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The features marked with a star (\*) are based entirely on material taken straight from standard research (and other Official and Therefore Always Correct) literature. Many of the other articles are genuine, too, but we don't know which ones.



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### On the Front Cover

Bacteriologist Richard Losick lets his intestinal bacteria have their say, concluding the keynote speech at this year's Ig Nobel Prize Ceremony. Performing chemist Daniel Rosenberg wields the microphone. Photo: Kees Moeliker.

## On the Back Cover

The thrilling conclusion to The Bacterial Opera: mouthwash overwhelms the plucky bacteria on an obvilious woman's tooth. Photo: Mike Benveniste.

February 19, 2011	AAAS Annual Meeting,	April 2011	Cambridge (MA) Science Festival
	Washington, DC, USA	June 2011	Cairo, Egypt
March 2011	Ig Nobel Tour of the UK	September 2011	Geneva, Switzerland
April 2011	Edinburgh Science Festival	September 29 2011	Ig Nobel Prize Ceremony
April 2011	Ig Nobel Scandinavia Tour	1 ,	Ig Informal Lectures
		0000001,2011	ig informat Lectures

See WWW.IMPROBABLE.COM for details of these and other events.

## **LIBRETTO: The Bacterial Opera**

#### Words: Marc Abrahams

Music: Jacques Offenbach, Giuseppe Verdi, and Arthur Sullivan (And thanks to Mary Ellen Davey, Harriet Provine, Dany Adams, and Carl Zimmer for bacteriological insights, and Robert Csillag, DDS, and his staff for inspiration on microbial matters.)

The Bacterial Opera premiered as part of the 20<sup>th</sup> First Annual Ig Nobel Prize Ceremony, at Sanders Theater, Harvard University, Cambridge, Massachusetts, on September 30, 2010. Video of the performance can be seen at www.improbable.com.

### **Original Cast**

*Stage manager and conductor*: David Stockton

Kirkospocokococcus: Maria Ferrante

Gallileococcus: Ben Sears

Sidekickococcus: Roberta Gilbert

Accordionococcus: Thomas Michel

Bacillusnameless: Marc Andelman

The woman: Jenny Gutbezahl

Supporting bacilli: Sheldon Glashow, Roy Glauber, William Lipscomb, James Muller, Frank Wilczek, Neil Gaiman, Amanda Palmer, Jason Webley, Mary Ellen Davey, Rich Losick, and a multitude of bacteria.

Pianist: Branden Grimmett

Costume designer: Jenn Martinez.

The characters are a WOMAN, who spends the entire time—except at the very end—sitting on a chair napping with her mouth open so we can see her teeth, and the BACTERIA who live on one of her front teeth. Those bacteria, KIRKOSPOCKOCOCCUS, SIDEKICKOCOCCUS, and GALLILEOCOCCUS, do all the singing. Most of the characters on stage are non-singing bacteria. In the premiere one bacterium played the accordion.

TOP CENTER: Kirkospockococcus and Sidekickococcus. Photo: Mike Benveniste.



### ACT 1—Stuck on This Tooth

NARRATOR: Tonight's opera stars several trillion bacteria-would you all please take a bow?—several trillion bacteria... and one human being-a woman, who as you can see, is asleep on a chair, with her mouth hanging open. The action takes place on one tooth inside that woman's mouth. The main characters are called KIRKOSPOCKOCOCCUS. SIDEKICKOCOCCUS and GALLILEOCOCCUS. We have arranged a sort of microscope so you can see them. Let's take a look. Will one of the technicians please turn on the microscope?

[KIRKOSPOCKOCOCCUS AND SIDEKICK-OCOCCUS AND GALLILEOCOCCUS COME ON STAGE AND TAKE A BOW.]

Ah. Here they are, magnified so very much that—believe it or not—these teeny-tiny, liddle-widdle bacteria appear to be the SAME SIZE AS THE HUMAN BEING. Isn't that a hoot? Here in Act 1, KIRKOSPOCKOCOCCUS and SIDEKICKOCOCCUS will explain why they hate being stuck, their whole lives, on this tooth. But you know, and I know, that what they REALLY hate are all the many, many other bacteria species in their crowded neighborhood. Let's listen to them gripe...

Kirkospockococcus and Sidekickococcus try to ignore a nasty neighbor bacterium. Photo: Alexey Eliseev. [TUNE: "Barcarolle" by Offenbach, from "Tales of Hoffman"]

KIRKOSPOCKOCOCCUS and SIDEKICKOCOCCUS:

Nasty neighbors! Nasty neighbors! Nasty neighbors! Nasty neighbors! Nasty neighbors! Nasty neighbors!

[HERE IS WHERE WORDS BEGIN IN ORIGINAL OFFENBACH VERSION]

Streptococcus! Stuck on this tooth, With neighbors who hurt and mock us. Let's name names. Let's tell the whole truth.

Let's name the scum on this tooth!

TrepoNEEma dentiCOla! What a loathsome neighbor!

Squirts and leaks and drips and drools Such stinky molecules.

Such stinky molecules! Prob'ly some kind of peptide...

Those stinky molecules—They eat holes in my hide.

Stinky molecules. Stinky molecules. Pee yooo!

Porph'ro-MO-nas gingi-VA-lis! What a loathsome neighbor!

Night and day, they spew and they spray / Bacteriocin spray.

Bacteriocin spray / Makes our guts leak away.

Our guts leak away. They leak away. Oooh! Oooh!





Galileococcus uses a mock-up to show his fellow bacteria what a human being looks like and which portions of it are good habitats for bacteria. Photo: Eric Workman.

## ACT 2–A Vision of Distant, Bigger Things

NARRATOR: Among the billions of bacteria on this crowded tooth, there is a great-truly great-scientist, a microbe named Gallileococcus. Gallileococcus has just invented the telescope! Here's how he did it. As you know, the bacteria that live on teeth produce a kind of slime. You probably call it "biofilm," or even "a matrix of excreted polymeric compounds". But it's slime. One day, Gallileococcus burrowed down deep into that slime. And from down there, he looked back up, through the slime, toward the light. The slime acted as a lens, a sort of telescope. Looking through that telescope. Gallileococcus saw things that—until that moment—microbes believed were merely myths and legends. He saw.... human beings! And when he focused the telescope, he saw that those human beings are covered with-yes!-bacteria! Alien bacteria! Let's watch now, as GALILEOCOCCUS tells his fellow tooth bacteria that... they are not alone in the universe!

[TUNE: "I've got a little list" from "The Mikado," Gilbert and Sullivan]

[OPTIONALLY, HE CAN BRING OUT A TRADITIONAL TELESCOPE—IF SO, THEN WHEN HE FIRST SHOWS IT, PROJECT A SLIDE THAT SAYS: "NOTE: Telescope shown here is not actual shape"]

*The sleeping woman. Photo: Kees Moeliker.* 

#### GALILEOCOCCUS:

- My fellow microbes! Listen! I have got a new machine.
- It's called a telescope! It's called a telescope!
- Now it's possible to look at distant things we've never seen.
- Just look through the telescope! Look through the telescope!
- Folks, I found this telescope by going deep into the slime
- That we all make from schmutz that we secrete from time to time.
- Then I gazed back, up toward the sky— And through that slimy lens,
- I saw some human beings! I saw homo sapiens!
- THEN... I saw something BETTER—so good I can barely cope!
- It filled me full with hope! Now I am filled with hope!
- ALL [sing the second line slowly,
- enunciating each word distinctly]:
- You scientific dope! Now WE are filled with hope!
- Tell us what you saw, you dope, in that damn telescope!

[TUNE: "La donna e mobile" from "Rigoletto," Verdi]

[MAYBE HAS A STICK POINTER, USING IT TO POINT TO A WEIRD DRAWING OF A HUMAN ANATOMY CHART AS DRAWN BY A BACTERIUM] I saw bacteria /In far off places. I saw their faces./ They look quite friendly. They live in domiciles, / On human creatures, Lodged in the features / That are uncleanly. Beneath the toenails! Inside the entrails! Under the armpits! Where it is moist. It must be moist! Not dry! They'd die! It must be moist. Nice human real estate / In such variety

Nice human real estate / In such variety Fosters society /Among the microbes! All the best neighborhoods /

Have some concavity.

[ASIDE:] (You want depravity? /

Go live on ear lobes!) Caudal and rostral! Anus and nostril! Stomach and colon! Where it is moist. It must be moist! Not dry! They'd die!

It must be moist.

#### ACT 3 "Stand on the Shoulders of Giant Piles of Bacteria"

NARRATOR: Having seen that they are not alone in the universe, the bacteria want to leave their leave their detested home tooth, and voyage off to make contact with those far distant microbes. They have a plan. They will get all their neighbors—all the tooth bacteria—to reproduce madly. The bodies will pile up high, building a tower that will grow



up into the heavens, and eventually reach the distant places they see in the telescope. Let's eavesdrop as they prepare to boldly go where none of them has gone before.

[TUNE: "Sempre Libera" from "La Traviata," Verdi]

KIRKOSPOCTOCOCCUS: Let's go! Let's go! Let's go!

Come, bacteria! Into space—the place they call "the final frontier"!

We will voyage off, enterprisingly, and get the hell out of here!

On this tooth, we will build a tall tower. It will climb way up into the sky. Generations of microbes will build it. Listen to me—I'll tell you why!

Now that we know, Now that we know, Now that we know there's bacteria there,

Well, we must go—o—o. Go and—say hello.

#### GALLILEOCOCCUS:

[GEEKILY, GIVING A MATTER-OF-FACT RECITATION FROM AN ENGINEER'S PESPECTIVE]

To estimate our travel time, I've calculated our rate of climb.

KIRKOSPOCTOCOCCUS: Engineer!!!

GALLILEOCOCCUS:

This simple tower will double in height each time we reproduce. Total construction time: Just a few hours!

#### KIRKOSPOCTOCOCCUS:

Precisely! Precisely! Oh! Let's go! Let's go! Let's go! Let's go!

Come on! Come on! Oh, don't you wonder, wonder

What new species we'll meet there! What new shapes and sizes and

personalities will greet us up there! Are they rod-shaped or rounded or twisty?

Are they bulbous, or covered with zits? Are they rigid—or kind of misty? Are they friendly, or are they shits?

Soon we will know! Soon we will know!



Sheldon Glashow, bacterium, sweeps the old life away. Photo: Kees Moeliker.

Soon we will know what bacteria's there. Oh, let's go—o—o. Go-o-o-o, and say hello.

GALILEOCOCCUS: But if they're bumbling... Or they start grumbling...

KIRKOSPOCKOCOCCUS: Oh! Oh! Oh! Oh! Oh! You just know that they will!

GALILEOCOCCUS:

We'll make them disappear — Go find their own frontier!

KIRKOSPOCKOCOCCUS: O-o-o-o-oh!

We'll make them go. We'll make them go. Just boldly... go. Just coldly... go.

## ACT 4. "A Brush With Disaster"

is starting to awaken the sleeping woman-the woman whose tooth is the home planet for all these bacteria. Let's hope, for the bacteria's sake, that this woman is not one of those people who thinks only about her own comfort and well-being. You know the kind I mean-someone who would -viciously-brush, brush, brush her teeth, then mass-murderously floss, floss, floss her teeth, and then, for overkill, gargle with mouthwash. For the sake of this woman's oral bacteria. let's hope she has more consideration than to do any of that that. Anyway, before the woman wakes up, let's hear what her oral bacteria have to say about their upcoming journey.

[TUNE: "stride la vampa" from "Il Trovatore," Verdi. NOTE that in Verdi's original, this tune comes after, rather then before, the grand anvil chorus.]

#### KIRKOSPOCKOCOCCUS:

Soon we will go away. Go away. We'll go away.

Enough of watching this tooth decay. Festering away. Decay.

Life on this old tooth / Won't ever be the same.

Things have become so uncouth. / Now it's just an endgame.

Stay here? Who would do? Only a very few,



*Flossing overcomes the bacteria. Photo: Kees Moeliker.* 

It's just the residue. Life here will struggle on without us, without us.

Scre-e-ew you, you residue!

Now let us make our getaway! Cast the past away—

Far, far, far, far away!

Throw the old life away! Throw it all away! Throw it all away!

- Scrape the old life away! Scrape the life away!
- Brush the old life away! Brush the life away!

Scrub, scrub the old life away! Scrub it all away! Scrub it away! Rinse it away! Yes—flush everything... Flush everything away! Flush everything away!

[THE WOMAN AWAKENS, STANDS UP, BEGINS CLOSING AND OPENING AND FLEXING HER MOUTH. LIGHTS FLASH OFF AND ON DISTURBINGLY, IN SYNCH WITH HER MOUTH CLOSING AND OPENING. THE BACTERIA PANIC.]

[TUNE: "Vedi! Le fosche notturne spoglie" (the anvil chorus) from "Il Trovatore," Verdi]

ALL THE SINGING BACTERIA:

Darkness and lightning! It's frightening! It's frightening! It's frightening! It's frightening! Hey, what just happened?

Darkness and lightning! It's frightening! It's frightening! It's frightening! It's frightening! Hey, what just happened?

I don't know what the... What the...??? What happened??? [A GIANT TOOTHBRUSH IS CARRIED ON STAGE. A PROJECTED SLIDE SAYS: "NOTE: Toothbrush shown here is not to scale"]

[THE WOMAN BRUSHES HER TEETH, RHYTHMICALLY AND RATHER VIOLENTLY. A TREMENDOUS ANVIL-BANGING SOUNDS—AND LIGHTS FLASH ON AND OFF—EVERY TIME SHE BRUSHES ACROSS HER TEETH.]

Brush! Brush! This brushing is crushing us to pieces! Brush! Brush! This brushing is crushing us to pieces!

Brush! Brush! Brush! Brush! Brush!

Hey, what just happened? Hey, what just happened? Hey, what just happened?

Hey—what just happened? Can anyone tell us?—Or even hint?— Hey, what just happened?

Thunder and lightning!

It's frightening! It's frightening! It's frightening! It's frightening! Is this the end? It's oblivion!

[A GIANT ROPE IS CARRIED ON STAGE. A PROJECTED SLIDE SAYS: NOTE: "Dental floss shown here is not to scale"]

[THE WOMAN FLOSSES HER TEETH, RHYTHMICALLY AND RATHER VIOLENTLY. A TREMENDOUS ANVIL-BANGING SOUNDS—AND

LIGHTS FLASH ON AND OFF-EVERY TIME SHE SWEEPS THE FLOSS THROUGH HER TEETH. THE BACTERIA DIE OFF IN WAVES BETWEEN HERE AND THE END OF THE SONG.]

- Floss! Floss! This flossing is tossing us to pieces!
- Floss! Floss! This flossing is tossing us to pieces!

[A GIANT FILMY CLOTH, MEANT TO REPRESENT A WAVE OF MOUTHWASH, IS CARRIED ON STAGE. A PROJECTED SLIDE SAYS: "NOTE: Mouthwash shown here is not to scale"]

[THE WOMAN GARGLES WITH MOUTHWASH, RHYTHMICALLY AND RATHER VIOLENTLY. A TREMENDOUS ANVIL-BANGING SOUNDS—AND LIGHTS FLASH ON AND OFF—EVERY TIME SHE DOES.]

Flush! Flush! Flush! Flush! Flush!

[THE WOMAN SPITS OUT THE MOUTHWASH INTO THE AUDIENCE (OR, IF PROPRIETIES MUST BE OBSERVED, INTO A VAT)]

[ALMOST ALL OF THE BACTERIA ARE NOW DEAD. THE REMAINING FEW ARE BARELY STANDING—THEY WILL MANAGE TO SING THE FINAL WORDS, AND THEN THEY WILL DIE.]

This is the end of... This is the end of... Bacte-e-e-ria!

[ALL THE BACTERIA ARE NOW DEAD. THE WOMAN STANDS, SMILING, STRETCHING JOYOUSLY, AND NOW FULLY AWAKE. FOR HER IT'S JUST THE START OF ANOTHER DAY.]



Mouthwash overwhelms the bacteria. ABOVE Photo: Eric Workman. LEET Photo:

*LEFT Photo: Mike Benveniste.*