariaMed, you will test how different combinations of drugs affect the distribution of traits in a population of malaria parasites. You'll need to bring your knowledge of how natural selection can cause some adaptive traits, such as a trait for drug resistance, to become more common in a population. You will learn about different types of antimalarial drugs, what it means for a population to be drug resistant, and what criteria you must consider in order to create an optimal malaria treatment. The goal is to use your scientific understanding and engineering in order to reduce the problem of drug resistance in malaria parasites, since less drug resistance in that population means available drugs can be used to treat malaria for years to come.

Name: _____ Date: _____

Safety Guidelines

Workplace safety is always a concern, especially in the labs here at Futura. Please review and follow these safety guidelines. If you have any questions, ask your internship coordinator for assistance.

1. **Follow instructions and listen carefully.** If you don't know what to do, ask your internship coordinator.
2. **Don't taste things.** No tasting anything or putting it near your mouth unless your internship coordinator says it is safe.
3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.
4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.
5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.
6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.
7. **Tell your internship coordinator if you have allergies.** We want you to be safe and comfortable at work.
8. **Be calm and careful.** Move carefully and slowly around the office and labs.
9. **Report all spills, accidents, and injuries to your internship coordinator.**
10. **Avoid anything that could cause a burn.** Ask your internship coordinator for help with hot water or hot equipment.
11. **Wash your hands with soap and water at the end of the workday, especially if you've handled plants, animals, or chemicals.**

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Safety Agreement

By writing my name below, I agree to follow the rules outlined in the Safety Guidelines while working at Futura.

Name: _____ Date: _____

Day 1: Welcome to Futura!

Hello interns,

Welcome to your new engineering internship! I'm Ken Tapaha, your project director.

You'll be working with me to design treatments that help people infected with a disease called malaria. There are three criteria to consider when designing malaria treatments. We want to:

1. minimize the percentage of the malaria population with high drug resistance;
2. minimize patient side effects; and
3. keep costs low.

We want to accomplish all of this, while still making sure the malaria parasite population doesn't increase. In this project, you will apply what you know about natural selection and mutations to figure out ways to stop these tiny malaria parasites. You will also learn more about ways to make sure malaria treatments will be able to help sick people now and in the future.

Today you'll learn more about malaria by using the Futura Biomedical Engineer's Dossier and the MalariaMed Design Tool. Note: *Dossier* (DAW-see-ay) is a term professional engineers sometimes use for a set of related documents.

Deliverables

- Annotations for Chapter 2: "Basic Facts About Malaria"
- After-Hours: Read and annotate Chapter 1: "Request for Proposals"

I am looking forward to working with you,

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Name: _____ Date: _____

After-Hours Work

Return to Message 1 on page 3 from Ken Tapaha and be sure you've completed all internship tasks for the day.

1. Read and annotate Chapter 1 in the Dossier: "Request for Proposals" (RFP).

- Answer the reflection question below when you are done reading the RFP.

How well did this reading help you understand your internship project?

The reading was . . . (check one)

☐ very helpful

☐ somewhat helpful

☐ not helpful

☐ confusing

2. Your internship coordinator may have asked you to complete additional tasks.

- If you are required to read the Safety Guidelines and read and complete the Safety Agreement form, find those on page 2 of your Engineering Notebook.
- Double-check the Daily Message to see if there are other deliverables that need to be completed after hours.

Name: _____ Date: _____

Day 2: Selection Pressure

Hi interns,

Today you will continue research on malaria and drug resistance. You'll read in the Dossier and then do an activity to help you see how a selection pressure affects a population of parasites. After hours, please reread Chapters 2–3 of the Dossier and add to or revise your annotations. I always have to read things many times in order to understand all the information!

Understanding that mutations in a population can lead to a change in the distribution of traits will help you in your drug treatment designs. In our study of malaria, the drugs act as a selection pressure and can change the distribution of traits in the population of malaria parasites, resulting in more parasites that will not die when treated with the drugs.

Deliverables

- Read and annotate Chapter 3: “Antimalarial Drugs as Selection Pressure”
- Modeling Population Shifts sheet
- After-Hours: Reread and revise annotations in Chapter 2: “Basic Facts About Malaria” and Chapter 3: “Antimalarial Drugs as Selection Pressure”

Best,

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

[illegible]

What do you notice?

Name: _____ Date: _____

After-Hours Work

Return to Message 2 on page 5 from Ken Tapaha and be sure you've completed all internship tasks for the day.

- Reread Chapter 2: "Basic Facts About Malaria" and Chapter 3: "Antimalarial Drugs as Selection Pressure" in the Dossier.
- Add to or revise your annotations using this focus question:
How do antimalarial drugs work as a selection pressure on malaria parasite populations?
- Your internship coordinator may have asked you to complete additional tasks. Double-check the Daily Message and Daily Message Notes to see if there are other deliverables that need to be completed after hours.

Name: _____ Date: _____

Day 3: Causes of Drug Resistance

Hello interns,

Today, you will read about how drug resistance can develop in malaria parasite populations in Chapter 4: “Antimalarial Drug Resistance” of the Dossier. You’ll then use MalariaMed to see how a single-drug treatment affects the amount of the malaria parasite population that has traits for resistance to that drug. Understanding how each drug affects the population is a big deal in fighting malaria!

You’ve already considered how natural selection and mutations can play a role in changing the distribution of traits in a population. To better understand this, you should first focus on applying malaria treatments that use only one drug to see how single-drug treatments affect drug resistance. You will use this information when designing effective malaria treatments in the future.

Deliverables

- Read and annotate Chapter 4: “Antimalarial Drug Resistance”
- Analyzing Single-Drug Treatments sheet
- After-Hours: Reread and revise annotations in Chapter 4: “Antimalarial Drug Resistance”

Focus on the tasks at hand!

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

Analyzing Single-Drug Treatments

Drug A

 BUILD Design Details	 TEST Test Results										
Malaria Treatment: 7 days of Drug A at SMALL doses	<table><tr><td>Percentage of Parasite Population with High Resistance</td><td>Total Parasite Population</td><td>Total Cost for 1000 Treatments (\$)</td><td>Patient Side Effects</td></tr><tr><td> A </td><td> B </td><td> C </td><td> ☐ Decrease ☐ No change ☐ Increase ☐ Large Increase </td><td> </td><td> ☐ None ☐ Mild ☐ Moderate ☐ Severe </td></tr></table>	Percentage of Parasite Population with High Resistance	Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects	A	B	C	☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe
Percentage of Parasite Population with High Resistance	Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects								
A	B	C	☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe						

OBSERVATIONS:

Drug B

 BUILD Design Details	 TEST Test Results										
Malaria Treatment: 7 days of Drug B at SMALL doses	<table><tr><td>Percentage of Parasite Population with High Resistance</td><td>Total Parasite Population</td><td>Total Cost for 1000 Treatments (\$)</td><td>Patient Side Effects</td></tr><tr><td> A </td><td> B </td><td> C </td><td> ☐ Decrease ☐ No change ☐ Increase ☐ Large Increase </td><td> </td><td> ☐ None ☐ Mild ☐ Moderate ☐ Severe </td></tr></table>	Percentage of Parasite Population with High Resistance	Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects	A	B	C	☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe
Percentage of Parasite Population with High Resistance	Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects								
A	B	C	☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe						

OBSERVATIONS:

Drug C

 BUILD Design Details	 TEST Test Results										
Malaria Treatment: 7 days of Drug C at SMALL doses	<table><tr><td>Percentage of Parasite Population with High Resistance</td><td>Total Parasite Population</td><td>Total Cost for 1000 Treatments (\$)</td><td>Patient Side Effects</td></tr><tr><td> A </td><td> B </td><td> C </td><td> ☐ Decrease ☐ No change ☐ Increase ☐ Large Increase </td><td> </td><td> ☐ None ☐ Mild ☐ Moderate ☐ Severe </td></tr></table>	Percentage of Parasite Population with High Resistance	Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects	A	B	C	☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe
Percentage of Parasite Population with High Resistance	Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects								
A	B	C	☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe						

OBSERVATIONS:

Name: _____ Date: _____

Pros and Cons of Antimalarial Drugs

1. List the pros and cons of each drug, based on the test results for each single-drug treatment.
2. Later, while reading Chapter 5: “Designing Antimalarial Drugs” in the Dossier, add additional pros and cons for each drug type.

	Pros	Cons
DRUG A		
DRUG B		
DRUG C		

Name: _____ Date: _____

After-Hours Work

Return to Message 3 on page 8 from Ken Tapaha and be sure you've completed all internship tasks for the day.

- Reread Chapter 4: "Antimalarial Drug Resistance" in the Dossier.
- Add to or revise your annotations using this focus question:
How do malaria treatments influence drug resistance?
- Your internship coordinator may have asked you to complete additional tasks. Double-check the Daily Message and Daily Message Notes to see if there are other deliverables that need to be completed after hours.

Name: _____ Date: _____

Day 4: Drugs to Treat Malaria

Hello interns,

Today, you will complete your research by continuing to run isolated tests in MalariaMed to understand how drugs affect the traits for resistance in the malaria parasite population. First, you will read the final section of the Dossier, which has more information about the different drugs in our model. Then you'll run more tests to see how the other variables, or things you can change, can affect the results. For after-hours work, I want you to submit a Project Summary so I can see what you understand about the project so far.

You may not have realized you have run isolated tests. The Analyzing Single-Drug Treatments sheet was an isolated test because we only changed which drug was used—everything else in the tests stayed the same. You'll continue this important technique to complete your research about the drugs available to treat malaria.

Deliverables

- Read and annotate Chapter 5: “Designing Antimalarial Drugs”
- Understanding MalariaMed Variables sheet
- After-Hours: Project Summary

Record data carefully!

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

Understanding MalariaMed Variables

1. How does dose size affect a single-drug treatment?
2. How do the number of days affect a single-drug treatment?

BUILD Design Details		TEST Test Results					
Drug		Percentage of Parasite Population with High Resistance			Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects
Number of days					☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe
Dose size		A	B	C			

OBSERVATIONS:

BUILD Design Details		TEST Test Results					
Drug		Percentage of Parasite Population with High Resistance			Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects
Number of days					☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe
Dose size		A	B	C			

OBSERVATIONS:

BUILD Design Details		TEST Test Results					
Drug		Percentage of Parasite Population with High Resistance			Total Parasite Population	Total Cost for 1000 Treatments (\$)	Patient Side Effects
Number of days					☐ Decrease ☐ No change ☐ Increase ☐ Large Increase		☐ None ☐ Mild ☐ Moderate ☐ Severe
Dose size		A	B	C			

OBSERVATIONS:

Name: _____ Date: _____

Understanding MalariaMed Variables (continued)

CONCLUSIONS

	How do the number of days affect...	How does the dose size affect...
Total Parasite Population		
Drug Resistance		
Patient Side Effects		
Total Cost		

Name: _____ Date: _____

After-Hours Work

Return to Message 4 on page 12 from Ken Tapaha and be sure you've completed all internship tasks for the day.

- Complete the Project Summary form on the next page. If needed, refer back to the Request for Proposals (RFP) in the Dossier to review the project details.
- Your internship coordinator may have asked you to complete additional tasks. Double-check the Daily Message and Daily Message Notes to see if there are other deliverables that need to be completed after hours.

Name: _____ Date: _____

Project Summary

Defining the Problem: Summarize your understanding of the project by answering the following questions. You may wish to review the Dossier to help you respond.

1. What is the engineering problem you are trying to solve?

2. Describe the first criterion—minimize drug resistance—and why it is important.

3. Describe the second criterion—minimize patient side effects—and why it is important.

4. Describe the third criterion—keep costs low—and why it is important.

5. Based on your research so far, which criterion do you think is most important for a successful malaria treatment? Why?

6. Based on your research, describe a strategy you will use when designing a malaria treatment.

Name: _____ Date: _____

Day 5: Designing Malaria Treatments

Hi interns,

Today you will begin the Design phase of The Design Cycle. Think about what you've learned during the Research phase in order to plan some treatments to fight malaria. Then use MalariaMed to build a treatment and test how effective it is. Before you leave today, your team should send me the results of one design using the form called MalariaMed Design.

For each malaria treatment version you test, you will analyze the results to see how you can improve your next test. When engineers test designs, they use the results to help plan the next design. I will also be sending you feedback about how your design addresses the project criteria, which will help you in further improving your design.

Deliverables

- Several designs recorded on MalariaMed Data sheet
- MalariaMed Design
- After Hours: Read and annotate the “Meet an Engineer Who Prints in 3-D with Living Material” article and answer the questions

Best,

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

MalariaMed Design

Record your best design here. Then you will submit your best design in the MalariaMed Design form in the Futura Workspace in order to receive feedback from the project director. Note: Only one partner needs to submit a form for feedback.

1. List the design details of your design.

Version: _____

Day 1	☐ Drug A Large	☐ Drug B Large	☐ Drug C Large
	☐ Drug A Small	☐ Drug B Small	☐ Drug C Small
Day 2	☐ Drug A Large	☐ Drug B Large	☐ Drug C Large
	☐ Drug A Small	☐ Drug B Small	☐ Drug C Small
Day 3	☐ Drug A Large	☐ Drug B Large	☐ Drug C Large
	☐ Drug A Small	☐ Drug B Small	☐ Drug C Small
Day 4	☐ Drug A Large	☐ Drug B Large	☐ Drug C Large
	☐ Drug A Small	☐ Drug B Small	☐ Drug C Small
Day 5	☐ Drug A Large	☐ Drug B Large	☐ Drug C Large
	☐ Drug A Small	☐ Drug B Small	☐ Drug C Small
Day 6	☐ Drug A Large	☐ Drug B Large	☐ Drug C Large
	☐ Drug A Small	☐ Drug B Small	☐ Drug C Small
Day 7	☐ Drug A Large	☐ Drug B Large	☐ Drug C Large
	☐ Drug A Small	☐ Drug B Small	☐ Drug C Small

2. Percentage of Parasite Population with High Resistance to Drug A (%): _____

3. Percentage of Parasite Population with High Resistance to Drug B (%): _____

4. Percentage of Parasite Population with High Resistance to Drug C (%): _____

5. Of the three percentage values, which is the largest value? _____

Name: _____ Date: _____

MalariaMed Design (continued)

6. After 10 years of this treatment, the total parasite population showed: (check one)

- ☐ a decrease
- ☐ no change
- ☐ an increase
- ☐ a large increase

7. Patient Side Effects (check one)

- ☐ none
- ☐ mild
- ☐ moderate
- ☐ severe

8. Total Cost for 1000 Treatments: _____

Name: _____ Date: _____

After-Hours Work

Return to Message 5 on page 17 from Ken Tapaha and be sure you've completed all internship tasks for the day.

- Read and annotate the "Meet an Engineer Who Prints in 3-D With Living Material" article.
- Answer the questions below.
- Your internship coordinator may have asked you to complete additional tasks. Double-check the Daily Message and Daily Message Notes to see if there are other deliverables that need to be completed after hours.

1. Why is Maya Lim excited about classroom bioprinters?

2. What parts of Maya Lim's job as a chemical engineer sound interesting to you?

Name: _____ Date: _____

Day 6: Optimal Designs

Hello interns,

Today, you'll review my feedback on the malaria treatment design your team submitted. Open the Design feedback letter in your inbox and skim it now. Your internship coordinator will assist you in understanding my feedback so you can work on optimal malaria treatments. After hours, you'll write a trade-offs reflection.

You might have noticed that each version you've designed has trade-offs—a design can be strong for one criterion, and weak for another. To design an optimal solution to a problem, engineers share results, discuss feedback, and consider trade-offs in order to improve their designs.

Deliverables

- Design Feedback Summary
- Several additional designs recorded on MalariaMed Data Sheet
- After-hours: Trade-Offs Reflection

Keep up the good work!

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

Design Feedback Summary

CRITERIA			
	Minimize Drug Resistance	Minimize Patient Side Effects	Keep Costs Low
Submitted Version # _____: Test results	Drug A: Drug B: Drug C:		
Feedback from project director			
Goal			
Redesign strategy			

Name: _____ Date: _____

After-Hours Work

Return to Message 6 on page 21 from Ken Tapaha and be sure you've completed all internship tasks for the day.

- Complete the Trade-Offs Reflection form on the next page.
- Your internship coordinator may have asked you to complete additional tasks. Double-check the Daily Message and Daily Message Notes to see if there are other deliverables that need to be completed after hours.

Name: _____ Date: _____

Trade-Offs Reflection

A *trade-off* happens in a situation where a design has good results for one criterion but not for another. Look at your optimal malaria treatment. Describe some of the trade-offs you noticed while designing your treatment.

1. Which criterion did you prioritize? (check one)

- ☐ minimize drug resistance
- ☐ minimize patient side effects
- ☐ keep costs low

2. Why did you prioritize this criterion?

3. When you prioritized this criterion, what were some of the trade-offs? Describe what happened to the results of the other two criteria.

Name: _____ Date: _____

Day 7: Outlining Design Decisions

Hello interns,

By now, you should have picked the design that you believe is optimal. Now it's time to explain why! Today, you'll start working on your proposal. I want to know why you made each decision for this design, so you'll begin by outlining an important section of your proposal, the Design Decisions. You might also want to refer to the Dossier for information and resources to help you outline.

Engineering proposals explain how a design addresses the project criteria. Strong evidence will improve your argument, and make your design more likely to be considered by Global Health Organization. The outline you prepare today will help you organize the evidence you have that supports the argument that your selected design is an *optimal* design.

Deliverables

- Proposal Outline

Cheers,

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

Proposal Outline

Optimal Design

List the design details of your proposed optimal design.

Version #: _____

Day	1	2	3	4	5	6	7
Drug							
Dose							

Design Decisions

For each criterion, list the pieces of evidence from your data analysis and background research that support your optimal design.

Minimize Drug Resistance

DATA ANALYSIS

Final results (%):

Design goal (%):

Drug A

Drug B

Drug C

Comparison to another design:

BACKGROUND RESEARCH

Think about how your design choices affect the percentage of the parasite population with high resistance to each drug. How did dose size, number of days, or the combination of drugs used in the treatment affect drug resistance?

Name: _____ Date: _____

Proposal Outline (continued)

Minimize Patient Side Effects

DATA ANALYSIS

Final result:

Design goal:

Comparison to another design:

BACKGROUND RESEARCH

Think about how your design choices affected the patient side effects. How did dose size, number of days, or the combination of drugs used in the treatment affect patient side effects?

Keep Costs Low

DATA ANALYSIS

Final result (\$):

Design goal (\$):

Comparison to another design:

BACKGROUND RESEARCH

Think about how your design choices affected the total cost for 1000 treatments. How did dose size, number of days, or the combination of drugs used in the treatment affect the cost?

Name: _____ Date: _____

Day 8: Writing Design Decisions

Hello interns,

Today you'll review my feedback on your Proposal Outlines. Take a look at the feedback letter after you finish your Daily Message Notes. You will discuss my feedback with your colleagues in order to help you write a strong argument that explains why your design is an optimal one. You might also want to refer to the Dossier for information and resources to help you write.

Writing your argument can be difficult, but helping people understand your decisions is an important part of being an engineer. You know more about the science behind your design than most of the people who will be reading your proposal, so your writing should be clear and professional. Writing clear arguments that explain your thinking is an essential part of scientific communication.

Deliverables

- Design Decision paragraphs of the Final Proposal

Cheers,

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

Proposal Feedback Notes

Use this page to take notes on your feedback letter.

[illegible]

Name: _____ Date: _____

Tips: Help with Your Proposal

Interns,

If you need some help getting started with your paragraphs, here are some ideas to choose from.

Design Decisions Paragraphs

About specific criteria:

- For our proposed design, the percentage of the malaria population with high resistance was . . .
- We were able to keep the patient side effects to . . .
- We were able to minimize side effects by . . .
- The treatment cost per 1000 treatments was . . .
- Using the Futura MalariaMed Design Tool, we picked a design that . . .

When talking about your goals:

- Our goal was . . .
- Based on design feedback, we chose to set a goal to . . .

For comparing designs:

- In another design, we got _____ but . . .

For talking about background research:

- Background research told us that . . .

Introduction

- This malaria treatment used _____ (list drug type, doses, and number of days).
- The results showed the largest percentage of malaria parasites with high resistance to Drug _____ at _____%.
- The side effects were _____, and the cost was _____ per 1000 treatments.

Conclusion

- We think this is an optimal design because . . .
- Because we focused on the criterion/criteria of _____, our design . . .
- Our priority was the criterion _____ because . . .
- Our malaria treatment design is the optimal choice because . . .
- Our malaria treatment will meet the needs of Global Health Organization because . . .
- Even though our design does not _____, we think it is optimal because . . .
- This malaria treatment will _____ (write something about one criterion here) well because . . .

Name: _____ Date: _____

Final Proposal

When writing your Final Proposal, remember to write in a clear and professional manner. Refer to these resources:

- The Proposal Rubric and Sample Proposal
- MalariaMed Data
- Biomedical Engineer's Dossier
- Notes on Proposal Outline feedback from your project director

Introduction

Use your responses from the Project Summary to describe the project goal and criteria. Add one to two sentences to describe your optimal design.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins or other markings on the paper.

Name: _____ Date: _____

Final Proposal (continued)

Design Decisions

Use your Proposal Outline and feedback from your project director to explain how your design addresses each criterion.

Minimize Drug Resistance

Minimize Patient Side Effects

Name: _____ Date: _____

Final Proposal (continued)

Keep Costs Low

[illegible]

Name: _____ Date: _____

Final Proposal (continued)

Conclusion: Considering Trade-Offs

Use your responses from the Trade-Offs Reflection on page 24 to describe your design priority and the resulting trade-offs. Add your closing statement.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Name: _____ Date: _____

Day 9: Finishing Your Proposal

Hello interns,

Today is all about the beginning and the end of your proposal. Your internship coordinator will help you take the work you have already done—in the Project Summary and Trade-Offs Reflection—and turn it into your Introduction and Conclusion paragraphs. You might also want to refer to the Dossier for information and resources to help you write.

These two paragraphs are the final parts of your proposal. The introduction shows the reader what you know about the project, while the conclusion shows that you’ve thought deeply about the trade-offs involved. Remember to use scientific and professional language to communicate your ideas.

Deliverables

- Final Proposal

Good luck,

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

Day 10: Thanks, Interns!

Hello interns,

Today marks the end of your internship with the Biomedical Engineering Division. There is one last task that I have for you: an Internship Exit Survey. Go ahead and begin it as soon as you've read the rest of this message.

It has been a pleasure working with you. I'm impressed by the malaria treatments you produced. I hope you'll be able to take some of what you learned here and apply it to your life and your studies. I've found that my life is filled with trying to find the optimal path, almost always by choosing a priority and considering trade-offs!

Deliverables

- Internship Exit Survey

Good luck in the future!

Ken

Ken Tapaha, Project Director
Futura | Biomedical Engineering Division

Daily Message Notes

Name: _____ Date: _____

Internship Exit Survey

Futura would like to improve the internship experience for future interns. Please complete this survey to give us feedback.

1. How comfortable would you feel explaining to a new intern how a student's job is different from an intern's job? (check one)

- ☐ Very uncomfortable. I don't understand this.
- ☐ Uncomfortable. I'm not sure I understand this.
- ☐ Pretty comfortable. I think I understand this.
- ☐ Very comfortable. I totally understand this.

2. How comfortable would you feel explaining to a new intern what criteria are and how they are related to designing something? (check one)

- ☐ Very uncomfortable. I don't understand this.
- ☐ Uncomfortable. I'm not sure I understand this.
- ☐ Pretty comfortable. I think I understand this.
- ☐ Very comfortable. I totally understand this.

3. How comfortable would you feel explaining to a new intern what a trade-off is and how a trade-off affects engineering designs? (check one)

- ☐ Very uncomfortable. I don't understand this.
- ☐ Uncomfortable. I'm not sure I understand this.
- ☐ Pretty comfortable. I think I understand this.
- ☐ Very comfortable. I totally understand this.

Name: _____ Date: _____

Internship Exit Survey (continued)

4. How comfortable would you feel explaining to a new intern *why* it is important to choose an optimal design and *how* to choose an optimal design? (check one)

- ☐ Very uncomfortable. I don't understand this.
- ☐ Uncomfortable. I'm not sure I understand this.
- ☐ Pretty comfortable. I think I understand this.
- ☐ Very comfortable. I totally understand this.

5. Imagine you are giving advice to a new Futura Engineering intern. What would you tell them about the engineering design process?

6. Imagine you are giving advice to a new Futura Engineering intern. What was hard or challenging?

7. Imagine you are giving advice to a new Futura Engineering intern. What tips would you suggest for a successful internship?

Natural Selection Engineering Internship Glossary

adaptive trait: a trait that makes it more likely that an individual will survive in a specific environment

rasgo adaptativo: un rasgo que hace más probable que un individuo sobreviva en un ambiente específico

analyze: to examine in detail for a purpose

analizar: examinar en detalle y con un propósito

antimalarial: a drug or medicine that kills the parasites that cause malaria

antimalárica: una droga o medicina que mata los parásitos que causan la malaria

argument: a claim supported by evidence

argumento: una afirmación respaldada por evidencia

biomedical engineer: an engineer who applies concepts from biology and medicine to improve human health and save lives

ingeniero/a biomédico/a: un/a ingeniero/a que aplica conceptos de la biología y la medicina para mejorar la salud humana y salvar vidas

CEO: C.E.O. stands for “Chief Executive Officer,” the leader of an organization, group, or company

CEO: C.E.O. son las siglas en inglés para “Oficial Ejecutivo en Jefe”, es decir, el director de una organización, grupo o compañía

constraint: a limit or restriction

restricción: un límite o condicionamiento

criteria: standards by which something may be judged

criterios: normas por medio de las cuales se puede juzgar algo

deliverable: a thing to be delivered, usually in a development or design process

entregable: una cosa que debe entregarse, usualmente durante un proceso de desarrollo o diseño

distribution: the number of individuals with each trait in a population

distribución: el número de individuos que tienen cada rasgo en una población

dose: the amount of a drug or medicine given in a treatment

dosis: la cantidad de una droga o medicina que se da en un tratamiento

dossier: a set of related documents about a particular topic

expediente: un conjunto de documentos relacionados sobre un tema particular

engineer: a person who uses math and science to design things

ingeniero/a: una persona que utiliza las matemáticas y la ciencia para diseñar cosas

environment: everything (living and nonliving) that surrounds an organism

ambiente: todo (viviente y no viviente) lo que rodea a un organismo

Natural Selection Engineering Internship Glossary (continued)

evidence: information about the natural world that is used to support or go against (refute) a claim

evidencia: información sobre el mundo natural que se utiliza para respaldar o rechazar (refutar) una afirmación

gene: an instruction for making a protein molecule

gen: una instrucción para formar una molécula de proteína

histogram: a graph that uses bars to show how characteristics or values are distributed within a group

histograma: una gráfica que usa barras para mostrar cómo se distribuyen las características o los valores dentro de un grupo

host: an organism that a parasite lives on or in

huésped: un organismo en el cual o dentro del cual vive un parásito

interns: beginners at a workplace who do work that is closely supervised because they are learning on the job

becarios: principiantes que hacen un trabajo estrechamente supervisado porque están aprendiendo durante el mismo

internship coordinator: the person who supervises interns during a project

coordinador/a de becarios: la persona que supervisa becarios durante un proyecto

isolate: to separate or set apart

aislar: separar o apartar

iterative testing: repeating a process in a way that considers the results of a previous design

pruebas iterativas: la repetición de un proceso de manera que se consideren los resultados de un diseño anterior

malaria: a serious disease caused by parasites spread to humans by mosquitoes

malaria: una enfermedad seria causada por parásitos que los mosquitos transmiten a los humanos

mild: not serious

leve: no serio

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

Natural Selection Engineering Internship Glossary (continued)

moderate: somewhat bad or serious

moderado: relativamente malo o serio

mutation: a random change to a gene that sometimes results in a new trait

mutación: un cambio aleatorio a un gen que a veces da como resultado un rasgo nuevo

natural selection: the process by which the distribution of traits in a population changes over many generations

selección natural: el proceso por medio del cual cambia la distribución de rasgos en una población con el paso de muchas generaciones

non-adaptive trait: a trait that makes it less likely that an individual will survive in a specific environment

rasgo no adaptativo: un rasgo que hace menos probable que un individuo sobreviva en un ambiente específico

offspring: an organism produced as a result of reproduction

descendencia: un organismo producido como resultado de la reproducción

optimal: most successful, considering the situation

óptimo: más exitoso, considerando la situación

organ: a part of an organism that performs a specific function

órgano: una parte de un organismo que desempeña una función específica

organisms: living things, such as plants, animals, and bacteria

organismos: seres vivos, como plantas, animales y bacterias

parasite: an organism that lives in or on another organism and causes it harm

parásito: un organismo que vive dentro o sobre otro organismo y le causa daño

Plasmodium: the scientific name for the group of parasites that cause malaria

Plasmodium: el nombre científico del grupo de parásitos que causan la malaria

population: a group of the same type of organism living in the same area

población: un grupo del mismo tipo de organismo que vive en la misma área

project director: the person who is responsible for making sure a project's goals are addressed

director/a de proyecto: la persona responsable de asegurarse de que se cumplan las metas de un proyecto

Natural Selection Engineering Internship Glossary (continued)

proposal: a formal design that is supported by evidence, and submitted for discussion and review

propuesta: un diseño formal respaldado por evidencia y presentado para discusión y revisión

request for proposals: a document asking engineers to submit a well-supported, formal design describing how they would solve a problem

solicitud de propuestas: un documento para pedir a los/as ingenieros/as que presenten un diseño formal, bien sustentado, que describa cómo resolverían un problema

resistance: the quality of preventing or fighting against something

resistencia: la cualidad de prevenir o luchar contra algo

selection pressure: something in the environment that affects an individual's chances of surviving

presión de selección: algo en el ambiente que afecta las posibilidades de sobrevivir de un individuo

severe: very bad or serious

severo: muy malo o serio

shift: to move to one side or the other

desplazar: mover hacia un lado o el otro

side effects: unwanted effects of a drug or medical treatment

efectos secundarios: efectos indeseados de una droga o tratamiento médico

trade-off: when you have to give up one thing in return for another

concesión: una situación en la que se debe renunciar a algo para obtener otra cosa a cambio

vaccine: a substance that helps your body prepare to protect itself against an infection in the future

vacuna: una sustancia que ayuda a tu cuerpo a prepararse para protegerse contra una infección futura

variable: something that can be changed and may be measured

variable: algo que se puede cambiar y que se puede medir

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Natural Selection Engineering Internship:

Fighting Drug-Resistant Malaria

Article Compilation

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FUTURA BIOMEDICAL ENGINEER'S DOSSIER



FUTURA
BIOMEDICAL ENGINEERING

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Chapter 1:

Request for Proposals

Malaria is a disease that kills more than one million people every year. It is caused by malaria parasites. Malaria can be treated with antimalarial drugs. However, the population of malaria parasites changes due to natural selection. Many malaria parasite populations adapt to past malaria treatments and become resistant to certain drugs. Once those populations adapt, those drugs may no longer work on them.



The Global Health Organization (GHO) seeks proposals for new malaria treatments. Successful proposals will address three criteria:

Malaria is a disease caused by a parasite that is passed between humans by certain mosquitoes.

1. Minimize drug resistance

All drug treatments for malaria eventually stop working as drug resistance becomes more common in the population of malaria parasites. Once a population of malaria becomes resistant, scientists need to find new drugs to treat the disease. New drugs can be expensive and difficult to create. Keeping drug resistance low means the drug is more likely to continue to cure patients and save lives.

2. Minimize patient side effects

There are several drugs that kill malaria parasites, but each has different side effects. Some drugs work well, but have severe side effects that make patients feel bad. These side effects may make patients less likely to follow their malaria treatments correctly. Other drugs may not work as well, but have milder side effects, so patients are more likely to finish their malaria treatments.

3. Keep costs low

In regions where malaria is common, many people live in poverty. The more each treatment costs, the fewer people can receive the drug treatment. It's important to keep costs low so the GHO can help treat as many patients, especially children, as possible.

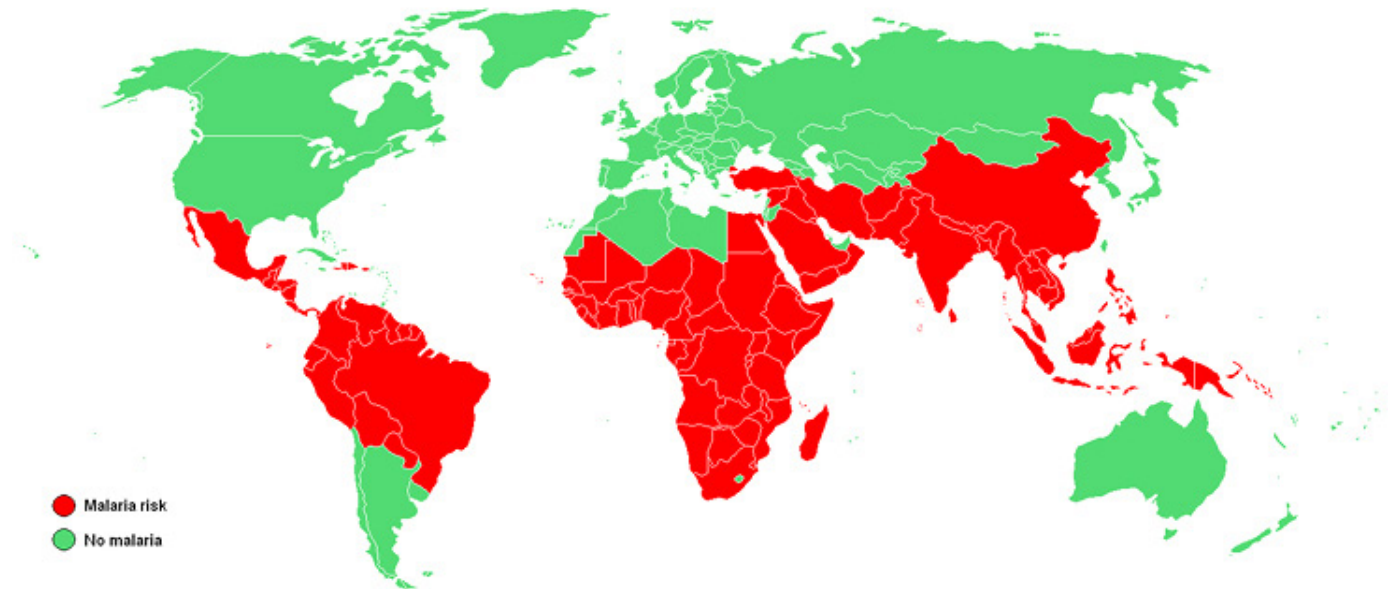
In addition to meeting the above criteria, the new malaria treatments need to take into account the constraints, or limits to the possible solutions. These constraints include:

- The proposed malaria treatment must not cause an increase in the malaria population.
- The proposed malaria treatment must last between one and seven days.

Chapter 2:

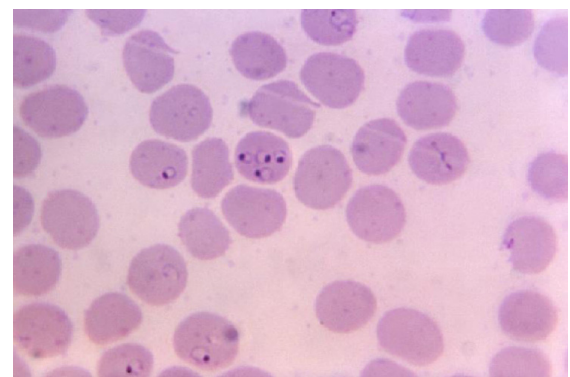
Basic Facts About Malaria

Malaria is a serious disease that kills more than one million people every year in certain regions of the world. The majority (over 70%) of those infected with malaria are children under the age of 5. The symptoms of malaria include fever, chills, headache, body aches, and vomiting.



Malaria is found in many tropical and subtropical areas of the world. Malaria is a serious problem in Africa, Southeast Asia, and South America.

Malaria is caused by a tiny parasite called *Plasmodium*. These parasites live inside humans and certain types of mosquito. When a person with malaria parasites in his or her blood is bitten by a mosquito, those parasites are picked up by the mosquito and can be passed on to other people it bites. Sometimes people can have malaria parasites and not show any signs of being sick. Their parasites can still be passed on to infect other people. Once inside the human body, *Plasmodium* parasites reproduce in the liver and infect red blood cells. If malaria is not treated, it can quickly become life-threatening by preventing blood flow to important organs.



This microscope image shows malaria parasites inside an infected person's red blood cells. Since malaria parasites are too small to see with the naked eye, this photograph has been magnified 1,125 times to make it easier to see.

To fight malaria, researchers and governments are exploring many different ideas. Some focus on using insect repellents and putting mosquito nets over people's beds to prevent the mosquito bites that spread malaria parasites. Others are working on vaccines that protect people from contracting malaria even if they are bitten by an infected mosquito. Another way to fight the disease involves designing new treatments that will cure those who already have malaria and keep populations of malaria parasites from developing resistance to drugs.

Once people are infected with malaria, they can be treated using antimalarial drugs. Scientists have developed several different drugs that are effective at killing the malaria parasites in a patient's body. However, the population of malaria parasites, like all organisms, changes due to natural selection and some populations of malaria parasites are becoming resistant to these antimalarial drugs. When parasites have resistance to a drug, the drug no longer kills the parasites. The parasites survive and reproduce, and can be transferred to more humans through new mosquito bites.



One of the simplest measures against malaria is the use of mosquito nets. Sleeping under a mosquito net prevents the bites that spread malaria parasites.

Chapter 3:

Antimalarial Drugs as Selection Pressure

Antimalarial drugs act as a selection pressure on the population of malaria parasites. What is a selection pressure? Let's look at a common example. Take a population of rabbits. What happens to this population if their environment changes? Let's say the mountain where the rabbits live becomes colder than it used to be. In a colder environment, rabbits with thick fur stay warmer and are more likely to survive than rabbits with less fur. For this environment, thick fur is an adaptive trait. The colder temperature is a selection pressure for the rabbits—that means it is something that only the rabbits with certain traits are likely to survive. Because of the cold, rabbits with thick fur are more likely to survive long enough to reproduce and pass on the adaptive trait of thick fur to their offspring. Over time, the population begins to have more rabbits with thick fur. We call this process natural selection.

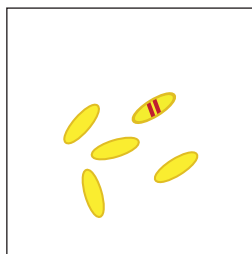
Even microscopic organisms can respond to selection pressures. For populations of malaria parasites, antimalarial drugs are a selection pressure. When a doctor gives a patient antimalarial drugs, he or she changes the environment inside the patient's body where the parasites live. In that changed environment, drug resistance is an adaptive trait. Parasites with the trait of drug resistance are more likely to survive than parasites without the trait of drug resistance. Since they survive, they are also more likely to reproduce and pass on the adaptive trait of drug resistance to their offspring. Over time, in this environment, more and more parasites in the the population are drug-resistant. This, too, is natural selection!



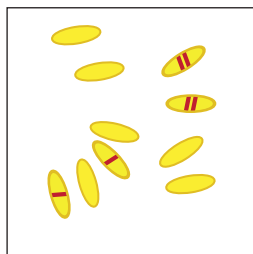
In this environment, the cold temperatures are acting as a selection pressure on a population of rabbits. Adaptive traits, such as thick fur in cold temperatures, help organisms survive.

Rabbits must be several months old before their bodies are mature enough to reproduce, and each rabbit pregnancy lasts around 30 days, so changes in rabbit populations due to selection pressure happen slowly. However, there are billions of malaria parasites living in each infected person, and each of these parasites can reproduce every 48 hours! Every time a malaria parasite reproduces is a chance for a mutation to occur. A mutation is a random change to a gene that sometimes results in a new trait. If one of those mutations results in a trait that gives the parasite drug resistance, then that drug is less likely to kill that individual parasite. These resistant parasites can survive and reproduce quickly, changing the distribution of traits in the parasite population so that drug resistance becomes more common. This resistant population can spread and is harder to treat with existing antimalarial drugs. In the case of malaria parasites, natural selection can cause serious problems for human health.

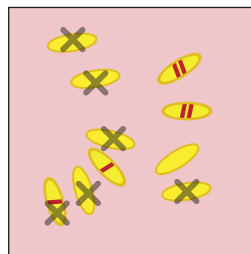
Natural Selection in Malaria—Population Shift



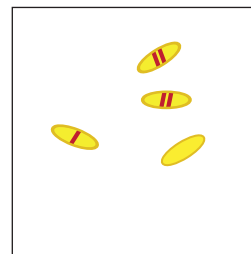
One parasite has a trait for resistance to Red Drug.



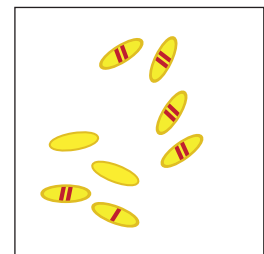
The parasites reproduce and some have a mutation.



Red Drug is applied. Many non-resistant parasites die.



Most of the remaining parasites are resistant to Red Drug.



The parasite population has shifted toward having traits for drug resistance.

KEY

-  has no trait for resistance
-  some Red Drug resistance
-  death
-  high Red Drug Resistance

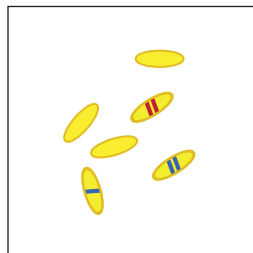
Antimalarial drugs act as a selection pressure that shifts the population of malaria parasites toward having the trait of drug resistance.

Chapter 4:

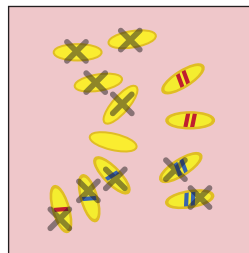
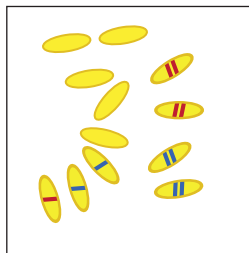
Antimalarial Drug Resistance

When malaria is treated with the same single-drug treatment for many years, the parasite population can adapt so that more parasites have the trait of resistance to that drug. When a large percentage (50% or greater) of the parasite population has traits for drug resistance, that drug treatment no longer works to cure malaria. When a population of parasites becomes drug-resistant, it is important to stop using that one drug and use a different drug treatment instead.

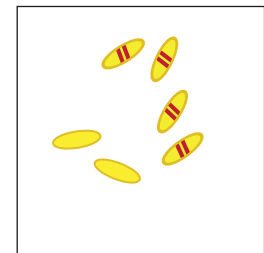
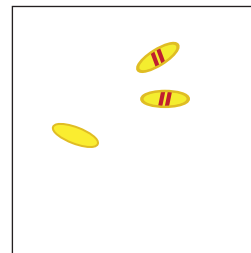
Natural Selection in Malaria—Single-Drug Treatment (Red Drug)



A few parasites have resistance to red drug. Other parasites have resistance to blue drug.

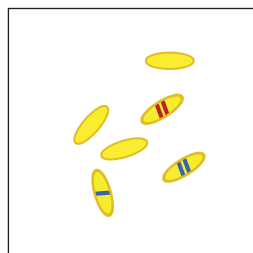


Red Drug is applied. Many non-resistant parasites die.

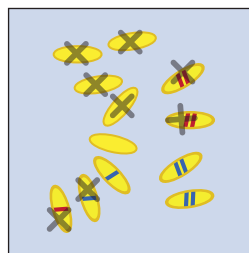
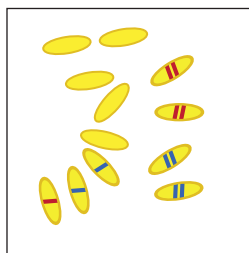


A high percentage of parasites are resistant to Red Drug.

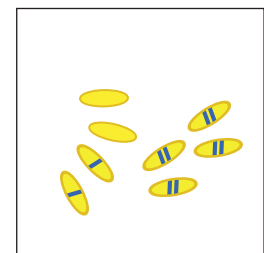
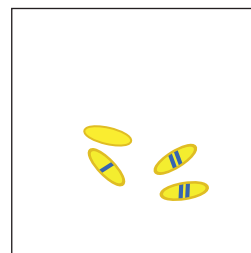
Natural Selection in Malaria—Single-Drug Treatment (Blue Drug)



A few parasites have resistance to blue drug. Other parasites have resistance to red drug.



Blue Drug is applied. Many non-resistant parasites die.



A high percentage of parasites are resistant to Blue Drug.

KEY

has no trait for resistance

some Red Drug resistance

high Red Drug resistance

death

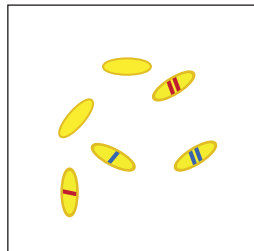
some Blue Drug resistance

high Blue Drug resistance

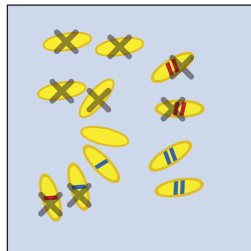
Different antimalarial drugs act as different selection pressures to shift the distribution of drug resistance traits in a population of malaria parasites.

Fortunately, there are several different drugs that can kill malaria parasites. Using a combination of different antimalarial drugs makes it more likely that more malaria parasites will be killed, even if there are traits for drug resistance in the population. Parasites that are resistant to one drug might be killed by the other drug and not have the chance to pass the trait of drug resistance on to their offspring.

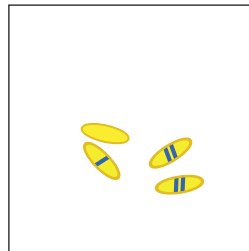
Natural Selection in Malaria—Combination Drug Treatment



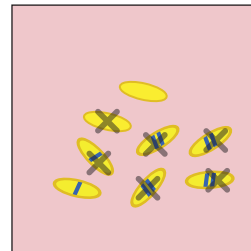
A few parasites have resistance to blue drug. Other parasites have resistance to red drug.



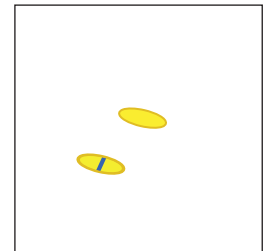
Blue Drug is added to the parasites' environment.



A high percentage of parasites are resistant to Blue Drug.



Then, Red Drug is added to the parasites' environment.



Drug resistance stays low. Some parasites survive by chance.

KEY

- | | | |
|-----------------------------|---------------------------|---------------------------|
| has no trait for resistance | some Blue Drug resistance | high Red Drug resistance |
| death | some Red Drug resistance | high Blue Drug resistance |

Chapter 5:

Designing Antimalarial Drugs

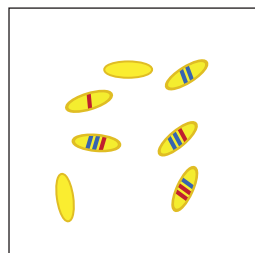
When designing malaria treatments, engineers have to consider more than how well each drug kills parasites. Many drugs have patient side effects, or unwanted problems from a treatment. These may be mild, such as headaches, trouble sleeping, or an upset stomach, or they may be severe, such as vomiting and seizures. Severe side effects can make patients feel so bad that they may not finish their treatments.

If a patient does not finish all of his or her treatment, or the treatment is not strong enough, this can cause problems in the future. Because antimalarial drugs act as a selection pressure, over time as a patient undergoes a malaria treatment, more and more parasites in the population are likely to become drug-resistant. If a patient does not finish the entire treatment, or if the treatment is not strong enough, more malaria parasites remain in the body. Each of those parasites might produce offspring with a mutation that is the trait for resistance to the drug. An incomplete treatment, or one that is too weak, may cause an increase in drug-resistant malaria. Biomedical engineers can make a malaria treatment stronger by using a higher dose (amount of the drug) or by using the drug for more days of treatment.

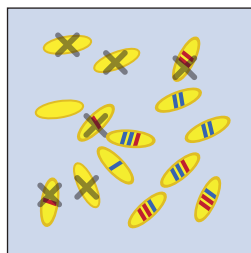
Engineers also have to consider how each drug used in a malaria treatment acts as a different selection pressure, resulting in different shifts in the distribution of traits in the parasite population.

Finally, malaria parasites can and do have traits of drug resistance to more than one drug at the same time. This is called multi-drug resistance. Malaria parasites with multi-drug resistance can result in populations of parasites that are difficult to treat, even with a combination of drugs!

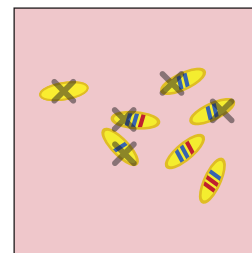
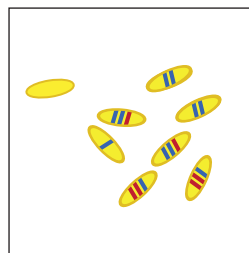
Natural Selection in Malaria—Multi-drug Resistance



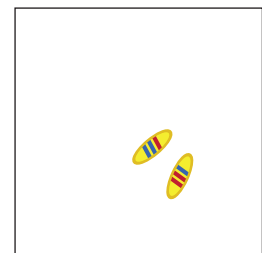
Some parasites have traits of resistance to BOTH Red Drug and Blue Drug.



Blue Drug is added to the parasites' environment.



Then, Red Drug is added to the parasites' environment.



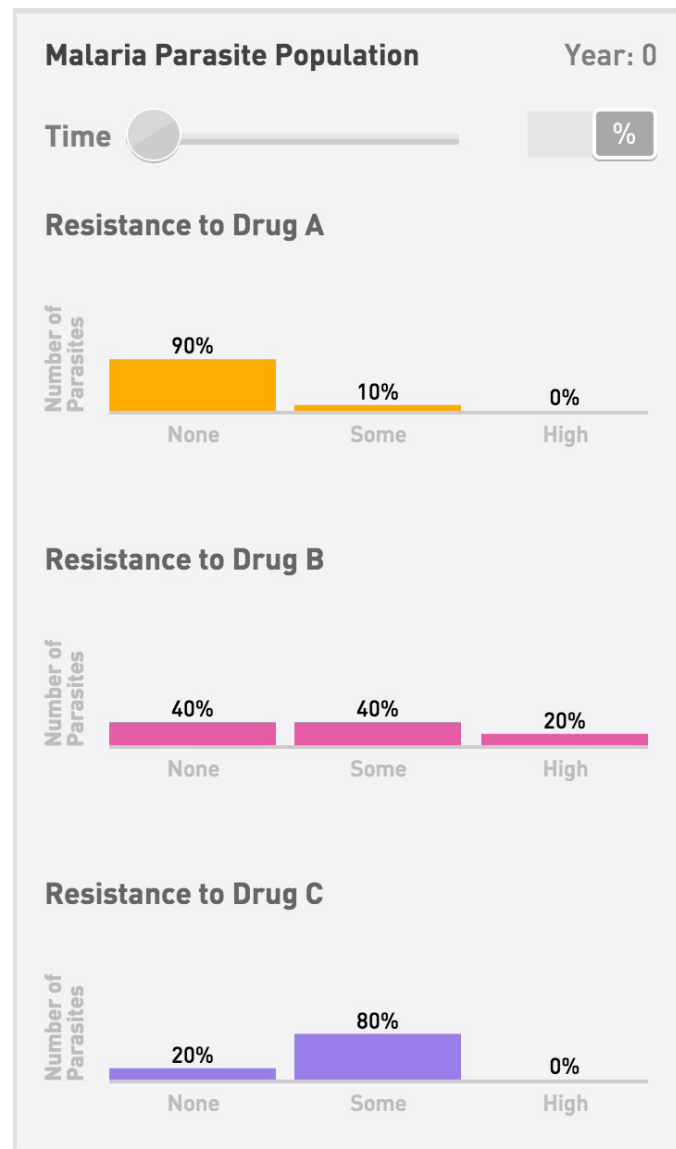
Many of the remaining parasites now have resistance to both Red Drug and Blue Drug.

KEY

has no trait for resistance some Red Drug resistance some Blue Drug resistance high Red Drug resistance high Blue Drug resistance multiple-drug-resistant death

Futura has identified three drugs to test using MalariaMed:

	Drug Effectiveness	Current percentage of population with no resistance	One large dose	
			side effects	cost
Drug A	High kills most parasites	large	mild	\$\$\$\$
Drug B	Medium kills many parasites	medium	none	\$\$
Drug C	Low kills some parasites	small	moderate	\$



These histograms show the distribution of traits for drug resistance in a population before any drugs have been introduced. This malaria parasite population has no individuals with high resistance to Drug A or Drug C, and some individuals with high resistance to Drug B.

Proposal Resources

Sample Proposal: Designing a Greener Toothbrush

INTRODUCTION

Our team at Futura Engineering is working for Dentists for the Planet to design a better toothbrush that isn't bad for the Earth but is also good for people's teeth. The toothbrush should have a low environmental impact so it doesn't make trash or pollution when you're done with it. Designs should have a high clean-mouth rating because that means the toothbrush removes as much tooth plaque as possible. And the toothbrush should be low-cost so more people can buy the toothbrush and help the planet. Our optimal design uses a plant-based plastic handle and natural-fiber bristles. This toothbrush design has a medium environmental impact rating of 3.1, a clean-mouth rating of 84%, and costs \$2.08 per toothbrush.

DESIGN DECISIONS

Environmental impact: The proposed toothbrush design has an environmental impact rating of 3.1. Based on design feedback, we set a goal of an environmental impact rating of 3.5 or lower. We had another design with a lower impact rating of 1.9 with bamboo handle and natural-fiber bristles, but it didn't do well for other criteria. The handle we chose is made of a plastic that comes from plants and is meant to be recycled, and can slowly biodegrade, which means it is better for the environment. The bristles are natural fibers and are completely biodegradable. These materials are made from trees, which can break down in a compost or landfill without producing pollution.

Keeping mouths clean: Our design has a clean-mouth rating of 84%, which is better than our goal of 80%. We found that plastic bristles and natural-fiber bristles both removed at least 80% of



Not all toothbrushes are the same. They come in different styles and have different strengths and weaknesses.

plaque, and the more plaque removed, the less tooth decay there is, and the healthier people are. Therefore, we selected the natural-fiber bristles for our design. We had a cheaper design using nylon bristles (\$1.20 per toothbrush), but the clean-mouth rating for that toothbrush was only 53%. The plant-based plastic handle also affected the clean-mouth rating because the strength of the handle affects how much plaque is removed. Plastics are stiffer and help the person remove more plaque while brushing compared to more flexible handles made from all plant material.

Cost: Our proposed design costs \$2.08 per toothbrush. Our team tried to make a toothbrush that cost around \$1.90 based on our team goal. We had a plan that cost only \$1.20, but it had a high environmental impact and a very low clean-mouth rating. Plastic handles cost the least and plant-based plastic handles cost more but are still less expensive than all bamboo handles. Natural-fiber bristles cost more than nylon or plastic bristles. Since we didn't use the most expensive handles, our cost is still in an affordable range.

CONCLUSION: CONSIDERING TRADE-OFFS

We learned that toothbrush materials that work the best at cleaning the mouth are expensive and are not good for the environment. Toothbrush materials that are best for the environment don't do well at cleaning teeth and can also cost more. The cheapest handles were the worst for the environment but good at cleaning the mouth. The cheapest bristles were okay for the environment but not very good at cleaning the mouth. We focused on the criterion we think is most important: keeping mouths clean. Because we focused on the clean-mouth rating, the toothbrush costs more than other designs. Our proposed design is optimal because, even though it doesn't have the best environmental impact or cost, it is excellent at getting rid of tooth plaque which is important for keeping mouths, and people, healthy.



Toothbrushes can be made from many different materials.

Proposal Rubric

INTRODUCTION

Needs Improvement

Introduction is incomplete; missing one or more criteria and no mention of the proposed design

Developing

Lists the criteria of the project but does not describe them; mentions the proposed design by listing the results or details but not both

Proficient

Summarizes the design request and describes most criteria; describes the proposed design by listing the results or details but not both

Excels

Thoroughly summarizes the design request and describes the proposed design by listing the variables or details and the final results

DESIGN DECISIONS (same for each criterion)

Needs Improvement

No evidence is provided to support the design decision; explanation is inadequate or missing

Developing

Uses minimal evidence to support the design decision and does not explain why the specific feature was selected over other options and/or how that feature of the design relates to the criterion

Proficient

Uses some evidence to support design decision, mostly explaining why the specific feature was selected over other options and how that feature of the design relates to the criterion

Excels

Uses multiple pieces of strong evidence to support design decision, thoroughly explaining why the specific feature was selected over other options and how that feature of the design relates to the criterion

CONCLUSION: CONSIDERING TRADE-OFFS

Needs Improvement

Two or more of the following need attention: design priorities, summary of trade-offs in the optimal design, or a closing statement

Developing

One of the following needs attention: design priorities, summary of trade-offs in the optimal design, or a closing statement

Proficient

Includes all of the following, but may lack detail: design priorities, summary of trade-offs in the optimal design, and a closing statement

Excels

Description of design priorities is clear; summary of trade-offs in the optimal design is detailed and thorough; includes a strong closing statement

SCIENTIFIC COMMUNICATION

Needs Improvement

Lacks topic-specific vocabulary; uses informal style or language

Developing

Attempts to use topic-specific vocabulary and formal writing style, but needs improvement

Proficient

Uses some topic-specific vocabulary; uses formal writing style somewhat successfully

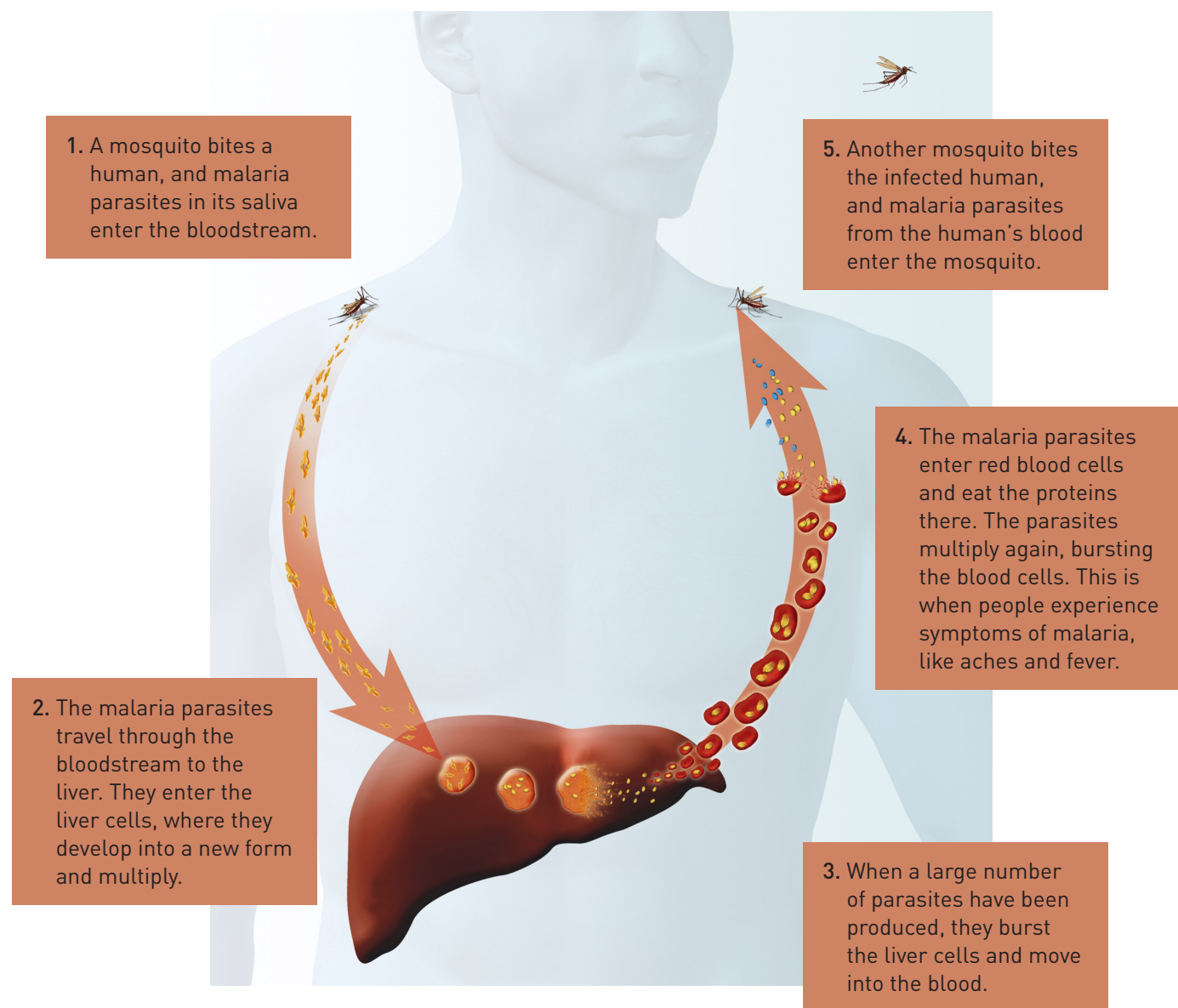
Excels

Uses topic-specific vocabulary clearly and appropriately; uses formal writing style successfully

Additional Resources

Malaria Life Cycle

Malaria parasites use both mosquitoes and humans as hosts. They are transported between human hosts by the mosquitoes and they use both mosquitoes' bodies and human bodies as places to multiply. In humans, malaria parasites first multiply in liver cells and take a new form that can infect red blood cells. They then move to the red blood cells, where they multiply until there are many more of them.



Chapter 8:

Glossary

adaptive trait: a trait that makes it more likely that an individual will survive in a specific environment

rasgo adaptativo: un rasgo que hace más probable que un individuo sobreviva en un ambiente específico

analyze: to examine in detail for a purpose

analizar: examinar en detalle y con un propósito

antimalarial: a drug or medicine that kills the parasites that cause malaria

antimalárica: una droga o medicina que mata los parásitos que causan la malaria

argument: a claim supported by evidence

argumento: una afirmación respaldada por evidencia

biomedical engineer: an engineer who applies concepts from biology and medicine to improve human health and save lives

ingeniero/a biomédico/a: un/a ingeniero/a que aplica conceptos de la biología y la medicina para mejorar la salud humana y salvar vidas

CEO: C.E.O. stands for “Chief Executive Officer,” the leader of an organization, group, or company

CEO: C.E.O. son las siglas en inglés para “Oficial Ejecutivo en Jefe”, es decir, el director de una organización, grupo o compañía

constraint: a limit or restriction

restricción: un límite o condicionamiento

criteria: standards by which something may be judged

criterios: normas por medio de las cuales se puede juzgar algo

deliverable: a thing to be delivered, usually in a development or design process

entregable: una cosa que debe entregarse, usualmente durante un proceso de desarrollo o diseño

distribution: the number of individuals with each trait in a population

distribución: el número de individuos que tienen cada rasgo en una población

dose: the amount of a drug or medicine given in a treatment

dosis: la cantidad de una droga o medicina que se da en un tratamiento

dossier: a set of related documents about a particular topic

expediente: un conjunto de documentos relacionados sobre un tema particular

engineer: a person who uses math and science to design things

ingeniero/a: una persona que utiliza las matemáticas y la ciencia para diseñar cosas

environment: everything (living and nonliving) that surrounds an organism

ambiente: todo (viviente y no viviente) lo que rodea a un organismo

evidence: information about the natural world that is used to support or go against (refute) a claim

evidencia: información sobre el mundo natural que se utiliza para respaldar o rechazar (refutar) una afirmación

gene: an instruction for making a protein molecule

gen: una instrucción para formar una molécula de proteína

histogram: a graph that uses bars to show how characteristics or values are distributed within a group

histograma: una gráfica que usa barras para mostrar cómo se distribuyen las características o los valores dentro de un grupo

host: an organism that a parasite lives on or in

huésped: un organismo en el cual o dentro del cual vive un parásito

interns: beginners at a workplace who do work that is closely supervised because they are learning on the job

becarios: principiantes que hacen un trabajo estrechamente supervisado porque están aprendiendo durante el mismo

internship coordinator: the person who supervises interns during a project

coordinador/a de becarios: la persona que supervisa becarios durante un proyecto

isolate: to separate or set apart

aislar: separar o apartar

iterative testing: repeating a process in a way that considers the results of a previous design

pruebas iterativas: la repetición de un proceso de manera que se consideren los resultados de un diseño anterior

malaria: a serious disease caused by parasites spread to humans by mosquitoes

malaria: una enfermedad seria causada por parásitos que los mosquitos transmiten a los humanos

mild: not serious

leve: no serio

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

moderate: somewhat bad or serious

moderado: relativamente malo o serio

mutation: a random change to a gene that sometimes results in a new trait

mutación: un cambio aleatorio a un gen que a veces da como resultado un rasgo nuevo

natural selection: the process by which the distribution of traits in a population changes over many generations

selección natural: el proceso por medio del cual cambia la distribución de rasgos en una población con el paso de muchas generaciones

non-adaptive trait: a trait that makes it less likely that an individual will survive in a specific environment

rasgo no adaptativo: un rasgo que hace menos probable que un individuo sobreviva en un ambiente específico

offspring: an organism produced as a result of reproduction

descendencia: un organismo producido como resultado de la reproducción

optimal: most successful, considering the situation

óptimo: más exitoso, considerando la situación

organ: a part of an organism that performs a specific function

órgano: una parte de un organismo que desempeña una función específica

organisms: living things, such as plants, animals, and bacteria

organismos: seres vivos, como plantas, animales y bacterias

parasite: an organism that lives in or on another organism and causes it harm

parásito: un organismo que vive dentro o sobre otro organismo y le causa daño

Plasmodium: the scientific name for the group of parasites that cause malaria

Plasmodium: el nombre científico del grupo de parásitos que causan la malaria

population: a group of the same type of organism living in the same area

población: un grupo del mismo tipo de organismo que vive en la misma área

project director: the person who is responsible for making sure a project's goals are addressed

director/a de proyecto: la persona responsable de asegurarse de que se cumplan las metas de un proyecto

proposal: a formal design that is supported by evidence, and submitted for discussion and review

propuesta: un diseño formal respaldado por evidencia y presentado para discusión y revisión

request for proposals: a document asking engineers to submit a well-supported, formal design describing how they would solve a problem

solicitud de propuestas: un documento para pedir a los/as ingenieros/as que presenten un diseño formal, bien sustentado, que describa cómo resolverían un problema

resistance: the quality of preventing or fighting against something

resistencia: la cualidad de prevenir o luchar contra algo

selection pressure: something in the environment that affects an individual's chances of surviving

presión de selección: algo en el ambiente que afecta las posibilidades de sobrevivir de un individuo

severe: very bad or serious

severo: muy malo o serio

shift: to move to one side or the other

desplazar: mover hacia un lado o el otro

side effects: unwanted effects of a drug or medical treatment

efectos secundarios: efectos indeseados de una droga o tratamiento médico

trade-off: when you have to give up one thing in return for another

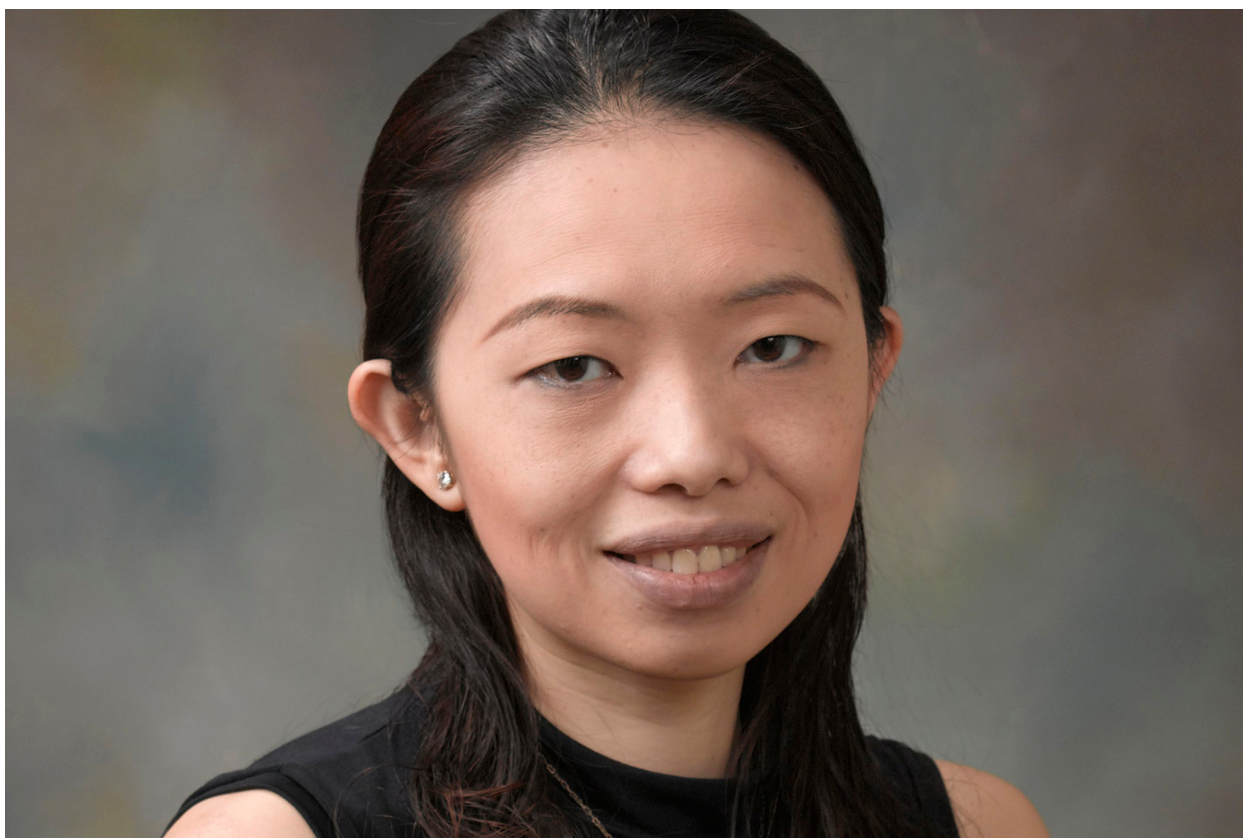
concesión: una situación en la que se debe renunciar a algo para obtener otra cosa a cambio

vaccine: a substance that helps your body prepare to protect itself against an infection in the future

vacuna: una sustancia que ayuda a tu cuerpo a prepararse para protegerse contra una infección futura

variable: something that can be changed and may be measured

variable: algo que se puede cambiar y que se puede medir



Maya Lim is an engineer who designed a 3-D printer that can print with living cells. It is called a bioprinter.

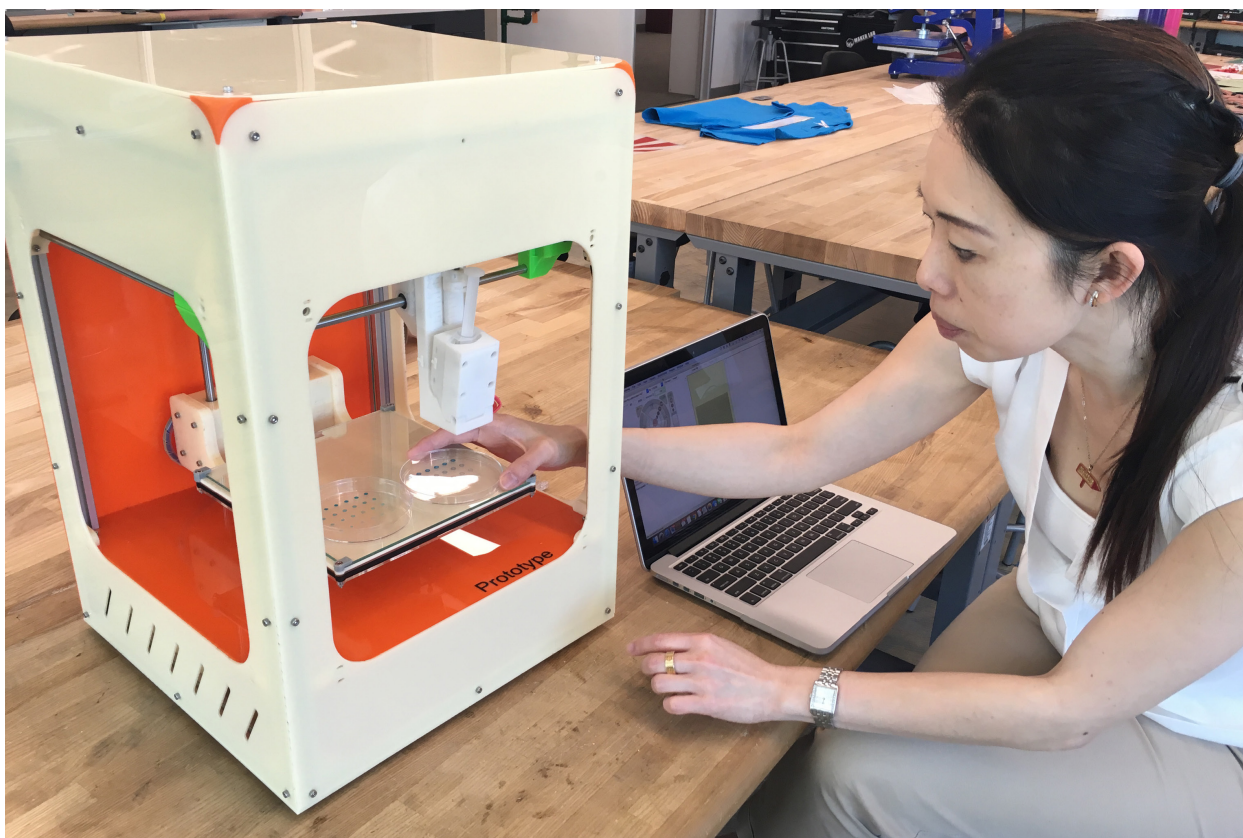
Meet an Engineer Who Prints in 3-D with Living Material

When you think of chemists and chemical engineers, you might think of scientists working in labs. Many chemical engineers do work in labs, but there are lots of other things chemical engineers can do, too. Maya Lim is a chemical engineer and the CEO of her own business. Her business designs and produces low-cost 3-D bioprinters to be used in school classrooms. Instead of ink, bioprinters print with natural materials, like cells and edible substances.

Lim is from Singapore, and she got the idea for classroom bioprinters when she was teaching at a school there. Her school bought an expensive bioprinter for students to use, but only a few students were trained to use it. Lim thought that

more students might be able to try bioprinting if the printer were less expensive and less fragile. “I wanted to make bioprinters that were highly accessible and low in cost, without the fear of breaking anything,” says Lim. She and her business partner applied for a grant from the National Science Foundation to start their business and began working on designs. Two years later, the printers they produce are used in a small but growing number of schools.

Lim’s education as an engineer began with a college degree in Chemical Engineering—she wanted to work in the oil industry, but ended up working on computer hardware instead. “I decided what I was doing wasn’t for me,



Bioprinters use substances like cells or food materials instead of ink.

and so I leaned towards biomedicine,” she says. Eventually, she went back to school for her Ph.D. and began teaching—and that’s where she got the idea for her company.

Bioprinting is a new technology, and scientists are still figuring out all the things it can be used for—things like medical uses, environmental uses, and producing things that are too tiny to make by hand. By using such a new technology, students aren’t that far behind professional scientists in shaping how bioprinters are used in the classroom, the lab, and in factory settings. Lim likes the idea that students can learn some of the basics of biology by printing cells and cell parts and seeing how they behave. She’s even more excited that students can work on printing anything they can think of once they understand the basics.

Students use all kinds of substances for printing. “Anything that goes into a syringe can

be printed,” Lim says, adding that she’s seen students use edible substances like honey, chocolate, and cheese! They also use substances found in nature, like plant cell material and collagen (COLL-a-jen), the substance that keeps human skin springy. The variation in materials means these bioprinters can be used for many different things in many different areas of study.

Lim says going from working in a lab to running a business has been a challenge. “As an entrepreneur, I’m always needing to learn something new,” she says. “Some things I’m not great at, like accounting! But you have to learn. I have to create videos, and I’m not good at memorizing scripts or anything. Being an actor is quite a tough job! You have to do things you’re not used to.” However, she says learning all those new skills is worth it as she gets better at running her business—and she hopes the students using her company’s printers will learn new skills, too.

Natural Selection Engineering Internship: Fighting Drug-Resistant Malaria

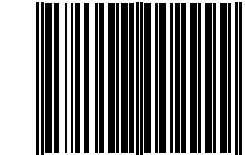


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