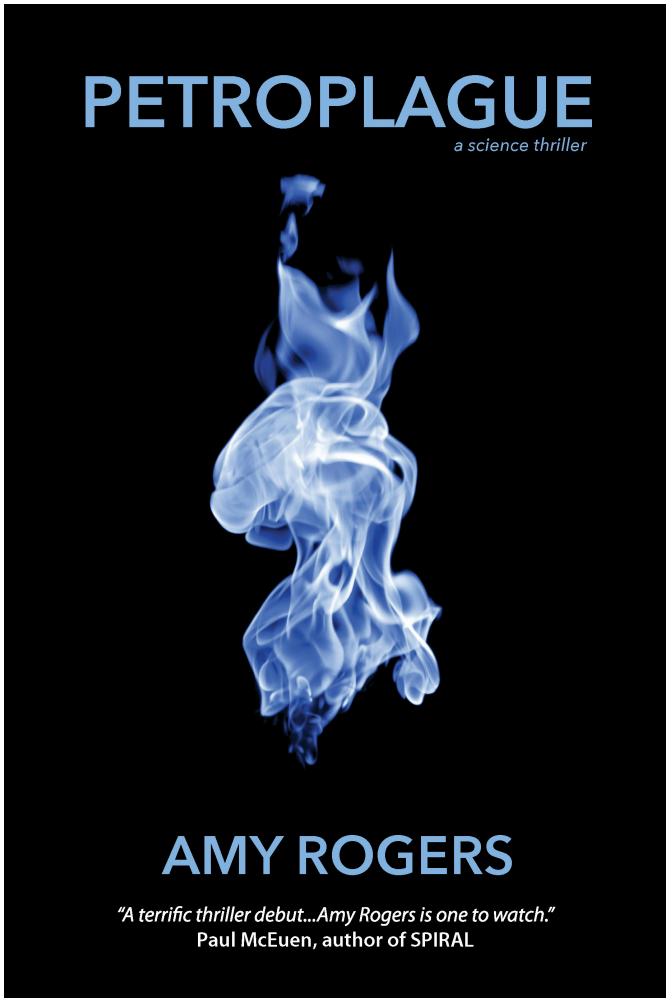
Petroplague:
Official Teacher's Guide

by Amy Rogers, MD/PhD



For grades 9-12 and college level

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Dear Educator:

Petroplague is a thriller novel with real science in the style of Michael Crichton (*Andromeda Strain, Jurassic Park*). Set in present-day Los Angeles, *Petroplague* is about oil-eating bacteria that contaminate the fuel supply, paralyze the city, and threaten civilization as we know it.

Sounds like a made-for-TV disaster movie—not typical source material for academic study. But *Petroplague* was written by a Harvard graduate with MD and PhD degrees. It's packed with accurate chemistry, microbiology, ecology, geology, and important social themes, all served in an entertaining, page-turning story.

Science thriller fiction like *Petroplague* can be a powerful tool for educators to excite their students' interest in the subject matter. When I taught microbiology at California State University, I asked my students to read one title from a selection of microbiology-themed popular books in addition to standard textbook fare. Many students reported they enjoyed this assignment and learned something, too.

This study guide is designed to make it easy for you to use *Petroplague* in your classroom, whether a high school AP biology class, a college microbiology course, or a science course for non-science majors.

Alert: In keeping with the tension in some scenes, characters in Petroplague *occasionally use profanity.*

If you are considering using *Petroplague* in your curriculum, contact me (amy@sciencethrillers.com) for a free educator's copy.

Happy teaching,

Dr. Amy Rogers

Themes and Topics in *Petroplague*:

Microbiology:
- Bacterial metabolism
- Extremophiles
- Obligate anaerobes
- Lateral gene transfers
- Synthetic biology
- Bacteriophages

Chemistry:
- Hydrocarbons
- Metabolic wastes
- Gases and liquids
- Flammability

Energy:
- Tar sands
- Fossil fuels
- Biofuels
- Photosynthesis
- Oil refining
- Carbon cycle
- Global warming
- Peak Oil

Geology:
- Earthquakes
- La Brea Tar Pits

Answer Key for Reading Comprehension questions of the Official Petroplague Teacher's Guide is available, but not posted online. If you are an instructor using this material, contact Amy Rogers (amy@ScienceThrillers.com) for an answer key.

Contact Amy Rogers (amy@ScienceThrillers.com) for **bulk purchases** of *Petroplague* paperbacks or hardcovers at a discount (4 or more copies shipped to one address).

Dr. Amy Rogers would love to **talk to your class or your book group via Skype**, or in person in the Sacramento region. Email her (amy@ScienceThrillers.com) to make arrangements.

Reading Comprehension Questions

Questions are drawn from book content; answers can be found in the text.

Chapters 1-20

1. For what valuable metal do thieves strip the wires from abandoned buildings?
2. What are the La Brea Tar Pits famous for?
3. Name three large, prehistoric mammals whose remains are found at La Brea.
4. Are there dinosaur bones in the asphalt at La Brea? Why or why not?
5. The pools at La Brea appear to boil, but they're actually not very hot. What causes the bubbles?
6. What gas smells like rotten eggs?
7. What is the difference between the largest petroleum deposits in the Western Hemisphere, and the oil fields of Saudi Arabia?
8. What are the names of the two biggest tar sands in the Western Hemisphere? In what countries are they located?
9. What simple hydrocarbon is the main component of natural gas?
10. The bacteria in Christina's experiment can eat what "food" that would be poison to you?
11. What waste product do the bacteria dump after digesting this "food"?
12. How would using these bacteria make it easier for humans to access the energy stored in an underground tar sand?
13. What do the police think caused the explosion next to the Papadakis residence?
14. What is a known natural hazard of digging tunnels in central Los Angeles between La Brea and Western Avenues?
15. Why did eco-terrorists target Christina's experiment?
16. What was odd about the bones excavated from the pit at La Brea in chapter 10?
17. Using your eyes, how could you tell the difference between methane gas and hydrogen gas even though they're both invisible?
18. What organic acid gives vinegar its distinct odor?
19. Why does the State of California require oil refineries to produce a different blend of gasoline in the summer than in the winter?
20. In the scene at the El Segundo refinery, what is the "pig" used for?
21. In chapter 20, Christina and Dr. Chen try to identify the microorganism that is breaking down gasoline. Their experiments include an important control for comparison. What is it?

22. Why does the petroplague break out on a hot day? (Hint: *Syntrophus* is thermophilic.)

Chapters 21-40

1. City buses that run on compressed natural gas are not affected by the plague. What is the significance of this clue?
2. What happened to Christina's experimental *Syntrophus* bacteria after Neil blew up the underground storage tank?
3. Name three types of hydrocarbons (organic molecules made entirely of carbon and hydrogen atoms) that are found in crude oil.
4. Christina and her mentor genetically engineered *Syntrophus* bacteria to efficiently break down hydrocarbons underground. What biochemical limitation did they think would prevent these bacteria from attacking oil and gasoline on the surface?
5. Why is L.A.'s electricity not affected by the petroplague?
6. What is the busiest container port in the U.S.?
7. What is a Hubbert peak? Why does this pattern repeat itself in individual oil wells, in oil fields, and in entire countries?
8. Why is Christina worried for her safety when she smells vinegar?
9. Preston Cobb expects that as the world's oil supply dwindles, nations will go to war over it. Neil suggests a way for the age of oil to end without war. How?
10. Why do some microorganisms produce antibiotics?
11. Dr. Chen suggests that in case they fail to find an antibiotic that kills the petroplague, they need a Plan B. What is his idea to get vehicles moving without gasoline?
12. What is Tequila Jack trying to do?

Chapters 41-60

1. What happens to liquid nitrogen when it gets warm? What if the liquid nitrogen is in a sealed container when this happens?
2. Christina suspects the petroplague is causing the disturbances at the La Brea Tar Pits, and also the earthquakes. How could bacteria do this?
3. Why does the X-car still work, unlike all the normal automobiles?
4. Why is Christina avoiding the police before she learns that they are looking for her?
5. How does Mayor Ramirez learn that the quarantine has failed?
6. What important biochemical fact did Neil fail to realize would ruin his plan to stop global warming?
7. Why did Trinley resist Dr. Chen's efforts to find a cure for the petroplague?
8. How does destroying the bioreactor hurt Trinley?
9. What is the value of Chen's samples of oil field microbes?
10. What mountain range separates Los Angeles from the Central Valley to the north?
11. What enormous fault line caused a 7.9 magnitude mega-quake at Fort Tejon in 1857?

Chapters 61-83

1. The earthquake in chapter 61 causes damage to what vital infrastructure?
2. An "acre-foot" is a unit of measure that is used to measure what?
3. How does Christina escape her bonds?
4. Ramirez sets out to find the X-car. How will he find it?
5. What risks do Ramirez and Mickey face when flying a helicopter?
6. In chapter 75, Christina explains why it's too late for the antibiotic. Summarize her argument in your own words.
7. What enormous project does CaliPetro undertake to temporarily reduce the earthquake risk?
8. Using Chen's notes, Christina comes up with a last-ditch strategy to fight the petroplague. What is it?
9. What do Ramirez and Christina use the brooms for?

Beyond the Book

Questions to prompt thinking and research; advanced questions marked with **

Chapters 1-20

1. The remains of more than 4,000 individual dire wolves have been found at La Brea Tar Pits, making it the most common large mammal at the site. Why so many wolves? {Hint: http://www.tarpits.org/la-brea-tar-pits/timeline look up Dire Wolf.}
2. How did animals become trapped at La Brea, and how did they die? {Hint: http://www.tarpits.org/la-brea-tar-pits/faqs}
3. What is the chemical formula for hydrogen sulfide? Methane? Isobutanol?
4. What is a hydrocarbon? Why do hydrocarbons make excellent fuels?
5. What does an oil refinery do? Suggested sources:
    a. http://science.howstuffworks.com/environmental/energy/oil-refining.htm
    b. http://elsegundo.chevron.com/home/abouttherefinery/whatwedo/refining_process.aspx
    c. http://www.bp.com/en/global/corporate/about-bp/what-we-do/making-fuels-and-products/how-refining-works.html
    d. http://www.sjvgeology.org/oil/refinery.html
6. What are bacteria?
7. What are viruses?
8. *What is *E. coli*?
9. **E. coli* is not naturally a photosynthetic microbe. Since it cannot get energy from the sun, where does it get the energy it needs to live?
10. *If a biofuel is made by a photosynthetic organism (whether plant or microbe), why does burning that fuel not contribute to global warming?
11. **What is PCR (polymerase chain reaction)? How might it be used to identify the type of bacteria in the gasoline?
12. **What is an ELISA test? How might it be used to identify the type of bacteria in the gasoline?

Chapters 21-40

1. How would the response to the plague be different if the bacteria infected and killed people instead of gasoline?
2. How would you personally be impacted if cars/buses/trucks/planes stopped working? What about your school? Your community?
3. If you had to fill one paper grocery sack with food to last you for a long time, what would you put in it? (Assume you will have access to water.)
4. **What are some common mechanisms of horizontal (also called lateral) gene transfer in bacteria? Horizontal gene transfer contributes to what worrisome clinical phenomenon in bacterial populations?
5. If you lived in Los Angeles during the petroplague, would you try to leave? Why or why not? If you did evacuate, how would you travel?
6. *What was the Kyoto Protocol on climate change?
7. To answer the following questions about Hubbert peaks, see graph and data table on U.S. crude oil production, 1860-present

http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpus1&f=a

   a. In what year did U.S. crude oil production reach its peak?
   b. After that year, production declined until it unexpectedly started to rise again in what year?
   c. What revolutionary (and controversial) new technology caused this change? {Hint: See Essay/Discussion Topic: Fracking on page 11}
8. What happened to Saul on the road to Damascus? How is this a metaphor for what happened to Tequila Jack?
9. What was Deepwater Horizon?
10. "Preparedness" describes a wide range of activities that people can do to prepare for possible disasters. What is the most likely type of natural disaster in your area? How can you prepare?
    a. Red Cross preparedness information http://www.redcross.org/prepare
    b. Preparedness for youth
        i. http://www.ready.gov/kids
        ii. Girls Scouts Emergency Preparedness Patch Program http://www.gscnc.org/dhs.html

Chapters 41-60

1. *Why do the photosynthetic *E. coli* in the bioreactor need a supply of carbon dioxide?
2. **What is lyophilization?
3. *Why would nitrogen gas extinguish a fire?
4. In California, people arrested for, but not necessarily convicted of, a felony can be forced to submit a DNA sample for the state's database. How is the DNA collected?

Chapters 61-83

1. Since 1800, Southern California has experienced four earthquakes magnitude 7.5 or greater. List them. Pick one and describe the type of fault that caused it, and the consequences of the quake.
    a. Source: http://www.data.scec.org/significant/chron-index.html
2. Illegal marijuana cultivation in public wildlands is a growing problem. What are some harmful consequences of these "farms"?
    a. http://www.kcet.org/updaily/socal_focus/commentary/reefer-madness-are-our-national-forests-going-up-in-smoke-34616.html
    b. http://www.sacbee.com/2013/08/04/5620421/environment-is-going-to-potgrowers.html
3. What is a tourniquet and how can it save a person's life?
4. What are bacteriophages?
5. **Summarize the life cycle of a lysogenic phage.
6. **What is microbial syntrophy? (Abstract of journal article: http://www.ncbi.nlm.nih.gov/pubmed/23480449)

Additional Topics for Essays & Discussion

U.S. domestic energy production activity

To answer the following questions, see interactive U.S. map "Where US energy is produced." http://www.nbcnews.com/id/51181011

1. Which two U.S. states produce the greatest amount of energy (measured in btu's)?
2. Which three U.S. states produce the greatest amount of crude oil?
3. Which four U.S. states produce the most coal?
4. Think: why is biofuel production concentrated in the Midwest states? (Hint: the predominant biofuels in the U.S. are ethanol and biodiesel.)
5. Do you live a state where "fracking" takes place? Do you know anyone who has a fracking well on their property?

Essay / Discussion Topic: Fracking

- First, watch this excellent two minute video by National Geographic "What is Fracking?" http://ngm.nationalgeographic.com/2013/03/bakken-shale-oil/fracking-animation-video
- Read "What is Fracking?" summary by LiveScience http://www.livescience.com/34464-what-is-fracking.html
- Opinions for and against fracking are often passionate. Find four online sources of information about fracking, two that are critical/opposed and two that are supportive/in favor.
    - What are the main arguments for and against fracking?
    - What are the benefits of fracking?
    - What are the *known* risks/costs?
    - What are the *potential* risks?

Essay / Discussion Topic: Keystone XL pipeline

Even without Christina's bacteria, petroleum is being extracted from the tar sands of Alberta. A Canadian company has applied for permission to build a massive pipeline to transport tar sand oil into the U.S. This Keystone XL pipeline project is controversial. What are the proposed benefits? Why are some people vehemently opposed to the Keystone pipeline?

- Sample website PRO: TransCanada http://keystone-xl.com/
- Sample website CON: Friends of the Earth http://www.foe.org/projects/climate-and-energy/tar-sands/keystone-xl-pipeline

Experiments: "Kitchen Science" based on *Petroplague*

These experiments do not require microbiology lab facilities.

Experiment #1: *Why can't Los Angeles flush the petroplague out of contaminated pipes?*

Materials:
2 small canning (Mason) jars and lids
2 cans of **clear** chicken broth

Procedure:
Submerge one of the jars and its (unattached) lid in boiling water for 2 minutes. Remove from water and let cool. Fill jar about ¾ full with fresh clear chicken broth at room temperature. Loosely cover jar with lid (do NOT tighten or seal). Set in a warm place until the broth becomes visibly cloudy (this might take days; if too slow, remove the lid).

Boil the second jar and lid.

Dump out the contaminated broth. Fill the first, dirty jar with tap water and dump the water once to rinse it. Now open a second can of clear chicken broth and fill both jars, the clean and the contaminated, about ¾ full with broth. Loosely cover and set them in a warm place. Observe the jars to see how long it takes for each to become cloudy.

Question: Which jar gets cloudy first?

Hypothesis: The previously contaminated jar will get cloudy sooner than the clean jar.

Interpretation: Once microbes have colonized a space or surface (such as a jar or a pipe), it is difficult to get rid of them by mechanical means (washing or flushing). Even if it *looks* like the vessel is clean, it only takes one microscopic cell left behind to start dividing and re-populate the space. That's why sterilization (using heat or harsh chemicals) is necessary for medical equipment. This is also why Los Angeles can't cure the petroplague simply by flushing all the pipes and tanks and adding fresh gasoline.

Experiment #2: *Demonstrate why the dipstick gauge used by the tanker truck in chapter 12 spread the petroplague beyond its origin at the GasMan station.*

Materials:
3 small canning (Mason) jars and lids
2 cans of **clear** chicken broth
Cotton swabs

Procedure:
Submerge one of the jars and its (unattached) lid in boiling water for 2 minutes. Remove from water and let cool. Label jar #0 and fill about ¾ full with fresh clear chicken broth at room temperature. Loosely cover jar with lid (do NOT tighten or seal). Set in a warm place until the broth becomes visibly cloudy (this might take days; if too slow, remove the lid).

Now boil two more jars and lids. Label jars #1 and #2. Fill both jars about ¾ full with fresh clear chicken broth at room temperature.

Dip a cotton swab in tap water and then swirl it in the broth in Jar #1. Take a fresh cotton swab and dip it in the cloudy broth in Jar #0. Then swirl the swab in the broth in Jar #2. (You may dispose of Jar #0 at this time, or let the culture keep growing if you want to see what happens.) Loosely cover and set Jars #1 and #2 in a warm place. Observe the jars to see how long it takes for each to become cloudy.

Question: Which jar gets cloudy first?

Hypothesis: Jar #2 will get cloudy first.

Interpretation: Even a tiny droplet of liquid can contain a very large number of cells. You transferred many bacteria from Jar #0 to Jar #2. If the bacteria reproduce (double) at the same rate in both jars, Jar #2 will get cloudy first because it started with a much bigger population of microbes.

More formal experiments about biofuels:

Great Lakes Bioenergy Research Center offers biofuels educational materials, demonstrations and laboratories for K-16.

Links

I recommend the following links related to topics in *Petroplague*.

- Excellent short videos on microbial biofuels (each only 2-3 minutes)
    - "Using microbes to make advanced biofuels" by the Joint Bioenergy Institute (Jay Keasling) http://www.youtube.com/watch?v=oFH56nvzYQk
    - "Algae to Fuels" by U.S. Department of Energy http://www.youtube.com/watch?v=IxyvVkeW7Nk
    - "Using microbes to manufacture biofuels" by CNN (again featuring synthetic biologist Jay Keasling) http://www.youtube.com/watch?v=fLcYrXSGFZg
    - "How technology works: Algae to biofuels" by AlgaeTec http://www.youtube.com/watch?v=QP_HbQ5cWSk
    - Cellulose into ethanol http://www.glbrc.org/education/bioenergy101/multimedia

- What are microbial biofuels? http://www.microbiologyonline.org.uk/about-microbiology/microbes-and-climate-change/microbes-and-biofuels

- Earthquakes and significant faults in Southern California (interactive map) http://www.data.scec.org/significant/index.html

- "Pigging": use of pipeline inspection gauges http://en.wikipedia.org/wiki/Pigging

- Shale oil in California http://www.nytimes.com/2013/02/04/us/vast-oil-reserve-may-now-be-within-reach-and-battle-heats-up.html

- Los Angeles settings in *Petroplague*
    - The J. Paul Getty Museum http://www.getty.edu/museum/
    - La Brea Tar Pits http://www.tarpits.org/la-brea-tar-pits
    - The Los Angeles County Museum of Art http://www.lacma.org/

- UCLA's program on Bioenergy and the Environment http://www.chemistry.ucla.edu/bioenergy-and-environment

Vocabulary

Chapters 1-20

egregious
destitute
paterfamilias
tenacity
macabre
millennia
sedimentary rock
fissure
mishap
catalepsy
du jour
gaudy
despotic
indiscernible
dilapidated
paraphernalia
hazmat
conglomerate
brownfield
unkempt
coterie
olfactory
paucity
decrepit
asphyxiate
biosphere
volatile
anaerobic
unscrupulous
fuselage
pandemonium
thermophilic
ascertain
trepidation
indigo
photosynthetic

Chapters 21-40

multifaceted
coiffed
provisions
bunker
ration
disconcerting
scapegoat
novice
garnish
paragon
swivel
foreboding
agape
vicarious
concentric
longshoreman
Saturnalia
aqueduct
disheveled
pumpjack
quarantine
slouch
liberate

Chapters 41-60

Donner party
intermittent
klaxon
amalgam
dissipate
debris
belated
dither
shoji screen
mirthless
chagrin
accost
rendezvous
surreal
adroit
tumult
breach
infrastructure
grandiose
wallow
anarchy
gingerly
fait accompli
odometer
stymie
alibi
malicious
lurid
confiscate
fugitive
brandish
loiter
veneer
bedlam
flotsam

Chapters 61-83

surreal
crescendo
subtlety
torrent
antagonize
mired
chassis
clamber
khakis
douse
teeming
ruffian
pantomime
harbinger
desiccated
pyromaniac
tattered
tourniquet
excruciating
decibel
cairn
ecstatic
prudent
supine
parched
quell
pandemonium
finicky
beleaguered
brusque
monotony