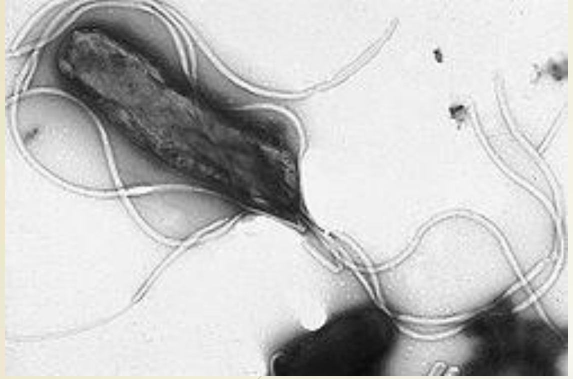
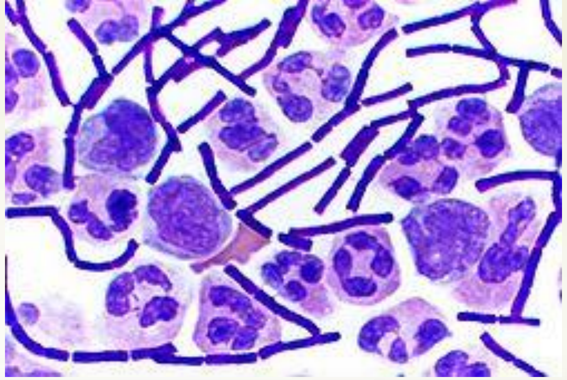
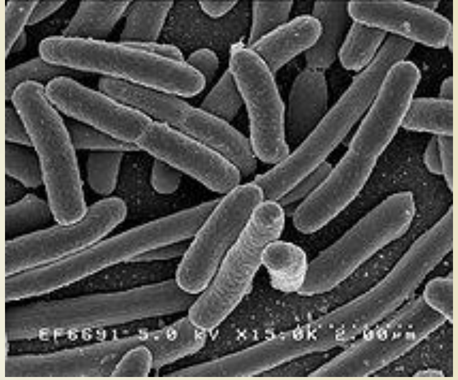






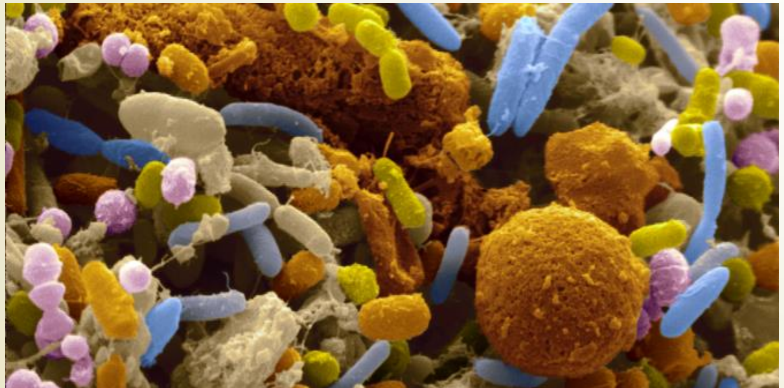
OSNOVE MIKROBIOLOGIJE
183958

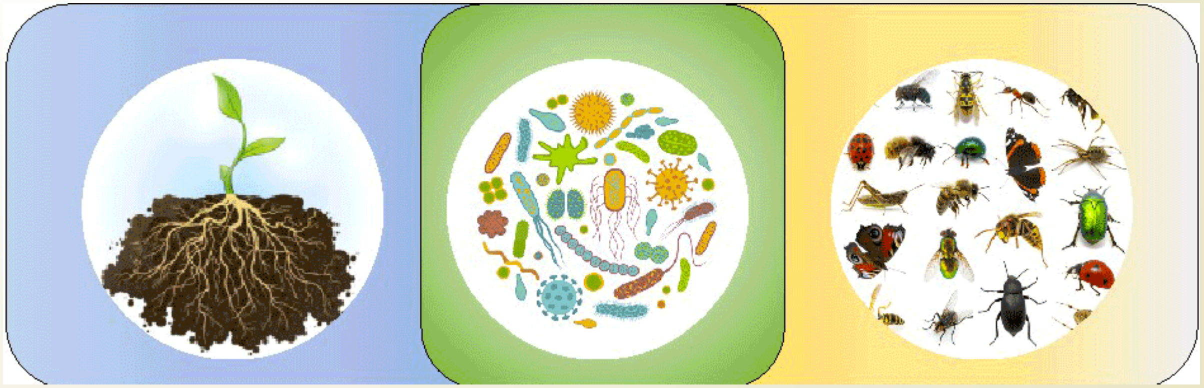
Prof. dr. sc. Martina Šeruga Musić

martina.seruga.music@biol.pmf.hr

akad. god. 2025./2026..

studij biologije i kemije



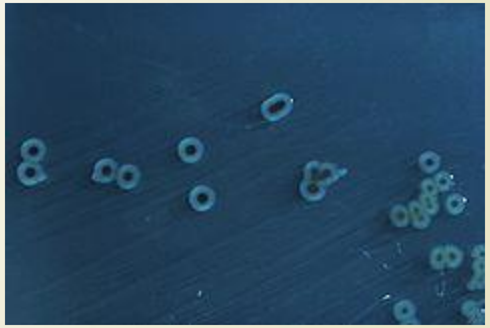


- MIKROBIOLOGIJA HRANE
- INDUSTRIJSKA MIKROBIOLOGIJA I BIOTEHNOLOGIJA

•MIKROBIOLOGIJA HRANE

Mikrobiologija hrane

- hrana, mikrobi i ljudi oduvijek su povezani
- mikrobi služe u proizvodnji i preradi hrane i pića, ali mogu uzrokovati i njeno kvarenje
- putem hrane prenose se i mnoge bolesti



Salmonella enterica

Mikrobi i kvarenje hrane

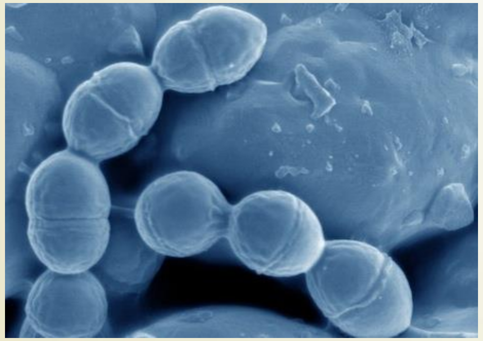
- rast mikroba u hrani ovisi o intrinzičkim (sastav hrane) i ekstrinzičkim faktorima (uvjeti u okolišu)

- npr. pokvarena hrana koja se sastoji uglavnom od ugljikohidrata ne rezultira neugodnim mirisima, dok se kvarenjem hrane bogate proteinima i mastima oslobađaju neugodni mirisi (pokvareno meso, jaje...)

- putrefakcija - razgradnja proteina iz hrane od strane anaerobnih bakterija – produkti – organski amini putrescin i kadaverin, neugodnog mirisa

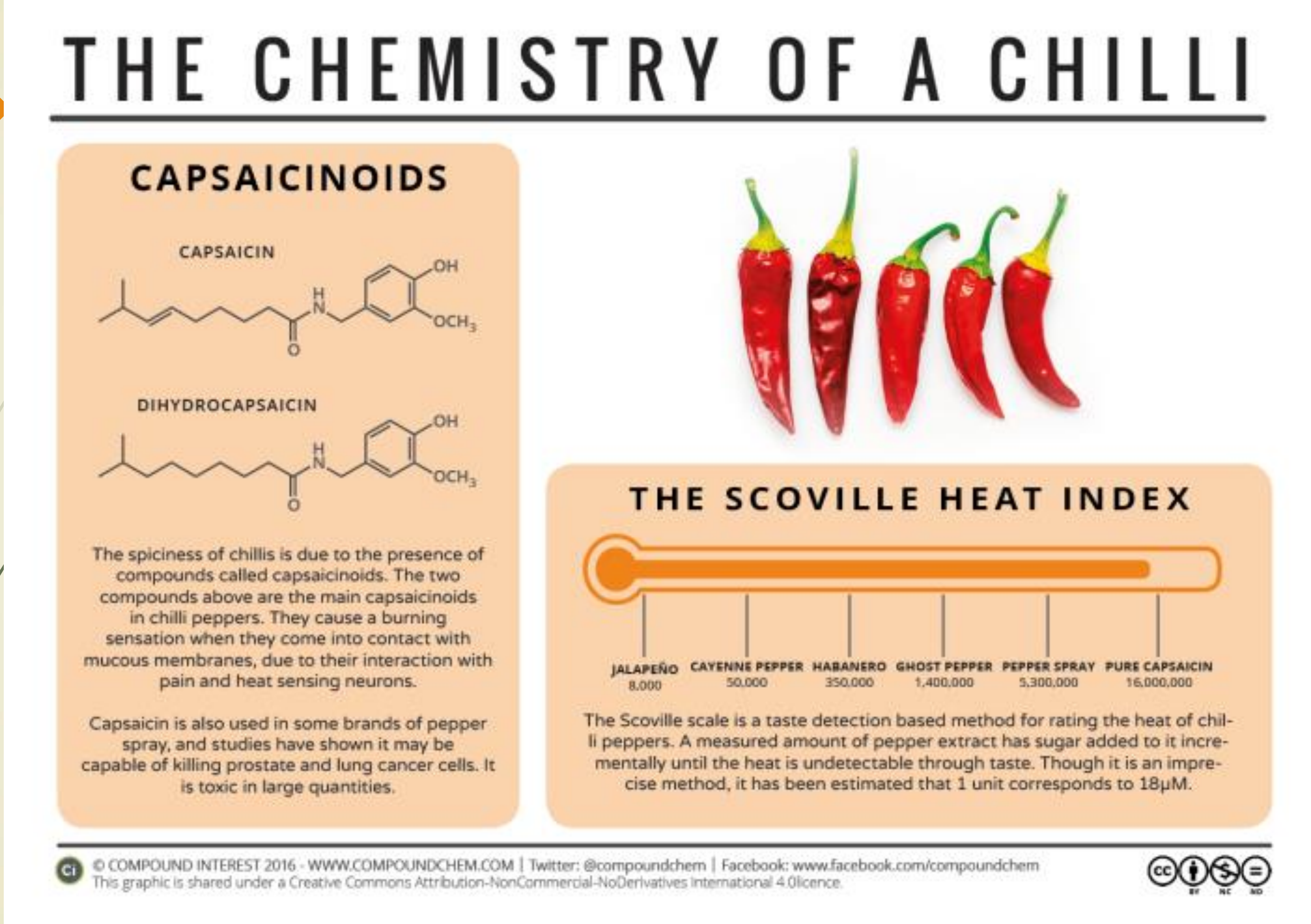
Table 40.1	**Differences in Spoilage Processes in Relation to Food Characteristics**		
Substrate	**Food Example**	**Chemical Reactions or Processes**[1]	**Typical Products (and Effects)**
Pectin	Fruits	Pectinolysis	Methanol, uronic acids (loss of fruit structure, soft rots)
Proteins	Meat	Hydrolysis, deamination	Amino acids, peptides, amines, H_2S, ammonia, indole (bitterness, souring, bad odor, sliminess)
Carbohydrates	Starchy foods	Hydrolysis, fermentation	Organic acids, CO_2, mixed alcohols (souring, acidification)
Lipids	Butter	Hydrolysis, fatty acid degradation	Glycerol and mixed fatty acids (rancidity, bitterness)

• kvarenje mlijeka: bakterije vrste *Lactococcus lactis* proizvode mliječnu kiselinu, što omogućava rast bakterijama roda *Lactobacillus* koje dodatnom proizvodnjom mliječne kiseline dalje snižavanju pH-vrijednost mlijeka; zatim nakupljenu mliječnu kiselinu razgrađuju kvasci i plijesni te smanjuju kiselost - aktiviranje bakterija koje razgrađuju proteine što rezultira gorkim okusom i neugodnim mirisom

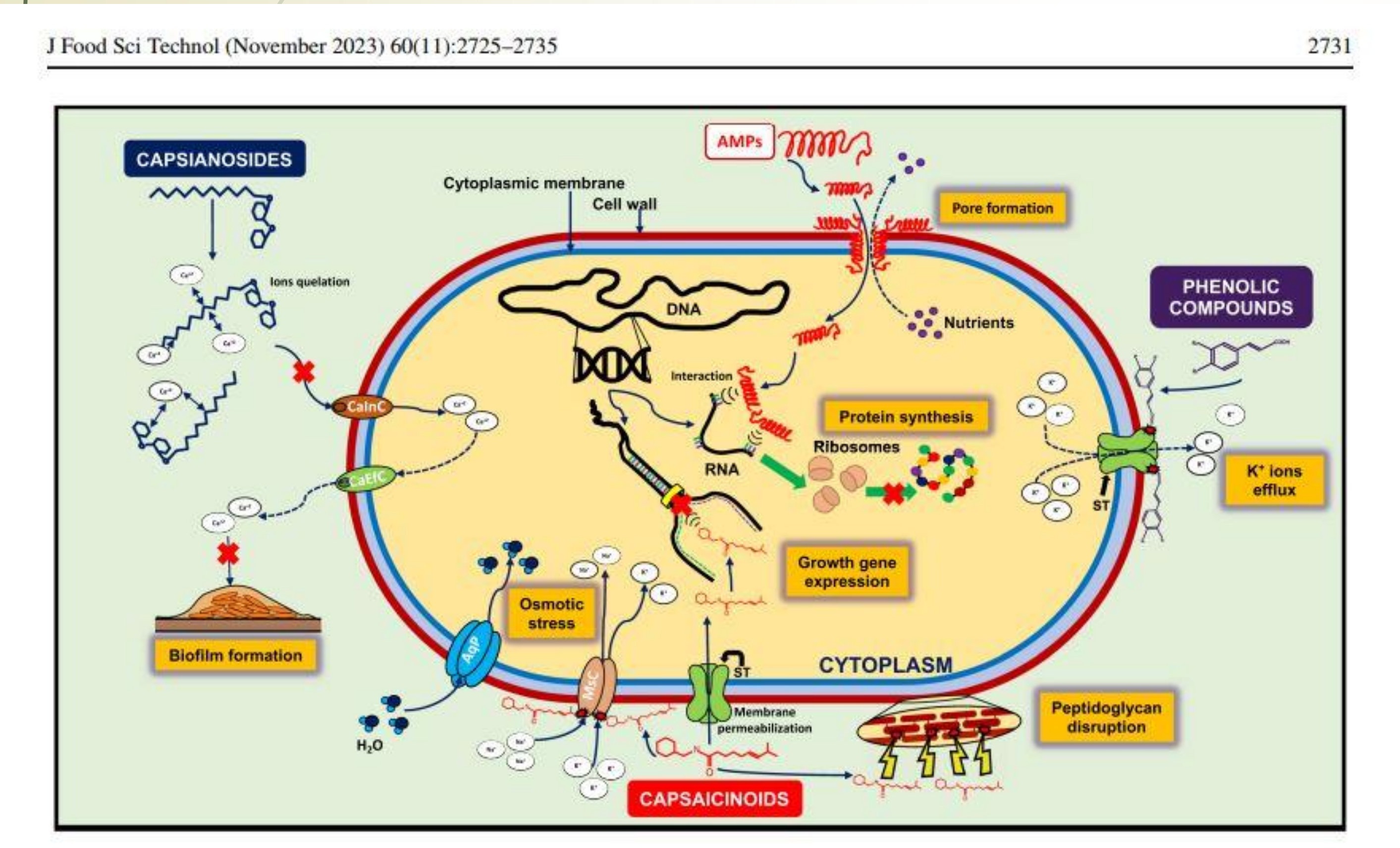


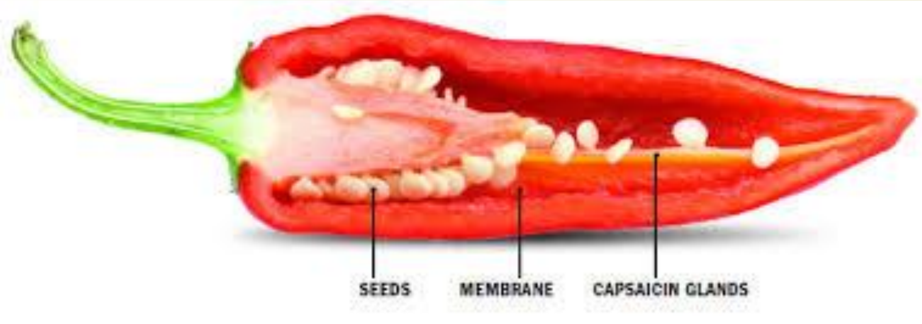
- mnoge prehrambene namirnice, začinsko bilje i začini prirodno sadrže tvari koje mogu imati antimikrobni učinak

- češnjak (alicin), ljute paprike (kapsaicin), kadulja, ružmarin (karnozol), papar (piperin), čajevac, brusnica, *Echinacea*, cimet, nefermentirani zeleni i crni čaj – sekundarni metaboliti biljaka - polifenolne tvari


THE CHEMISTRY OF A CHILLI
CAPSAICINOIDS
CAPSAICIN
OH
H
N
O
OCH3
DIHYDROCAPSAICIN
OH
H
N
O
OCH3
The spiciness of chillis is due to the presence of compounds called capsaicinoids. The two compounds above are the main capsaicinoids in chilli peppers. They cause a burning sensation when they come into contact with mucous membranes, due to their interaction with pain and heat sensing neurons.
Capsaicin is also used in some brands of pepper spray, and studies have shown it may be capable of killing prostate and lung cancer cells. It is toxic in large quantities.
THE SCOVILLE HEAT INDEX
JALAPEÑO 8,000
CAYENNE PEPPER 50,000
HABANERO 350,000
GHOST PEPPER 1,400,000
PEPPER SPRAY 5,300,000
PURE CAPSAICIN 16,000,000
The Scoville scale is a taste detection based method for rating the heat of chilli peppers. A measured amount of pepper extract has sugar added to it incrementally until the heat is undetectable through taste. Though it is an imprecise method, it has been estimated that 1 unit corresponds to 18μM.
© COMPOUND INTEREST 2016 - WWW.COMPOUNDCHEM.COM | Twitter: @compoundchem | Facebook: www.facebook.com/compoundchem
This graphic is shared under a Creative Commons Attribution-NonCommercial-NoDerivatives International 4.0 licence.

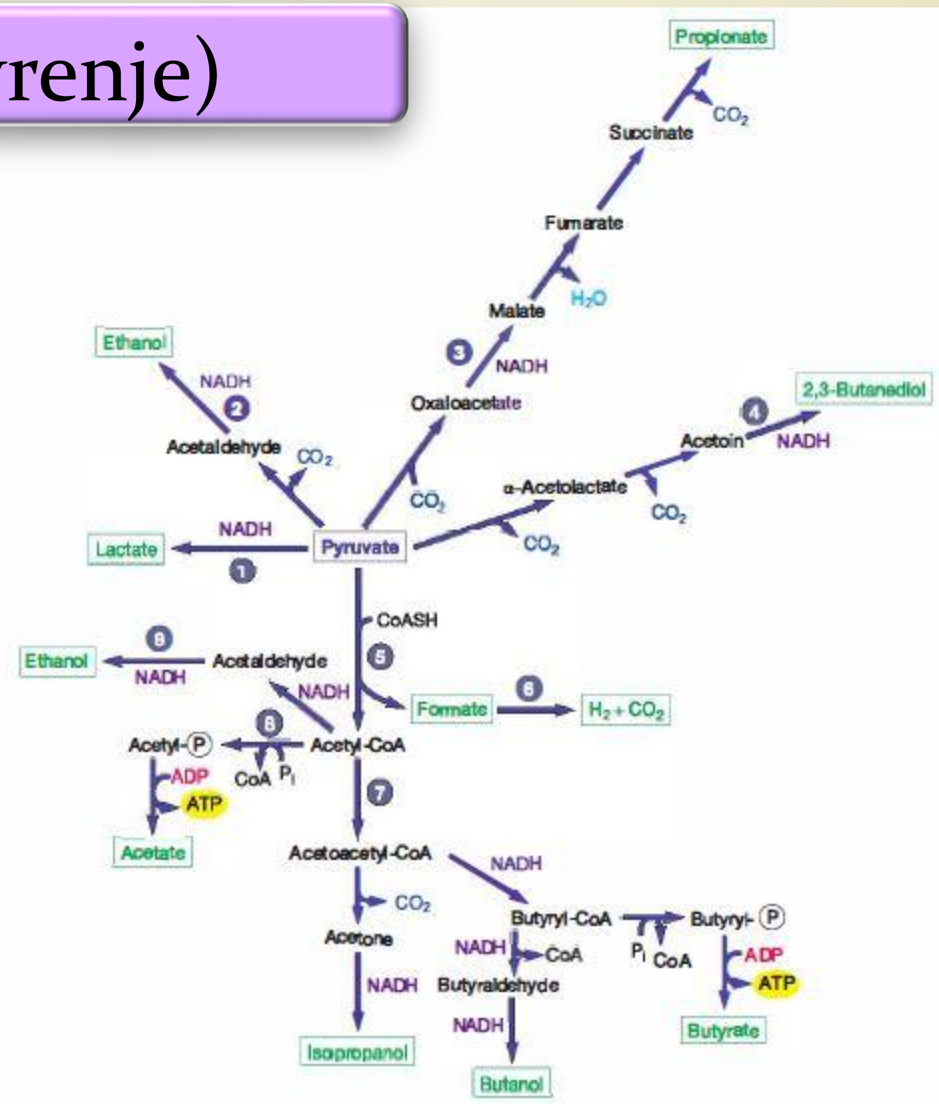
- kapsaicin i kapsaicinoidi – bakteriostatski i baktericidni učinak
- mehanizam – vezanjem na staničnu stijenku putem interakcija s lipidima poremeti se struktura peptidoglikana i olakšava ulazak iona kalcija i kalija u stanicu kao i kapsaicina – osmotski stres i liza stanica
- utjecaj na regulaciju ekspresije gena vezanih uz rast i replikaciju – smanjena stopa rasta
- utjecaj na stvaranje biofilma





Fermentacija (vrenje)

- različita značenja ovog pojma
- *zimologija* – dio primijenjene mikrobiologije koji se bavi fermentacijom
- pretvorba ugljikohidrata u alkohole korištenjem mikroba
- u prehrambenoj industriji - jedan od najvažnijih načina čuvanja hrane
- tipovi vrenja: mliječno, propionsko i etanolno vrenje



1. Lactic acid bacteria (*Streptococcus*, *Lactobacillus*), *Bacillus*, enteric bacteria (*Escherichia*, *Enterobacter*, *Salmonella*, *Proteus*)
2. Yeast, *Zymomonas*
3. Propionic acid bacteria (*Propionibacterium*)
4. *Enterobacter*, *Serratia*, *Bacillus*
5. Enteric bacteria
6. Enteric bacteria
7. *Clostridium*
8. Enteric bacteria
9. Enteric bacteria

Figure 11.20 Some Common Microbial Fermentations. Only pyruvate fermentations are shown for the sake of simplicity; many other organic molecules can be fermented. Most of these pathways have been simplified by deletion of one or more steps and intermediates. Pyruvate and major end products are shown in color.

- etanolno vrenje – razgradnja piruvata do etanola i CO_2 – kvasci (*Saccharomyces*) i neke bakterije

  - proizvodnja kruha, vina, piva

- mliječno vrenje – razgradnja piruvata do mliječne kiseline – bakterije roda *Lactobacillus*, *Lactococcus*, *Streptococcus*, *Bacillus* i neki kvasci

  - proizvodnja mliječnih fermentiranih proizvoda te fermentiranih suhomesnatih i ribljih proizvoda

- propionsko vrenje – razgradnja piruvata do propionske kiseline i CO_2 – bakterije roda *Propionibacterium*

  - proizvodnja švicarskog sira (Limburger, ementaler – rupe!)

Fermentiranje mlijeka

- mezofilne, termofilne i terapeutske mliječne bakterije (probiotici)
  - mezofili – kiselo mlijeko i kiselo vrhnje – *Lactobacillus* i *Lactococcus* (20 do 30°C)
  - termofili – jogurt – *Streptococcus thermophilus* i *Lactobacillus bulgaricus* (oko 45°C)

- probiotici – acidofil, AB-kultura

-*Lactobacillus acidophilus*, *Bifidobacterium bifidum*...

- "dobre" bakterije - pomažu probavnom i imunosnom sustavu - tolerancija laktoze, antitumorska i protuupalna svojstva, snižavanje kolesterola...

- kefir – fermentacija kulture koja se sastoji od pedesetak vrsta mliječnih bakterija i kvasaca – polisaharid kefiran – protuupalna i antitumorska svojstva

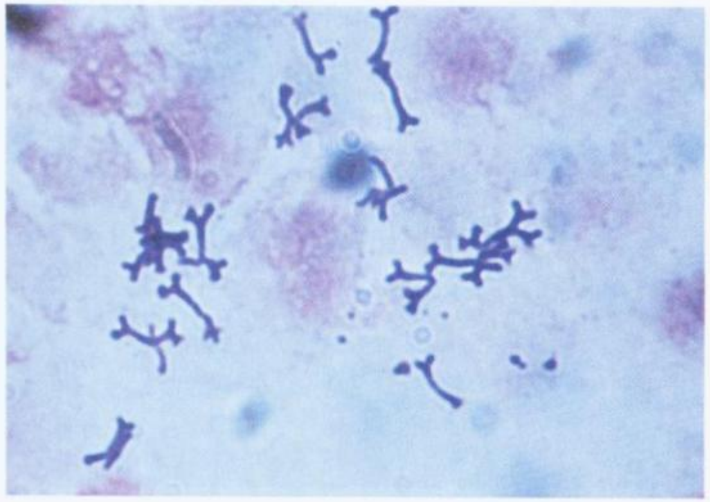


Figure 43.12 **Bifidobacterium.** Cultured milks are increasing in popularity. A light micrograph of *Bifidobacterium*, a microorganism suggested to provide many health benefits.

Proizvodnja sira

- prepostavlja se da datira još od 8000 godina p.n.e.
- više vrsta mikroba – rani stadij i kasniji stadij ("zrenje")
- meki sirevi

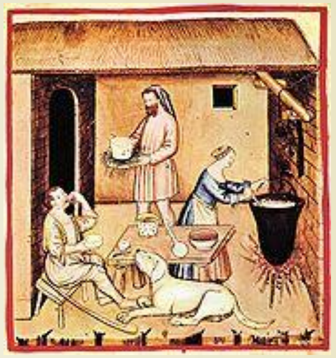
Lactococcus, Lactobacillus, Streptococcus → *Leuconostoc cremoris*

- sirevi s plemenitom plijesni

Lactococcus → *Brevibacter ili Penicillium* (plijesan)

- tvrdi sirevi

Lactococcus, Streptococcus → *Lactobacillus bulgaricus*



Proizvodnja alkoholnih pića

- etanolno vrenje
- prozvodnja vina, piva, žestokih alkoholnih pića....
- proizvodnja vina – kvasac *Saccharomyces cerevisiae* ili *S. elipsoideus*, ali i neke vrste "divljih" kvasaca
- konačni produkt sadrži 10-18% alkohola
- vinski ocat – nastaje oksidacijom etanola do octene kiseline dodatkom bakterija roda *Acetobacter* ili *Gluconobacter*

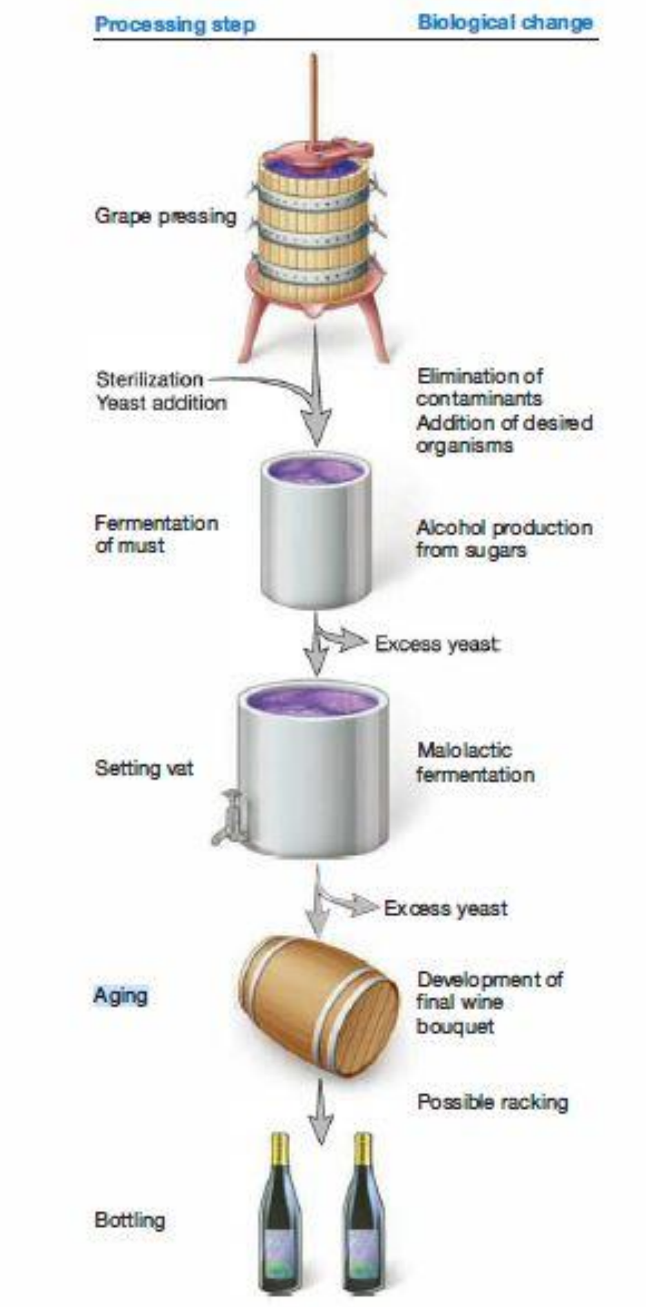


Figure 41.12 Wine Making. Once grapes are pressed, the sugars in the juice (the must) can be immediately fermented to produce wine. Must preparation, fermentation, and aging are critical steps.

- proizvodnja piva
- izvor škroba - ječam, žito, riža, kukuruz, krumpir
- hmelj – daje okus i arome te ima antibiotski učinak
- različite vrste kvasaca: *Saccharomyces cerevisiae*, *Saccharomyces pastorianum*, te rodovi *Brettanomyces* i *Torulaspora*
- može sadržavati od 3-30% alkohola

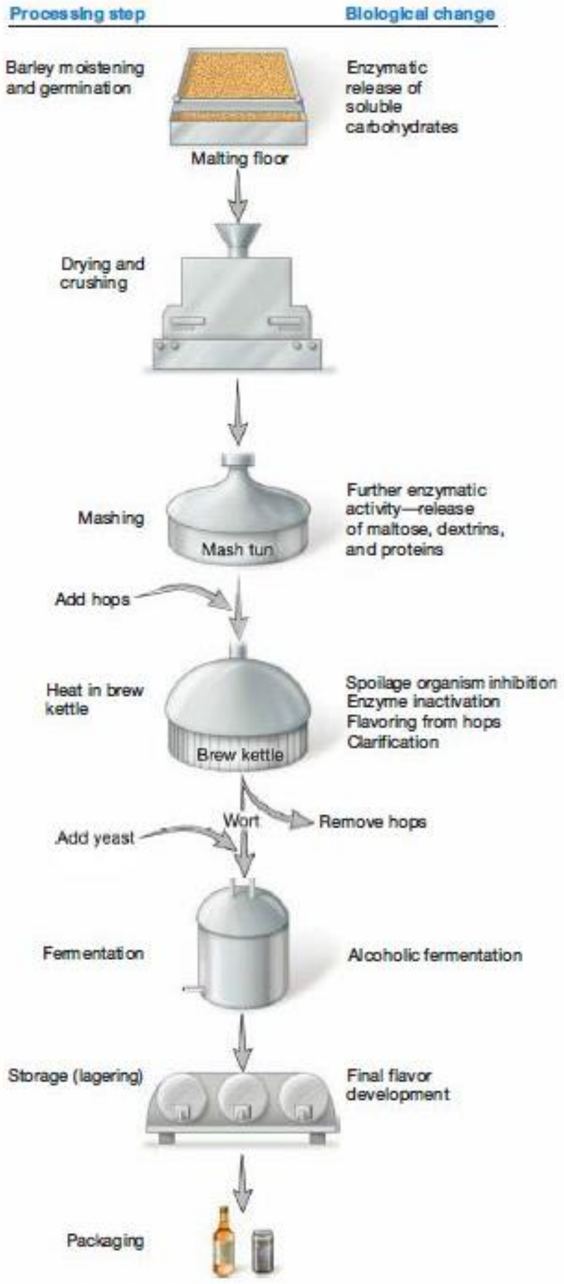


Figure 41.13 Producing Beer. To make beer, the complex carbohydrates in the grain must first be transformed into a fermentable substrate. Beer production thus requires the important steps of malting and the use of hops and boiling for clarification, flavor development, and inactivation of malting enzymes to produce the wort.

Ostala fermentirana hrana

- kruh – *S. cerevisiae*, ponekad i *Lactobacillus* – raženi kruh kiselog okusa
- kiseli kupus, masline – *Leuconostoc mesenteroides, Lactobacillus plantarum*
- kiseli krastavci – *Pediococcus cerevisiae*, *Lactobacillus plantarum*
- suhomesnati proizvodi, soja-sos, sake, kombuča, kava....

Table 40.3 Fermented Foods Produced from Fruits, Vegetables, Beans, and Related Substrates			
Foods	**Raw Ingredients**	**Fermenting Microorganisms**	**Location**
Bacteria-Fermented Foods			
Coffee	Coffee beans	*Enterobacter cloacae, Saccharomyces spp.*	Brazil, Congo, Hawaii, India
Gari	Cassava	*Corynebacterium manihot, Geotrichum spp.*	West Africa
Kimchi	Cabbage and other vegetables	Lactic acid bacteria	Korea
Ogi	Corn	Lactic acid bacteria, *Zygosaccharomyces rouxii*	Nigeria
Olives	Green olives	*Leuconostoc mesenteroides, Lactiplantibacillus plantarum*	Worldwide
Pickles	Cucumbers	*Lactic acid bacteria*	Worldwide
Poi	Taro roots	Lactic acid bacteria	Hawaii
Sauerkraut	Cabbage	*L. mesenteroides, L. plantarum, Levilactobacillus brevis*	Worldwide
Mold-Fermented Foods			
Kenkey	Corn	*Aspergillus* spp., *Penicillium* spp., lactobacilli, yeasts	Ghana, Nigeria
Miso	Soybeans	*Aspergillus oryzae, Zygosaccharomyces rouxii*	Japan
Soy sauce	Soybeans	*A. oryzae* or *A. soyae, Z. rouxii, Lactobacillus delbrueckii*	Japan
Sufu	Soybeans	*Actinimucor elegans, Mucor* spp.	China
Tempeh	Soybeans	*Rhizopus oligosporus, R. oryzae*	Indonesia, New Guinea, Suriname

Source: Jay, James M., Loessner, Martin J., Golden, David A. Modern Food Microbiology, *6th ed. New York: Springer, 2000.*

Tablica 19–3. Odabrane industrijske fermentacije

Produkt fermentacije	Komercijalna uporaba	Supstrat	Mikroorganizam
Etanol	pivo	sladni ekstrakt	*Saccharomyces cerevisiae* (kvasac)
	vino	*grožđe i ostalo voće*	Saccharomyces ellipsoideus (kvasac)
Octena kiselina	ocat	alkohol	*Acetobacter* (bakterija)
Mliječna kiselina	sir, jogurt	mlijeko	*Lactobacillus, Streptococcus* (bakterije)
	raženi kruh	*žitarice*	Lactobacillus bulgaricus (bakterija)
	zimska salama	*meso*	Pediococcus (bakterija)
Propionska kiselina i CO_2	švicarski sir	mlijeko	*Propionibacterium freudenreichii* (bakterija)
Aceton i butanol	farmaceutska industrija	melasa	*Clostridium acetobutylicum* (bakterija)
Limunska kiselina	začin	melasa	*Aspergillus* (plijesan)
Metanol	gorivo	poljoprivredni otpaci	*Clostridium* (bakterija)

Čokolada – slatka strana fermentacije

- srednja Amerika – 1900. p.n.e

- Maje (6. st.) i Asteci (13.-16. st.) – priprema napitka od sjemenki kakaovca *Theobroma cacao* ("hrana bogova") – za svečane ceremonije, obrede i prinos žrtvi bogovima

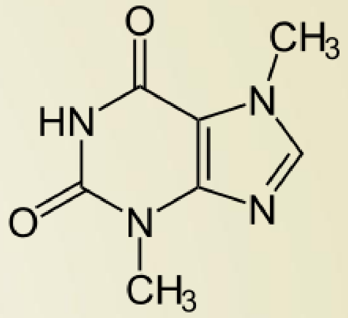
- aktivna tvar - alkaloid teobromin – sličan kofeinu

- uveden u Europu u 16. stoljeću i kasnije prenesen i u Zapadnu Afriku (19. st.)

- proces fermentacija sjemenki kakaovca nije se puno promijenio unatrag 500 godina
- sjeme i pulpa vade se iz mahune i pokrivaju lišćem banane
- fermentacija – sukcesija mikroba – traje 5-7 dana

- kvasci – *Saccharomyces cerevisiae, Candida rugosa, Kluyveromyces marxianus* – etanolno vrenje
- bakterije mliječnog vrenja – rodovi *Lactobacillus* i *Streptococcus*
- bakterije roda *Acetobacter* i *Gluconobacter*
- dodatne arome – rod *Bacillus* i plijesnji – *Aspergillus* i *Penicillium*
- sušenje
- prženje i rafiniranje – kakao-pasta – kakao-maslac i kakao-masa

- čokolada – 300 različitih kemijskih sastojaka – najzastupljeniji – teobromin



- vrste čokolade:
  - tamna čokolada – kakao-maslac, kakao-masa, šećer
  - mliječna čokolada - kakao-maslac, kakao-masa, šećer, mlijeko ili mlijeko u prahu, vanilija
  - bijela čokolada - kakao-maslac, šećer, mlijeko ili mlijeko u prahu, vanilija

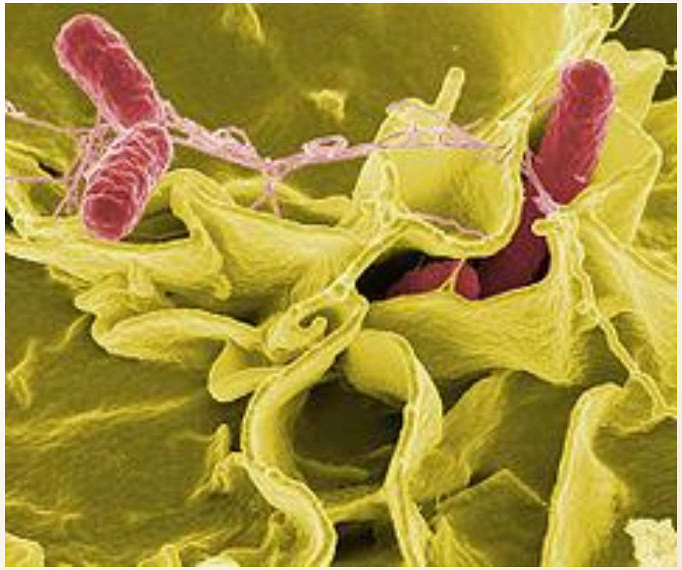
Bolesti koje se prenose hranom

- raste broj ljudi koji godišnje u svijetu umiru zbog bolesti koje se prenose hranom
- često povezano s lošim higijenskim uvjetima
- mogu biti: zaraze koje se prenose hranom i trovanja hranom

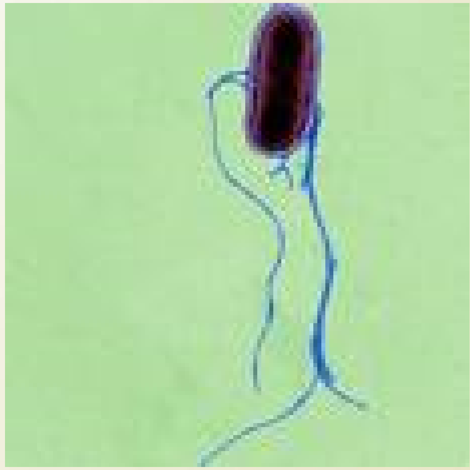
- zaraze koje se prenose hranom:

\- salmoneloze:

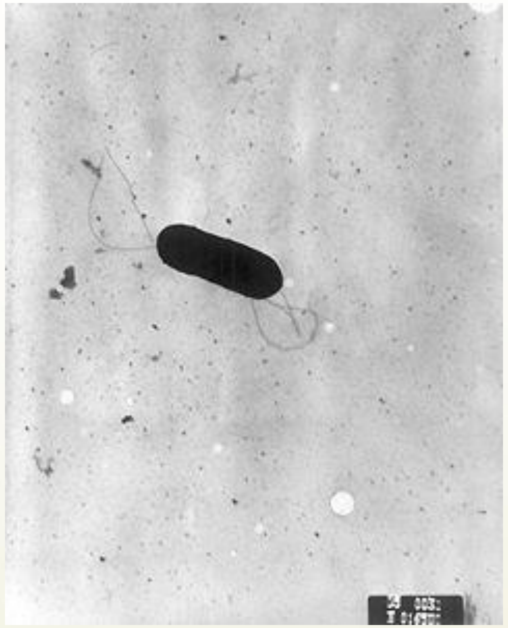
- *Salmonella enterica* subsp. *enterica* serovar *Enteritidis* i serovar *Typhimurim* (*Salmonella typhimurium*) - Gram-negativna enterobakterija koja uzrokuje salmonelozu (gastroenteritis – simptomi: povraćanje, proljevi, bolovi u trbuhu...)
  - nedovoljno termički obrađeno meso peradi, govedina, svinjetina, mlijeko i mliječni proizvodi, jaja.....
  - inkubacija 8-48h – bakterija luči enterotoksin i citotoksin koji uništava epitel crijeva



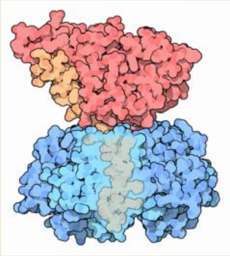
- *Salmonella enterica* serovar *Typhi* (*Salmonella* Typhi) – uzrokuje trbušni tifus (visoka temperatura, groznica, bolovi u trbuhu, kasnije proljevi, karakterističan ružičasti osip po prsima i trbuhu) – prenosi se hranom i vodom koja je bila u dodiru s fekalijama zaražene osobe
  - inkubacija 8-14 dana



- *Lysteria monocytogenes* – Gram-pozitivna bakterija, uzročnik listerioze
  - prenosi se putem zaraženog mlijeka i mliječnih proizvoda (osobito sireva kao što su Brie, Camembert, feta, nepasteriziranog mlijeka...), povrća i morskih plodova
  - simptomi: povraćanje, proljevi, glavobolje, ali i meningitis i sepsa često kod novorođenčadi



- *Vibrio cholerae* – Gram-negativna bakterija, uzročnik kolere
  - porijeklom s indijskog subkontinenta
  - prenosi se putem fekalijama zaražene hrane i vode; inkubacija od 24 do 72 h
  - bakterije u tankom crijevu luče toksin – (toksin kolere ili *choleragen)*, što uzrokuje jake proljeve, dehidraciju i smrt
  - toksin – kompleks koji se sastoji od podjedinica A i B
  - kodiran bakteriofagom CTXϕ ugrađenom u genom
  - “plava smrt”
  - ljudi krvne grupe 0 najosjetljiviji
  - oralna vakcina – pruža zaštitu 6 mjeseci do godinu dana
  - 1.3 – 4 milijuna ljudi u svijetu je ugroženo
  - 21000 – 143000 smrtnih slučajeva godišnje

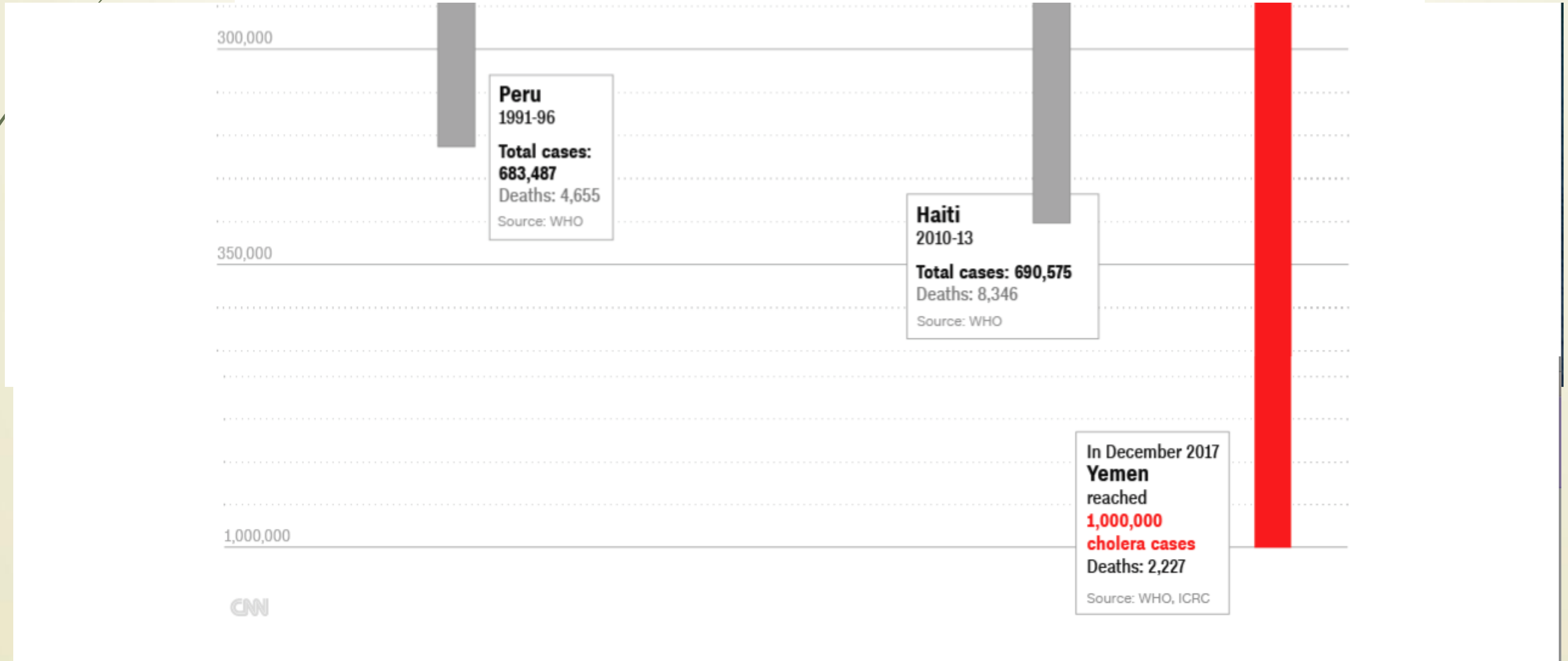


https://www.who.int/health-topics/cholera#tab=tab_1

https://www.youtube.com/watch?v=OQ15PKhPM6c

https://www.npr.org/sections/goatsandsoda/2019/04/02/707994461/cholera-101-why-this-ancient-disease-is-making-headlines-in-2019?t=1586244984729

Cholera outbreak hits record 1 million




africanews. EN
NEWS
Join us
NEWS
BUSINESS
SPORT
CULTURE
SCIENCE & TECHNOLOGY
NO COMMENT
PROGRAMMES
CHAN 2018
LIVE
Zambia: Cholera outbreak delays 2018 schools calendar
JUST IN
January 21, 2018
18:08 Ethiopia's Bekele to face Mo Farah, Kenya's Kipchoge in 2018 London marathon
18:08 Liberia's Sirleaf issues last minute order against female genital mutilation
17:12 Ethiopia protesters defy security to march over deaths in Amhara State
ADVERTISING
16:34 The Gambia's economy one year after Yahya Jammeh's departure
14:50 DR Congo security forces
By using this website, you agree with our use of cookies to improve its performance and enhance your user experience. More info in our Cookies policy page..
Ok

Multi-country outbreak of cholera

World Health Organization

External Situation Report n. 31, published 29 October 2025

Cases – 518 328 *Since Jan. 2025*	**Deaths – 6 508** *Since Jan. 2025*	**Countries affected – 32** *Since Jan. 2025*	**Population at risk 1 billion**	**Global risk – Very high**

Overview

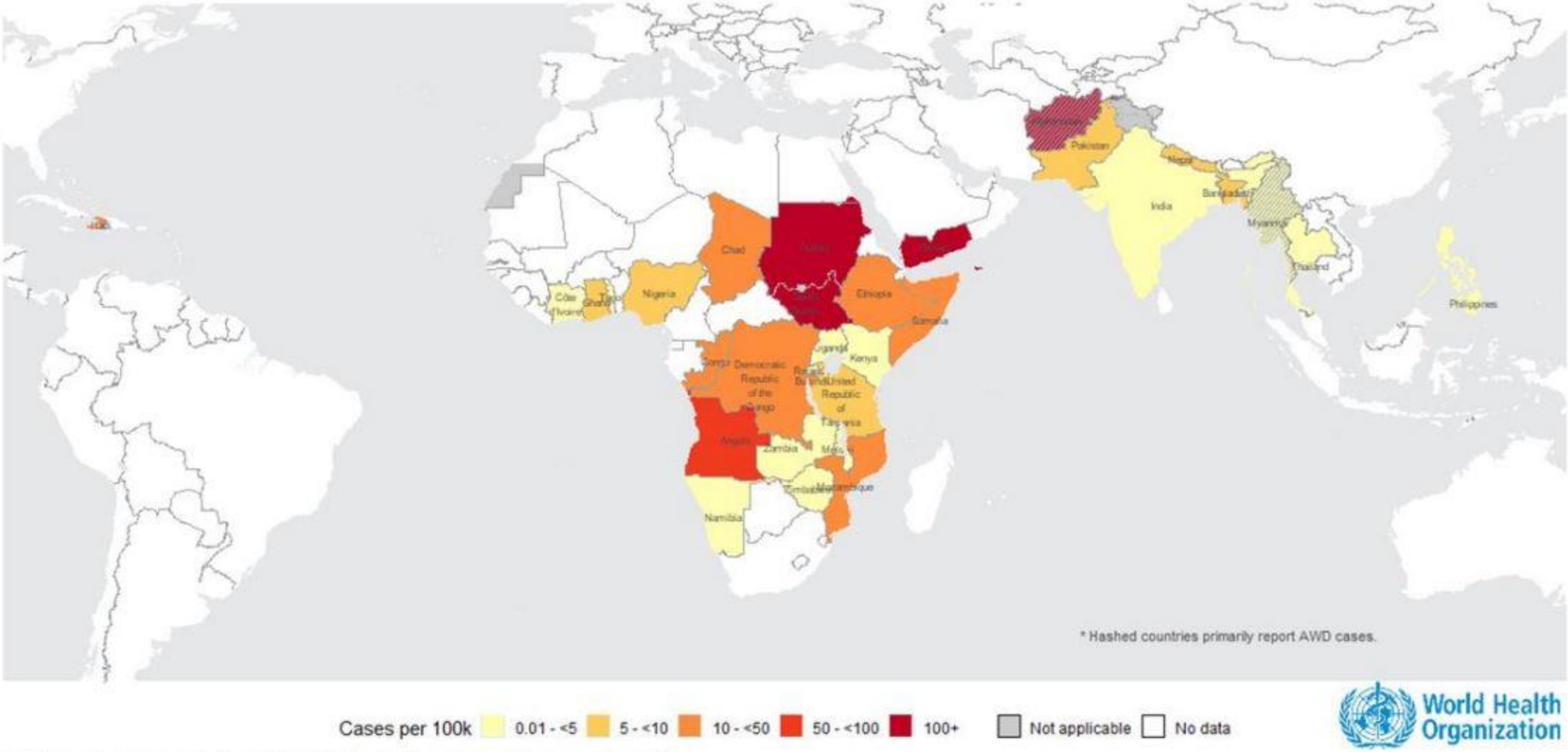
From 1 January to 28 September 2025, a cumulative total of 518 324 cholera cases and 6508 deaths were reported from 32 countries across five WHO regions, with the Eastern Mediterranean Region recording the highest numbers, followed by the African Region, the South-East Asia Region, the Region of the Americas, and the Western Pacific Region. No cases were reported from the European Region during this period.

In September 2025, a total of 45 765 new cholera and acute watery diarrhoea cases were reported from 21 countries across four WHO regions, showing a 27% decrease from August. The period also saw 601 cholera-related deaths globally, a 37% decrease from the previous month.

The preliminary number of deaths reported in 2025, as of 28 September, has already surpassed the 2024 total of 6028, which was itself a 50% increase on 2023.

In September 2025, the average stockpile of Oral Cholera Vaccine (OCV) was 5.2 million doses, exceeding the emergency threshold of 5 million doses during two weeks of the reporting period. This is the first time in three months that the average stockpile exceeded this threshold.

Figure 1. Cholera and acute watery diarrhoea (AWD) cases per 100 000, 1 January to 28 September 2025



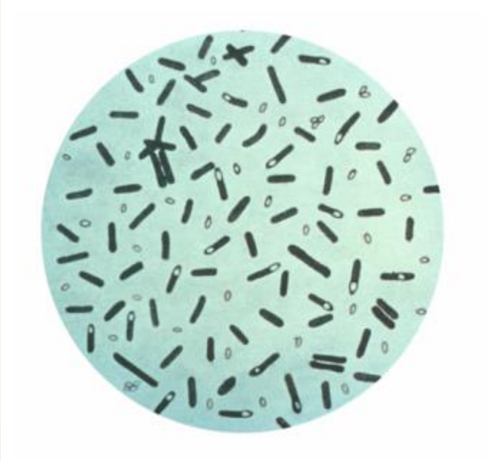
The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of WHO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

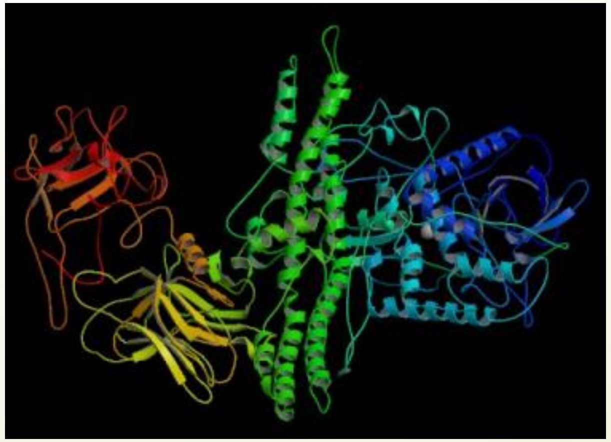
Data Source: World Health Organization
Map Production: WHO Health Emergencies Programme

Table 1. Reported cholera and AWD cases and deaths by WHO region, as of 28 September 2025

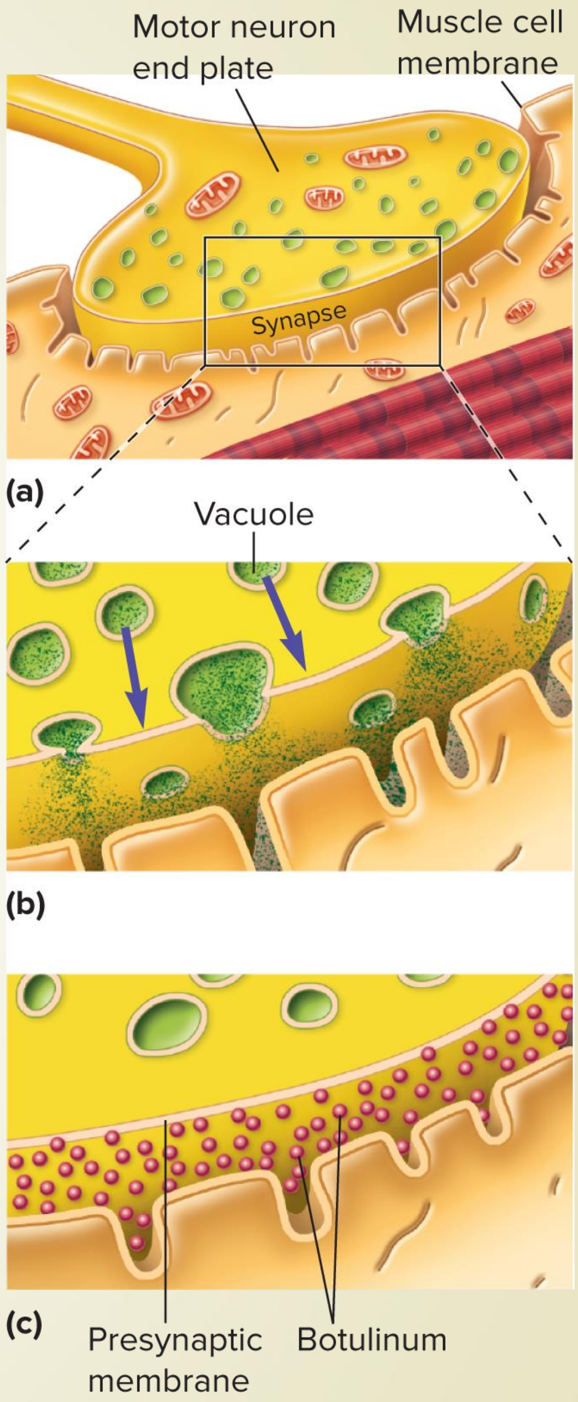
WHO Region	Country area territory	1 January to 28 September 2025				Last 28 days				
		Cases	Deaths	Cases per 100 000	CFR (%)	Cases	Deaths	CFR (%)	Monthly cases % change	Monthly deaths % change
African Region	Angola	29 347	809	81	2.8	1 356	28	2.1	416	460
	Burundi	1 360	6	11	0.4	679	1	0.1	257	0
	Chad	2 506	143	13	5.7	1 073	51	4.8	-14	-38
	Congo	747	65	13	8.7	78	3	3.8	-77	-91
	Côte d'Ivoire	503	20	2	4.0					
	Democratic Republic of the Congo	56 696	1 713	47	3.0	5 005	146	2.9	-24	-43
	Ethiopia	7 558	70	10	0.9	575	9	1.6	-30	80
	Ghana	2 562	14	8	0.5	8	0	0.0	-47	-
	Kenya[§]	426	20	1	4.7	-	-	-	-	-
	Malawi[§]	109	2	1	1.8	-	-	-	-	-
	Mozambique	4 266	35	15	0.8	41	0	0.0	71	-
	Namibia[§]	29	1	1	3.4	-	-	-	-	-
	Nigeria	10 353	244	5	2.4	615	10	1.6	-79	-85
	Rwanda	286	0	2	0.0	2	0	0.0	-33	
	South Sudan	77 388	1 249	624	1.6	2 036	22	1.1	-35	-42
	Togo[§]	164	4	2	2.4	-	-	-	-	-
	Uganda[§]	255	0	1	0.0	-	-	-	-	-
	United Republic of Tanzania	3 293	54	5	1.6	43	4	9.3	-56	-43
	Zambia	732	11	4	1.5	187	1	0.5	202	0
	Zimbabwe[§]	569	21	4	3.7	-	-	-	-	-
Eastern Mediterranean Region	Afghanistan[**]	133 211	65	407	0.0	17 128	8	0.0	-17	-27
	Pakistan[**§]	14 760	0	6	0.0	-	-	-	-	-
	Somalia	7 879	9	48	0.1	387	0	0.0	-16	-
	Sudan	69 723	1 653	166	2.4	6 772	293	4.3	-45	-26
	Yemen[¥]	81 189	225	241	0.3	8 929	25	0.3	-18	-24
Region of the Americas	Haiti[§]	5 231	78	45	1.5	127	2	1.6	-91	-90
South-East Asia Region	Bangladesh	67	0	8	0.0	2	0	0.0	-85	-
	India[#§]	1 389	5	0	0.4	-	-	-	-	-
	Myanmar[**]	2 223	0	4	0.0	69	0	0.0	13	-
	Nepal	1 659	0	6	0.0	701	0	0.0	-20	-
	Thailand[§]	5	0	0	0.0	-	-	-	-	-
Western Pacific Region	Philippines[§]	1 268	13	1	1.0	-	-	-	-	-

- trovanje hranom:
  - *Clostridium botulinum* – Gram-pozitivni anaerob, uzročnik botulizma (lat. *botulus* – kobasica)
    - bakterija iz tla
    - jaki neurotoksin botulin (BOTOX!) proizvodi se za vrijeme klijanja spora u anaerobnim uvjetima
    - prenosi se putem nepravilno proizvedenih konzervi
    - simptomi – zamućen vid, problemi s govorom, gutanjem, disanjem – paraliza mišića





- mehanizam djelovanja botulin toksina
- AB neurotoksin koji se veže na protein sinaptobrevin motoričkih neurona (mali membranski integralni protein sekretornih vezikula)
- proteaza koja selektivno cijepa sinaptobrevin te sprječava oslobađanje neurotransmitera acetilkolina
- zbog toga nema kontrakcije mišića što rezultira paralizom



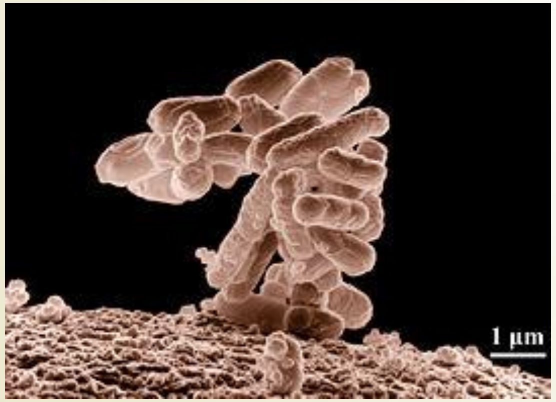
- *Staphylococcus aureus* - Gram-pozitivna bakterija; jedan od najčešćih uzročnika trovanja hranom
  - inkubacija 1- 8 h; luči enterotoksin koji uzrokuje povraćanje i proljeve
  - pojava sojeva rezistentnih na antibiotike (MRSA)!!! – svjetski problem u kliničkoj medicini
  - neki sojevi dio su mikrobne flore ljudske kože i nisu patogeni

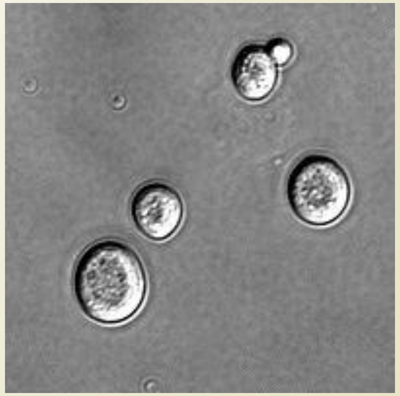
- INDUSTRIJSKA MIKROBIOLOGIJA I BIOTEHNOLOGIJA

Industrijska mikrobiologija i biotehologija

- korištenje mikroba za proizvodnju različitih produkata te u održavanju i poboljšanju okoliša
- mikrobi iz prirode ili modificirani – genetičko inženjerstvo
- medicina i farmaceutska industrija:

  - proizvodnja antibiotika (rodovi *Streptomyces, Bacillus, Penicillium*), inzulina, interferona (*Escherichia coli, Saccharomyces cerevisae*), antitumorskih lijekova, cjepiva.....





- poljoprivreda:

  - biološki pesticid i insekticid – *Bacillus thuringiensis* – proizvodi toksin-insekticid; bioherbicid – *Streptomyces hygroscopicus*

- kemijska industrija – proizvodnja etanola, acetona, butanola....

- proizvodnja biogoriva:

  - vodik (*Rhodobacter sphaeroides* i *Enterobacter cloacae*), metan (*Methanobacterium*), bioetanol (*Zymomonas*, *Thermoanaerobacter*, cijanobakterije - *Algenol*), biodizel (cijanobakterije)

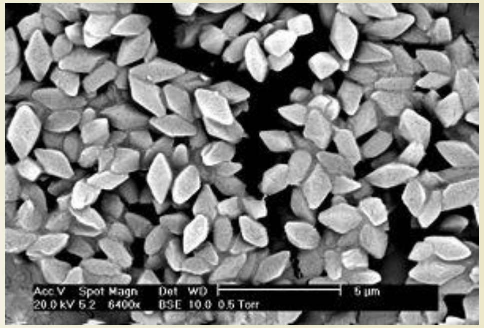


Table 41.1 Major Microbial Products and Processes of Industrial Importance	
Substances	**Microorganisms**
Industrial Products	
Ethanol	*Saccharomyces cerevisiae*
Acetone and butanol	*Clostridium acetobutylicum*
2,3-butanediol	*Enterobacter, Serratia*
Food Additives	
Amino acids (e.g., lysine)	*Corynebacterium glutamicum*
Organic acids (citric acid)	*Aspergillus niger*
Vitamins	*Eremothecium, Blakeslea*
Polysaccharides	*Xanthomonas*
Medical Products	
Antibiotics	*Penicillium, Streptomyces, Bacillus*
Alkaloids	*Claviceps purpurea*
Steroid transformations	*Rhizopus, Arthrobacter*
Insulin, human growth hormone, somatostatin, interferons	*Escherichia coli, Saccharomyces cerevisiae,* and others (genetic engineering)
Biofuels	
Hydrogen	Photosynthetic microorganisms
Methane	*Methanothermobacter*
Ethanol	*Zymomonas, Thermoanaerobacter*

- etanol
- aceton
- vitamini
- antibiotici
- biogoriva

- proizvodnja električne energije
  - *microbial fuel cells* (MFC) – biljka i arheje ili cijanobakterije, fotobioreaktor, fototrofni biofilm

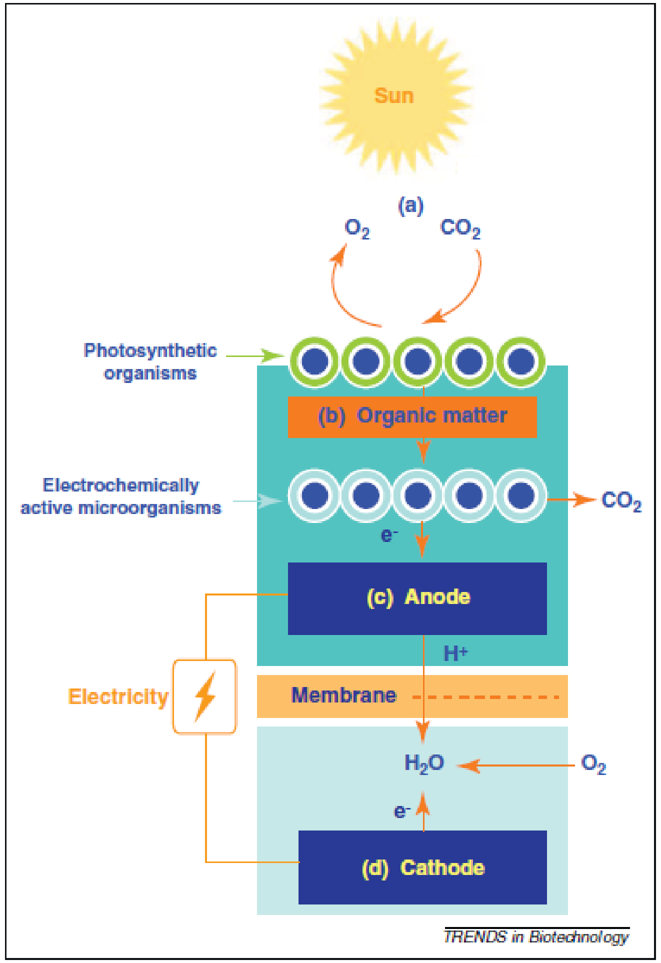
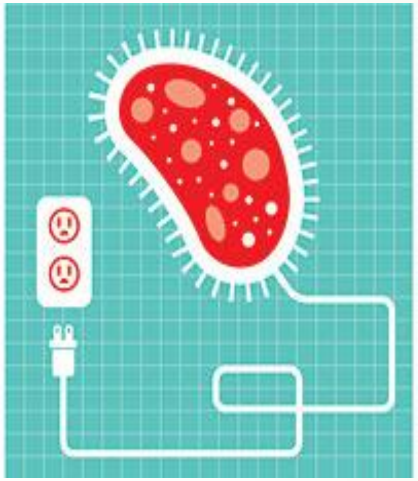


Figure 1. Model of a microbial solar cell including the basic principles. **(a)** Photosynthesis ($6CO_2+6H_2O \rightarrow C_6H_{12}O_6+6O_2$). **(b)** Transport of organic matter to the anode compartment. **(c)** Anodic oxidation of organic matter by electrochemically active bacteria (e.g. $C_6H_{12}O_6+12H_2O \rightarrow 6HCO_3^-+30H^++24e^-$). **(d)** Cathodic reduction of oxygen to water ($6O_2+24H^++24e^- \rightarrow 12H_2O$).



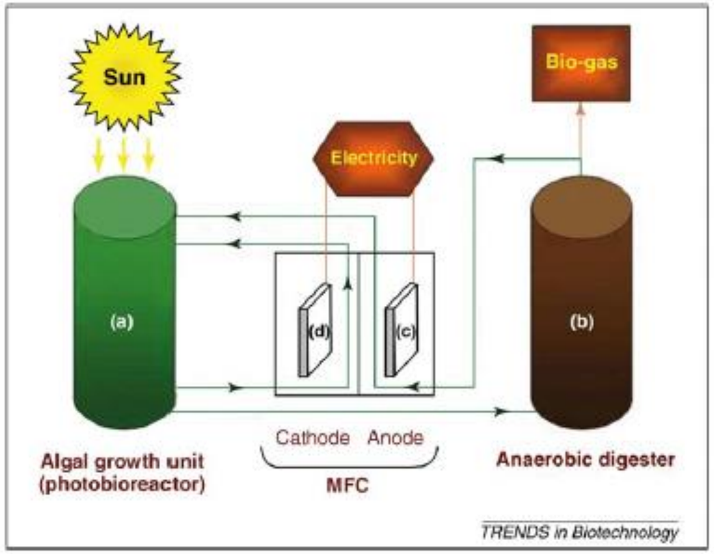


Figure 2. Schematic overview of a closed loop concept for an MSC with a photobioreactor and a digester. **(a)** Photosynthesis by microalgae takes place in the photobioreactor. **(b)** Bio-gas is produced from organic matter and is transported from the photobioreactor to the digester. **(c)** At the anode of the MFC, the remaining organic matter, which is transported from the digester to the anode, is oxidized by electrochemically active bacteria. **(d)** At the cathode of the MFC, oxygen, which is transported from the photobioreactor to the cathode, is reduced to water. Reproduced with permission from [40].

Review Cell PRESS

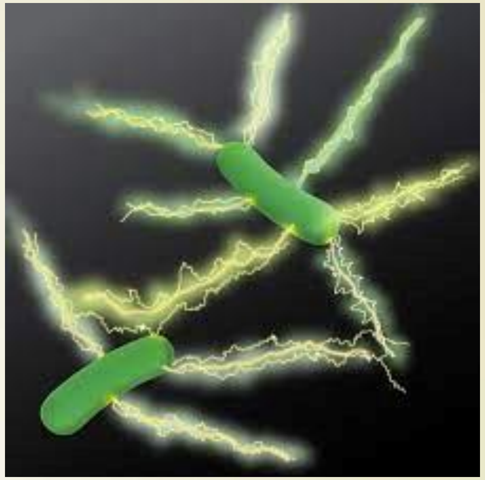
Microbial solar cells: applying photosynthetic and electrochemically active organisms

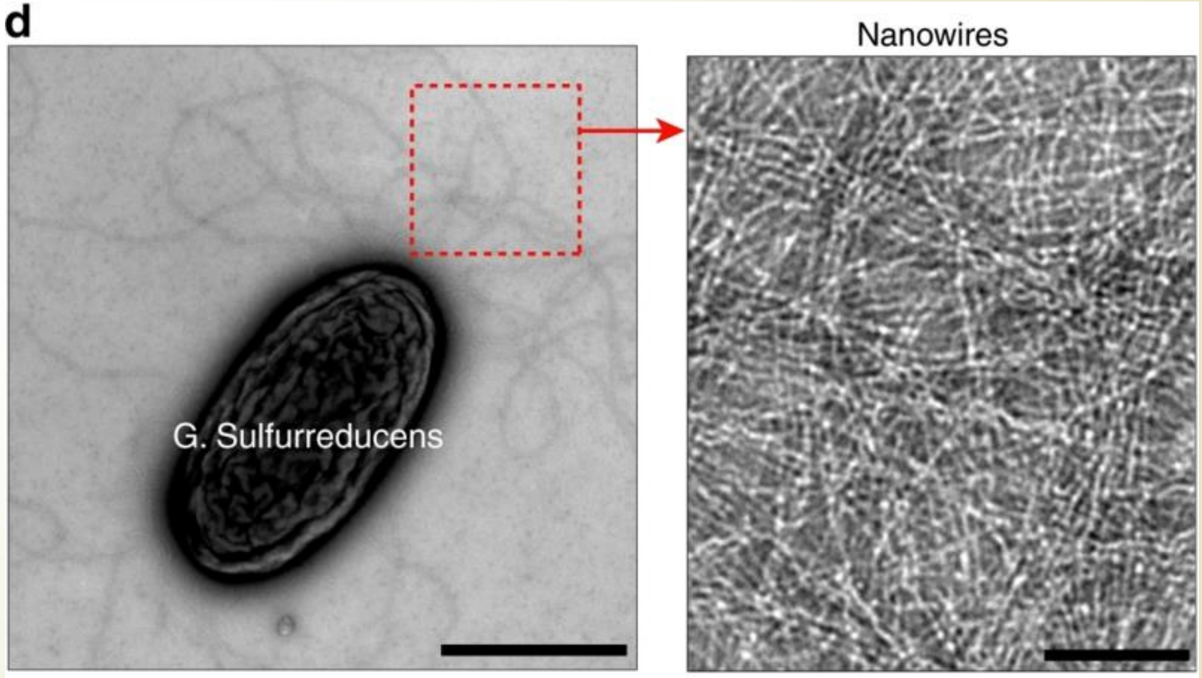
David P.B.T.B. Strik, Ruud A. Timmers, Marjolein Helder, Kirsten J.J. Steinbusch, Hubertus V.M. Hamelers and Cees J.N. Buisman

Sub-Department of Environmental Technology, Wageningen University, Bomenweg 2, P.O. Box 8129, 6700 EV Wageningen, The Netherlands

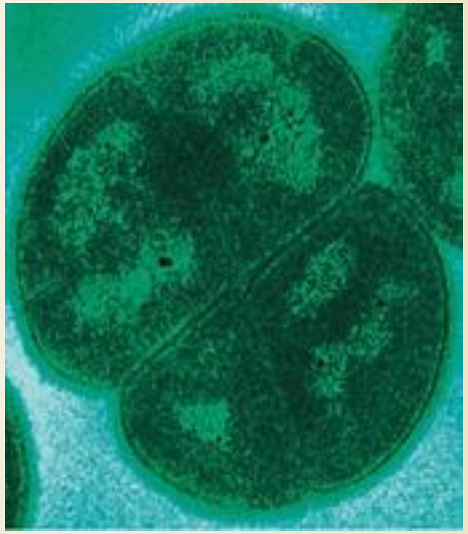
- rod *Geobacter* – anaerobne bakterije jedinstvenog metabolizma – oksidacija organskih spojeva i metala
- *G. metallireducens, G. sulfurreducens, G. uraniireducens*
- elektrogeneza, bioremedijacija, biodegradacija
- biofilm – provodljivost putem “nano-žica”

(bez fizičke povezanosti)



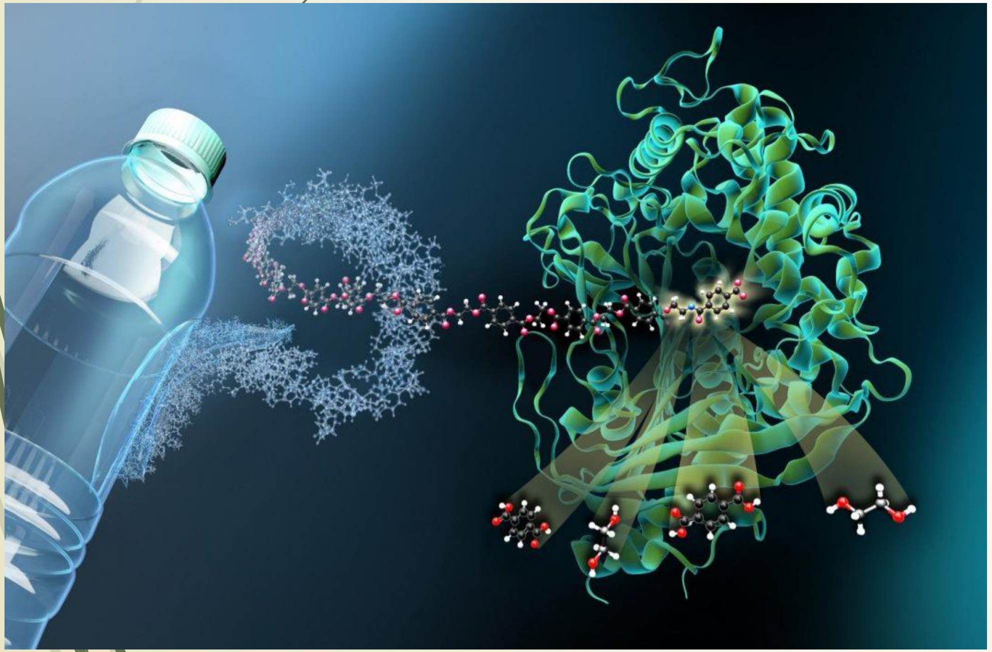


- bioremedijacija i biodegradacija:
  - "čišćenje" zagađenog okoliša, biološko obnavljanje okoliša ili razgradnja otpadnih tvari – npr. kompost, pročišćavanje otpadnih i industrijskih voda
  - *Pseudomonas aeruginosa* i *P. putida* – uklanjanje teških metala iz vode
  - *Deinococcus radiodurans* ("Konan" – bakterija) – poliekstremofil; može vezati toulen i živu iz radioaktivnog otpada, otporan na gama-zračenja, dehidraciju, vakuum… - mehanizam – višestruke kopije genoma i brzi mehanizam popravka DNA; preživljava uvjete u svemiru – 3 godine na površini svemirske stanice



- *Ideonella sakaiensis* – otkrivena 2016. u Japanu
- može degradirati i asimilirati polietilen-tereftalat (PET)
- enzim PET hidrolaza (PETaza) – cijepa esterske veze i degradira PET u MHET (tereftalna kiselina i etilen glikol)

https://www.shutterstock.com/image-vector/bacterium-that-destroys-plastic-ideonella-sakaiensis-1481401391



Preuzeto s https://www.genengnews.com/news/molecular-scissors-for-plastic-waste/

- biološko oružje (bioterorizam)
  - korištenje patogenih mikroba u svrhu masovnog uništenja
  - poznato još od starog vijeka – Asirci, Grci, Rimljani...
  - antraks – *Bacillus antracis*
  - kuga – *Yersinia pestis*
  - botulin – toksin bakterije *Clostridium botulinum*

- istraživanja svemira

  - planeti u Sunčevom sustavu možda nisu biološki izolirani
  - litopanspermija – interplanetarni transport mikroba unutar stijena

Review

Cell PRESS

Ancient micronauts: interplanetary transport of microbes by cosmic impacts

Wayne L. Nicholson

Department of Microbiology and Cell Science, University of Florida, Space Life Sciences Laboratory, Building M6-1025, Room 201-B, Kennedy Space Center, FL 32899, USA

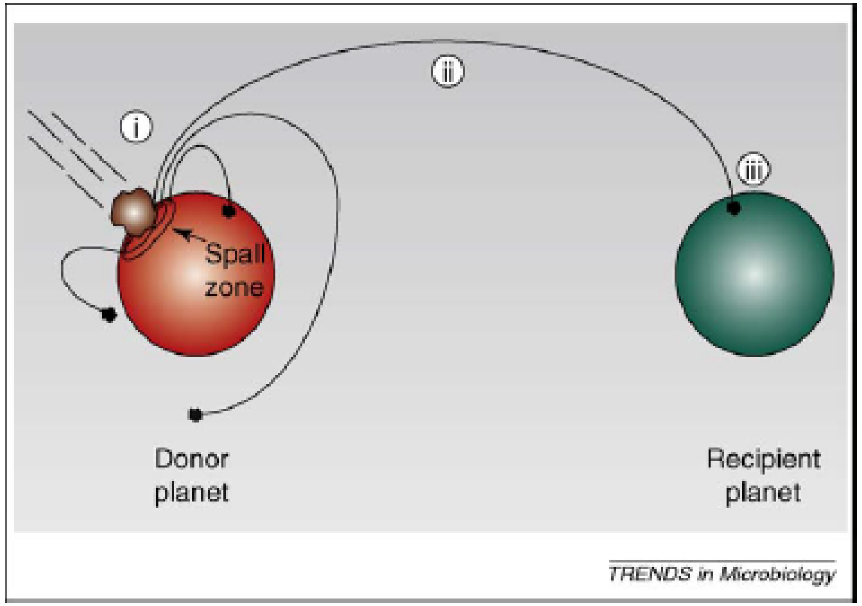


Figure 2. Stages in lithopanspermia. (i) An asteroid or comet strikes the donor planet, ejecting near-surface rocks from the spallation zone. (ii) A fraction of the rocks are accelerated to escape velocity and travel through space on a trajectory ultimately intersecting the recipient planet. (iii) The rocks are captured by the gravity of the recipient planet, enter the atmosphere and fall to impact the surface.

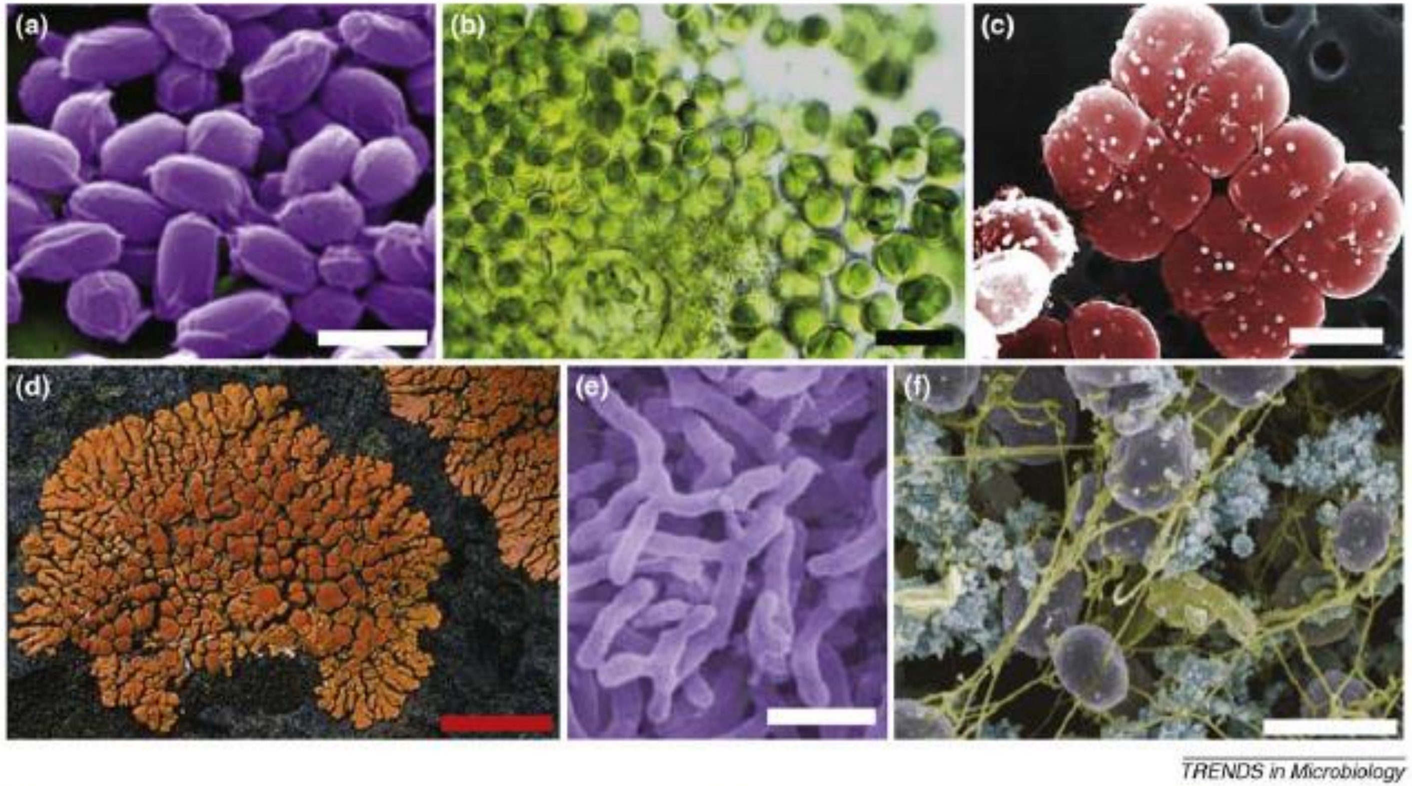


Figure 1. Some of the model microorganisms used in lithopanspermia simulations. **(a)** *Bacillus* sp. spores (false-color SEM image. Photo credit: Janice Hanley Carr). **(b)** The cyanobacterium *Chroococcidiopsis* (light micrograph by E.I. Friedmann and R. Ocampo-Friedmann). **(c)** *Deinococcus radiodurans* (false-color SEM image, by Peggy A. O'Cain and Margaret C. Henk, Louisiana State; modified by Peter Reid, The University of Edinburgh). **(d)** The lichen *Xanthoria elegans* (macroscopic colony on rock; image kindly provided by Stephen Sharnoff). **(e)** The Gram-positive nocardioform actinomycete *Rhodococcus erythropolis* (scanning electron micrograph by Ernesto Plagiario). **(f)** The halophilic archaeon *Halorubrum* (false-color SEM image kindly provided by Shil DasSarma). Scale bars are: 1 µm (white), 10 µm (black), 1 cm (red).

- sintetička biologija
    - interdisciplinarna grana – biotehnologija, evolucija, genetičko inženjerstvo, biofizika, bioinformatika, sistemska biologija....
    - sekvenciranje, umjetna sinteza DNA
    - Institut J. Craigh Venter, USA
    - prvi djelomično sintetički mikroorganizam – napravljen na bazi sekvence bakterije *Mycoplasma genitalium* (Gibson i sur. 2008)– minimalni bakterijski genom – (Glass i sur. 2006) - „*Mycoplasma laboratorium*”

J. Craig Venter INSTITUTE

Essential genes of a minimal bacterium

John I. Glass, Nacyra Assad-Garcia, Nina Alperovich, Shibu Yooseph, Matthew R. Lewis, Mahir Maruf, Clyde A. Hutchison III, Hamilton O. Smith*, and J. Craig Venter

Synthetic Biology Group, J. Craig Venter Institute, 9704 Medical Center Drive, Rockville, MD 20850

PNAS | January 10, 2006 | vol. 103 | no. 2 | 425–430

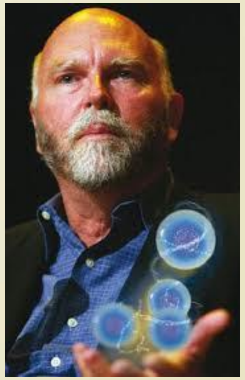
PNAS

One-step assembly in yeast of 25 overlapping DNA fragments to form a complete synthetic *Mycoplasma genitalium* genome

Daniel G. Gibson[a,1], Gwynedd A. Benders[b], Kevin C. Axelrod[a], Jayshree Zaveri[a], Mikkel A. Algire[a], Monzia Moodie[a], Michael G. Montague[a], J. Craig Venter[a], Hamilton O. Smith[b], and Clyde A. Hutchison III[b,1]

[a]The J. Craig Venter Institute, Synthetic Biology Group, Rockville, MD 20850 and [b]The J. Craig Venter Institute, Synthetic Biology Group, San Diego, CA 92121

20404–20409 | PNAS | December 23, 2008 | vol. 105 | no. 51



- umjetni život?

- 2010. godine sintetiziran genom baziran na genomu bakterije *Mycoplasma mycoides* koji je transplantiran u stanicu bakterije *Mycoplasma capricolum* iz koje je uklonjen genetički materijal (Gibson i sur. 2010) – „*Synthia*”

- vijabilna i može se replicirati, očekivanog fenotipa i proteinskih profila

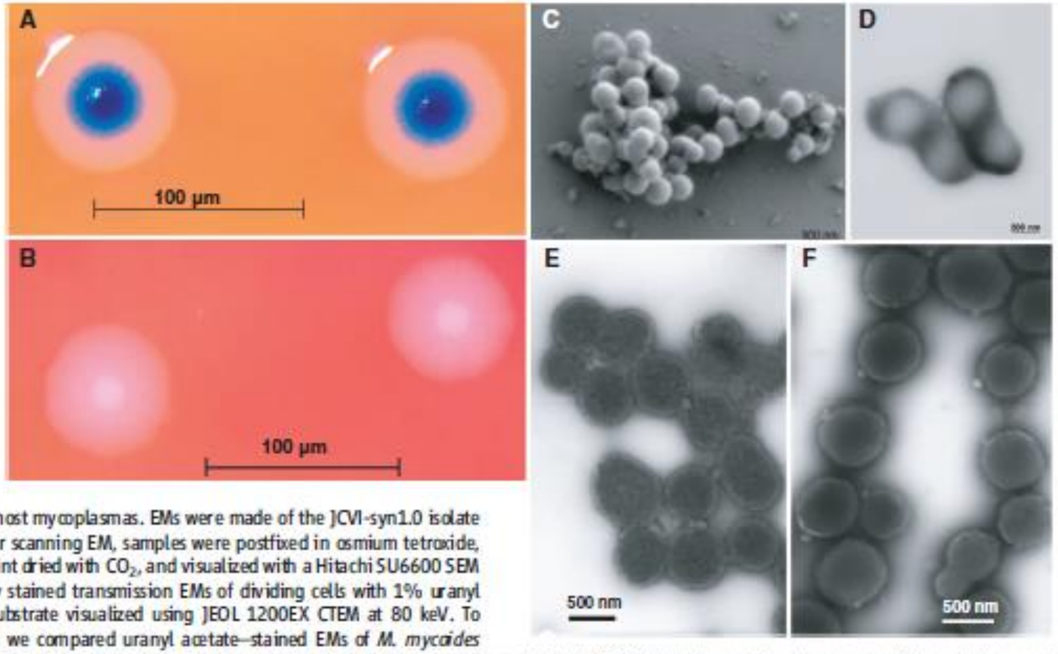


Fig. 5. Images of *M. mycoides* JCVI-syn1.0 and WT *M. mycoides*. To compare the phenotype of the JCVI-syn1.0 and non-YCp WT strains, we examined colony morphology by plating cells on SP4 agar plates containing X-gal. Three days after plating, the JCVI-syn1.0 colonies are blue because the cells contain the *lacZ* gene and express β-galactosidase, which converts the X-gal to a blue compound (**A**). The WT cells do not contain *lacZ* and remain white (**B**). Both cell types have the fried egg colony morphology characteristic of most mycoplasmas. EMs were made of the JCVI-syn1.0 isolate using two methods. (**C**) For scanning EM, samples were postfixed in osmium tetroxide, dehydrated and critical point dried with CO_2, and visualized with a Hitachi SU6600 SEM at 2.0 keV. (**D**) Negatively stained transmission EMs of dividing cells with 1% uranyl acetate on pure carbon substrate visualized using JEOL 1200EX CTEM at 80 keV. To examine cell morphology, we compared uranyl acetate–stained EMs of *M. mycoides* JCVI-syn1.0 cells (**E**) with EMs of WT cells made in 2006 that were stained with ammonium molybdate (**F**). Both cell types show the same ovoid morphology and general appearance. EMs were provided by T. Deerinck and M. Ellisman of the National Center for Microscopy and Imaging Research at the University of California at San Diego.

Colonies of the transformed *Mycoplasma mycoides* bacterium. Image Credit: J. Craig Venter Institute.

RESEARCH ARTICLE

Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome

Daniel G. Gibson,[1] John I. Glass,[1] Carole Lartigue,[1] Vladimir N. Noskov,[1] Ray-Yuan Chuang,[1] Mikkel A. Algire,[1] Gwynedd A. Benders,[2] Michael G. Montague,[1] Li Ma,[1] Monzia M. Moodie,[1] Chuck Merryman,[1] Sanjay Vashee,[1] Radha Krishnakumar,[1] Nacyra Assad-Garcia,[1] Cynthia Andrews-Pfannkoch,[1] Evgeniya A. Denisova,[1] Lei Young,[1] Zhi-Qing Qi,[1] Thomas H. Segall-Shapiro,[1] Christopher H. Calvey,[1] Prashanth P. Parmar,[1] Clyde A. Hutchison III,[2] Hamilton O. Smith,[2] J. Craig Venter[1,2]*

2 JULY 2010 VOL 329 SCIENCE www.sciencemag.org

Support The Guardian

Subscribe Find a job Sign in Search

News | Opinion | Sport | Culture | Lifestyle | More

World UK Science Cities Global development Football Tech Business Environment Obituaries

Craig Venter

Craig Venter creates synthetic life form

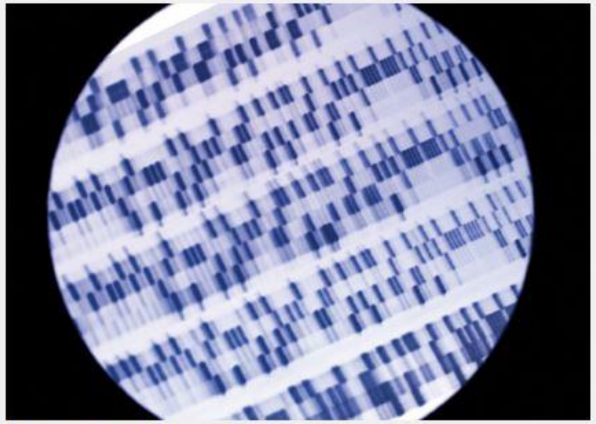
Craig Venter and his team have built the genome of a bacterium from scratch and incorporated it into a cell to make what they call the world's first synthetic life form

Life, Synthia, But Not as we Know It

NEIL SCOLDING

July/August 2010

Scientists playing God. Again. How many times has this most hackneyed of headlines been used? Since Darwin? Or Linnaeus, the "second Adam", and who after all called his followers "apostles" — though there weren't many newspapers in the 18th century. Now they're at it once more, those scientists and those headline writers, scientists playing God again. (Now if it were the sports pages, and this were a cricket match...)



Synthia's DNA — or should that be Lazarus's?

https://www.ted.com/talks/craig_venter_unveils_synthetic_life

MAR 24, 2016 @ 02:00 PM 16,776

After 20 Year Quest, Biologists Create Synthetic Bacteria With No Extra Genes

Matthew Herper, FORBES STAFF

I cover science and medicine, and believe this is biology's century. FULL BIO