

# Methanogens – ancient archaea

By Craig Paardekooper

Archaea are purported to be the first creatures on earth. They can be sub-divided into the following groups.

CATEGORY	DESCRIPTION	EXAMPLE SPECIES
METHANOGENS	Produce methane in anaerobic conditions; key in carbon cycling	<i>Methanococcus</i> , <i>Methanosarcina</i> , <i>Methanoculleus</i>
HALOPHILES	Thrive in high-salt environments	<i>Halobacterium</i> , <i>Haloarcula</i> , <i>Haloferax</i>
THERMOPHILES	Prefer high temperatures (often >60°C)	<i>Saccharolobus solfataricus</i> , <i>Thermoplasma</i>
ACIDOPHILES	Thrive in low pH environments	<i>Thermoplasma acidophilum</i>
ALKALIPHILES	Prefer high pH environments	Less commonly studied in archaea
PSYCHROPHILES	Adapted to cold environments (e.g., polar regions)	Some <i>Methanogens</i> in deep-sea sediments
BAROPHILES	Thrive under high pressure (e.g., deep ocean trenches)	Deep-sea <i>Methanogens</i>
SYNTROPHS	Engage in cooperative metabolism with other microbes	<i>Candidatus Prometheoarchaeum syntrophicum</i>

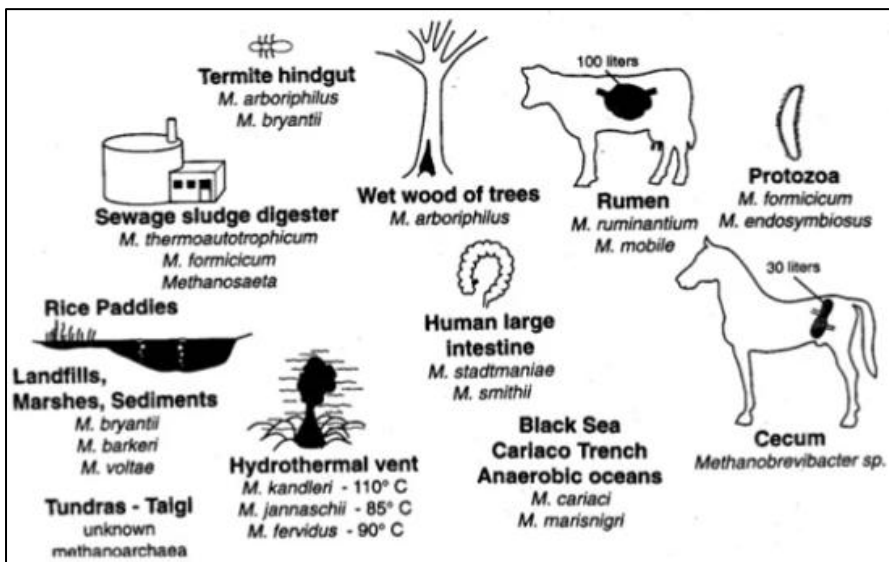
Sources: [Science Encyclopedia- JRank Articles](#) [Open Library Publishing Platform](#)

**Methanoarchaea** (like *Methanococcus*, *Methanosarcina*, *Methanoculleus*) are **methanogens**—they produce methane and thrive in anaerobic environments like swamps, sewage, or animal guts [Science Encyclopedia- JRank Articles](#).

## Methanogens



These creatures are found in the guts of animals, and in swamps and marshes. *Methanogens* are the main producers of methane in the biosphere, and are responsible for all the methane emitted by cows and other mammals.



They produce methane via a specialized metabolic pathway that directly generates ATP. This process is called methanogenesis, and it's their primary energy source, and is unique to them. No other creature has this method of energy production. *Methanogens* are the **only known organisms** that use methane production as a **core energy metabolism**, making them metabolically and evolutionarily distinct.

[wikipedia](https://en.wikipedia.org)

[cell.com](https://www.cell.com)

[libretexts.org](https://libretexts.org)

Bovaer® (3-nitrooxypropanol or 3-NOP) specifically suppresses *methanogens* in the rumen of cattle and other ruminants.

**Bovaer is not an mRNA.** It's actually a small molecule feed additive called **3-nitrooxypropanol (3-NOP)**. Its role is to inhibit a specific enzyme in the cow's rumen that produces methane during digestion.

It **inhibits the enzyme methyl-coenzyme M reductase**, which is **essential for methanogenesis**—the final step in methane production by methanogens.

This **blocks methane formation** without killing the *methanogens* outright, altering their activity rather than their population.

*Methanogens* help **scavenge hydrogen** during fermentation. Suppressing them may shift microbial dynamics, potentially affecting fermentation efficiency

It's been tested in multiple countries and shown to reduce enteric methane emissions by up to 30% or more.

<https://dellait.com/bovaer-friend-or-foe-in-the-fight-against-methane-dellait/>

*Methanogens* play a **crucial but indirect role** in digestion and fermentation—especially in **anaerobic environments** like the guts of ruminants, termites, and even humans.

*Methanogens* are **not fermenters themselves**, but they are **essential partners** in the fermentation ecosystem. By **removing hydrogen**, they **enable fermentative microbes** to keep breaking down complex carbohydrates into short-chain fatty acids—vital for host nutrition. In ruminants, this partnership is ancient and finely tuned, though it comes at the cost of methane emissions.

If suppressing methane production in animals involves removing *methanogens*, then there will be a buildup of hydrogen gases, and this will result in a suppression of fermentation microbes, and suppression of the breakdown of carbohydrates. The animals will suffer from poor digestion and nutrition – resulting in weakness and disease.

If hydrogen is not scavenged during fermentation—especially in anaerobic environments—the suppression of fermentation can be **significant and systemic**. In rumen systems, hydrogen accumulation can **reduce fermentation efficiency by 20–40%**, depending on diet and microbial composition. *Methanogens* help **maintain low H<sub>2</sub> levels**, enabling continuous breakdown of complex carbohydrates into short-chain fatty acids.

If hydrogen is not scavenged during fermentation—especially in anaerobic environments—the suppression can be **significant and systemic**.

## Malnutrition and Starvation

We need to realise what this means. If hydrogen is not removed by being bound to CO<sub>2</sub>, then the hydrogen concentration will increase and suppress fermentation, unless there are alternate means of removing the hydrogen. Suppression of fermentation means suppression the breakdown of plant carbohydrates, and the animals will not be able to digest the foods they eat. This will lead to a permanent state of hunger, and malnutrition.

MECHANISM	EFFECT ON FERMENTATION
THERMODYNAMIC INHIBITION	High H <sub>2</sub> partial pressure makes key fermentation reactions energetically unfavorable
MICROBIAL FEEDBACK	Fermentative microbes slow or halt activity due to redox imbalance
PRODUCT SHIFTS	Fermentation shifts toward less favorable pathways (e.g., lactate instead of acetate)
REDUCED ATP YIELD	Less efficient fermentation = lower energy for microbial growth
VOLATILE FATTY ACID DROP	Host animals receive less nutrition from fermentation products

## Hydrogen Buildup Suppresses Fermentation

Hydrogen buildup suppresses fermentation because it disrupts the **redox balance** that microbes rely on to extract energy anaerobically. Here's how it works:

### Fermentation and Electron Flow

- During fermentation, microbes break down organic substrates (like glucose) and release electrons.
- These electrons need to be transferred to **electron sinks**—typically hydrogen ions ( $H^+$ ), which get reduced to **molecular hydrogen ( $H_2$ )**.
- If  $H_2$  accumulates, it creates **backpressure**—making it energetically unfavorable for microbes to continue producing it.

### Why Suppression Happens

- **Thermodynamic inhibition:** High partial pressure of  $H_2$  shifts the equilibrium, making further hydrogen production less exergonic or even endergonic.
- **Enzyme inhibition:** Key enzymes like hydrogenases become less active when  $H_2$  levels rise.
- **Microbial feedback:** Some microbes slow down or switch pathways to avoid inefficient energy extraction.

### What Happens Instead?

- Microbes may divert electrons to alternative sinks like:
  - **Formate**
  - **Lactate**
  - **Ethanol**
  - **Methane** (via methanogens, which consume  $H_2$  and  $CO_2$ )

This is why methanogens are crucial in rumen ecosystems—they **scavenge hydrogen**, keeping fermentation efficient. Hydrogen buildup signals a thermodynamic bottleneck, forcing a shift in metabolic strategy [Animal Microbiome](#).

## Effect of Reduced Fermentation on Carbohydrate Breakdown

A 20–40% decrease in fermentation efficiency would significantly impair carbohydrate breakdown—especially in anaerobic systems like the rumen or large intestine.

EFFECT	CONSEQUENCE
REDUCED MICROBIAL ACTIVITY	Fewer fermentative microbes actively breaking down polysaccharides
ACCUMULATION OF SUBSTRATES	Complex carbohydrates (e.g., cellulose, hemicellulose) remain undigested
LOWER VOLATILE FATTY ACIDS	Less acetate, propionate, and butyrate produced—key energy sources for host
INCREASED GAS IMBALANCE	Hydrogen builds up, methane drops, $CO_2$ may rise—altering gut dynamics
SHIFT IN MICROBIAL POPULATIONS	Favoring lactate producers or pathogens over fiber-degrading symbionts
REDUCED NUTRIENT ABSORPTION	Host receives less usable energy from feed

Sources: [Microbiome Journal](#), [Frontiers in Chemistry](#)

- Carbohydrate breakdown in fermentation is **not just enzymatic**—it’s **syntrophic**, relying on hydrogen scavengers like *methanogens* to keep the system flowing.
- Suppressing *methanogens* without compensatory pathways (e.g., acetogenesis or sulfate reduction) risks **metabolic gridlock**.

### Fermentation is Needed to Breakdown Complex Carbohydrates

In ruminants, fermentative microbes are needed to keep breaking down complex carbohydrates into short-chain fatty acids—vital for host nutrition. Without these microbes, what % of carbohydrates would remain undigested?

Without fermentative microbes in the rumen, **a substantial portion of dietary carbohydrates—especially fibrous ones—would remain undigested**, severely compromising the ruminant’s energy supply. **Grass would cease to provide food for cows.**

So, by reducing methanogenesis by 30%, animals would suffer **hunger without satiation**. Plants would no longer be digested properly. Cattle would have to eat much more to obtain the minimal energy for survival, which means they would eat more often, and put on bulk – undigested bulk. The impact on farmers would be livestock with poor nutrition. Animals would sicken and die. Farmers would not be able to feed them any foods that require microbial digestion, which would mean much higher feed bills.

This would be an appalling situation for animals. Imagine someone replacing your human intestine with a plastic pipe that could not absorb food, then putting a feast before you each day!

### Fake Science?

Existing studies assessing the side effects of Bovaer may be compromised by corporate interest. Many of the studies evaluating Bovaer—especially those used in regulatory approvals—**were sponsored or conducted by DSM Nutritional Products**, the company that developed Bovaer. And these studies were then reviewed by “FactChecker”!

- **Food Standards Agency (UK):** Their safety assessment of 3-NOP was conducted by DSM Nutritional Products.
- **EU Regulatory Trials:** Most of the data submitted for approval came from DSM-sponsored studies, often conducted in collaboration with academic or industry partners.
- **Australian and Canadian Trials:** Several were funded or co-authored by DSM or affiliated researchers.
- **Meta-analyses and reviews:** While some are independent, many rely heavily on DSM-generated data.

## Essential for the Carbon Cycle

The importance of methanogens for ruminant digestion is evident from the same role methanogens play in the breakdown of organic matter in swamps and wetlands.

*Methanogens* are **absolutely vital** in swamp environments—they're the microbial engines driving anaerobic carbon cycling.

FUNCTION	ROLE IN SWAMP ECOSYSTEM
TERMINAL DECOMPOSERS	Final step in organic matter breakdown—convert $\text{CO}_2 + \text{H}_2 \rightarrow \text{CH}_4$
HYDROGEN SCAVENGERS	Remove excess $\text{H}_2$ from fermentation, enabling continued microbial activity
METHANE PRODUCTION	Major source of atmospheric methane—swamps are natural emitters
CARBON CYCLING	Close the loop on anaerobic decomposition of plant material
MICROBIAL SYNTROPHY	Partner with fermenters and acetogens to maintain redox balance
CLIMATE INFLUENCE	Swamp methanogens contribute to global warming via $\text{CH}_4$ emissions

Sources: [ASM mSystems](#) [ASM Journals](#), [Iris Publishers](#) [Iris Publishers](#), [Frontiers in Microbiology](#) [Frontiers](#)

*Methanogens* in swamps are like **metabolic keystones**—without them, fermentation stalls, hydrogen builds up, and organic matter remains partially degraded.

So, we can see how *methanogens* play a key role in decomposition.

The deliberate suppression of methanogenesis in animal populations to suit a “climate change” agenda, would likely result in significant mal-nutrition. Methanogenesis is more than methane—it's a **keystone metabolic process** that enables life in anoxic niches. Removing it would be like pulling the plug on the biosphere's anaerobic engine.

Fermentation would stall, hydrogen would accumulate, and microbial ecosystems would collapse in swamps, sediments, and guts.

## 1. Cost Comparison: Nitrate Supplementation vs. Open Grazing

Feeding nitrates to ruminants as a methane mitigation strategy typically involves supplementing their diet with nitrate-rich feed or additives. This approach is more expensive than open grazing, primarily due to:

Supplement cost: Nitrate salts (e.g., calcium or potassium nitrate) must be purchased and mixed into feed.

Monitoring and management: Animals require close supervision to avoid toxicity, adding labor and infrastructure costs.

Feeding logistics: Unlike open grazing, nitrate supplementation often requires controlled feeding environments like feedlots or paddocks.

While exact cost differences vary by region and system, studies suggest that supplemented feeding can increase costs by 20–50% or more compared to unmanaged grazing systems NDSU- North Dakota State University

(<https://www.ndsu.edu/agriculture/extension/publications/alternative-feeds-ruminants>)

(<https://www.ndsu.edu/agriculture/extension/publications/alternative-feeds-ruminants>)

## 2. Efficiency Compared to Methanogenesis

Methanogenesis is the natural microbial process in the rumen that converts hydrogen and carbon dioxide into methane — a major greenhouse gas. Suppressing methanogenesis and redirecting hydrogen to reduce nitrate to ammonia can:

Reduce methane emissions by 10–30% or more, depending on the nitrate dose and diet composition.

Improve energy efficiency: Less energy is lost as methane, potentially improving feed conversion efficiency.

Provide non-protein nitrogen: Nitrates can serve as a nitrogen source for microbial protein synthesis, similar to urea.

However, nitrate reduction is less efficient than methanogenesis in terms of microbial growth if not carefully balanced. It requires adaptation time and co-supplementation with sulfur to optimize rumen microbial function NDSU- North Dakota State University

(<https://www.ndsu.edu/agriculture/extension/publications/alternative-feeds-ruminants>)

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## 3. Safety: Risk of Nitrite or Ammonia Poisoning

This is the most critical concern. Nitrate supplementation carries a real risk of nitrite toxicity, which can lead to:

Methemoglobinemia: Nitrite oxidizes hemoglobin, reducing oxygen transport in blood.

Sudden death: Especially if animals are not adapted or consume large doses quickly.

Ammonia toxicity: If nitrate is rapidly reduced to ammonia without proper microbial assimilation.

To mitigate these risks:

Gradual adaptation is essential — start with low doses and increase slowly.

Split feeding or slow-release formulations help reduce nitrite spikes.

Monitoring of feed nitrate levels and animal health is crucial.

When managed properly, nitrate feeding can be safe, but the margin for error is narrow compared to traditional feeding systems Nebraska Extension Publications

(<https://extensionpubs.unl.edu/publication/g1779/2019/html/view>)

(<https://extensionpubs.unl.edu/publication/g1779/2019/html/view>)

## How Nitrate Feed Production Impacts the Environment

Here's a breakdown of the key environmental concerns:

### 1. Fossil Fuel Use in Nitrate Production

Most commercial nitrates (e.g., ammonium nitrate, calcium nitrate) are synthesized using the Haber-Bosch process, which converts atmospheric nitrogen into ammonia.

This process is energy-intensive and typically powered by natural gas, a fossil fuel.

As a result, nitrate production has a significant carbon footprint, contributing to CO<sub>2</sub> emissions.

### 2. Indirect Emissions from Agriculture

Nitrate fertilizers used to grow forage crops or added directly to feed can lead to nitrous oxide (N<sub>2</sub>O) emissions, a potent greenhouse gas.

N<sub>2</sub>O has a global warming potential ~300 times greater than CO<sub>2</sub> over a 100-year period MU Extension

<https://extension.missouri.edu/publications/g9800>

<https://extension.missouri.edu/publications/g9800>

### 3. Environmental Risks

Improper use or runoff of nitrates can contaminate water sources, leading to eutrophication and aquatic ecosystem damage.

High nitrate levels in soil and water can also pose health risks to humans and animals, especially through nitrite conversion msipublishers.com

<https://msipublishers.com/wp-content/uploads/2025/05/MSIJMR682025-GS.pdf>

<https://extension.missouri.edu/publications/g9800>.

<https://extension.missouri.edu/publications/g9800>

## Summary

The animals will starve without an alternate means of removing hydrogen. If methanogenesis is suppressed then synthetic alternatives would be required to allow the natural digestive processes. Expensive nitrate supplement would be required that bind to the hydrogen and convert it into nitrites then into ammonia.

The problem with a nitrate sink is that it means **natural grazing must be supplemented** with nitrate feeds which is expensive for farmers. In addition, if nitrate converts to nitrite faster than nitrite conveys to ammonia then the animal is poisoned.

What is happening here is that **natural feeding and digestion is being supplanted by synthetic digestion**, in a similar way that natural immunity was deemed inadequate and they attempted to replace it with synthetic immunity.

Farmers will end up paying so their animals can digest.

Nature has already found an efficient way of allowing digestion naturally. Using any alternate means is going to be less efficient, costly and have more toxic side effects such as nitrite poisoning.

So, besides inflicting harm on animals and reducing farm productivity, the supplements needed to replace methanogenesis are costly nitrates.

These nitrates feeds are themselves **produced using huge amounts of fossil fuels** so they have a very large carbon footprint.

Finally, the animals on nitrate supplement have to be closely monitored to avoid nitrite or ammonia poisoning.

The climate change hoax and its associated measures have spawned activities like these which are profiteering at the expense of animal and human welfare as well as threatening global food supplies.

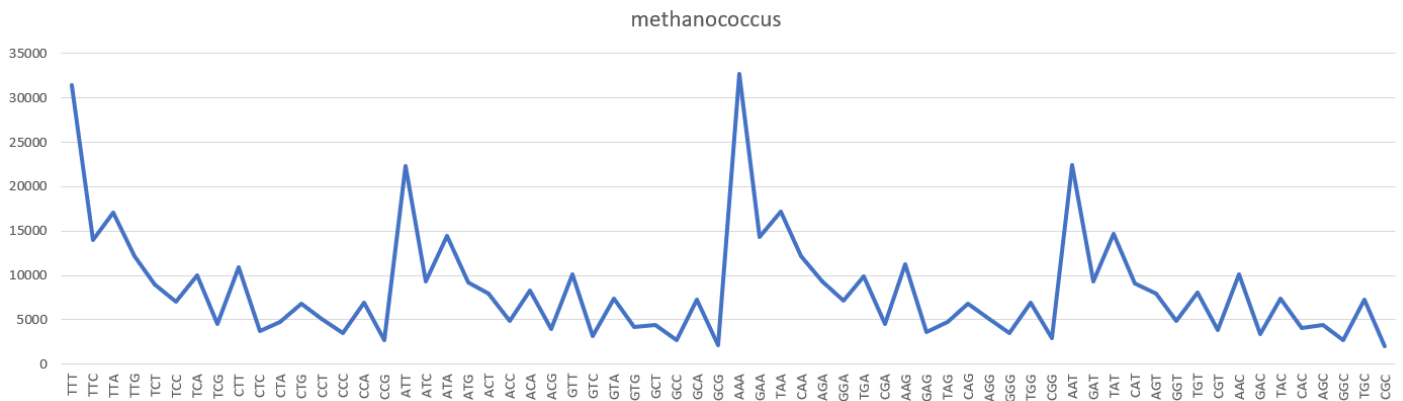
We have seen how such policies are approved by corrupt regulators in UK, EU and Australia, without even minimal concern for the safety and risks.

Such mindless activities endanger fragile communities in developing countries where the health and productivity of farm animals is vital. Such communities rely on open grazing without expensive supplements. Sheep and cattle are pastured, and nature provides efficient digestion through methanogenesis and fermentation.

The introduction of ruthless western protocols that use drugs to prevent natural digestion will inflict upon innocent rural populations a level of malnutrition, poverty and famine that the world has never seen before.

The populations of developing countries should resist such insidious encroachments where ever possible.

## Symmetries in Methanogens



In *Methanococcus-maripaludis*, there is a peak every 8 codons, and a trough every 8 codons, because the genome is AT rich and GC poor.

The reverse compliment of a codon is where you reverse the letters then replace every C with a G, every G with a C, every A with a T and every T with an A.

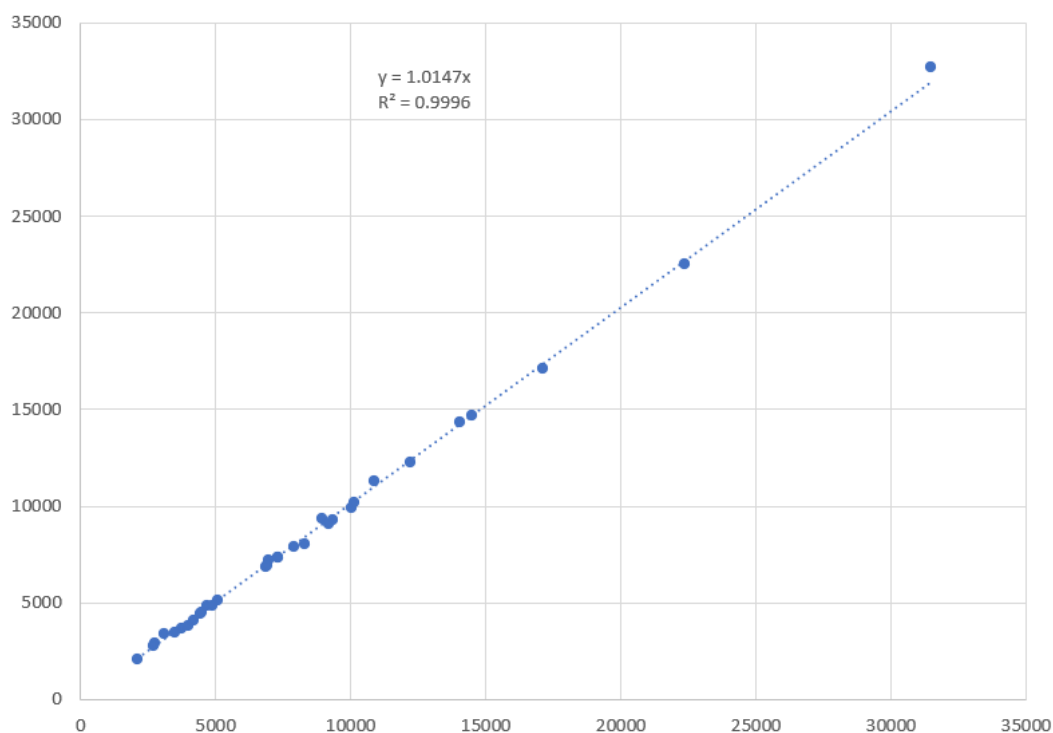
For example, the reverse of ATG is GTA, and the compliment of the reverse is CAT.

Though 80% of the methanococcus genome codes for proteins, its genome maintains an almost perfect balance between the frequency of any codon, and the frequency of its reverse compliment. The correlation between codons and reverse compliments is shown below (0.9996).

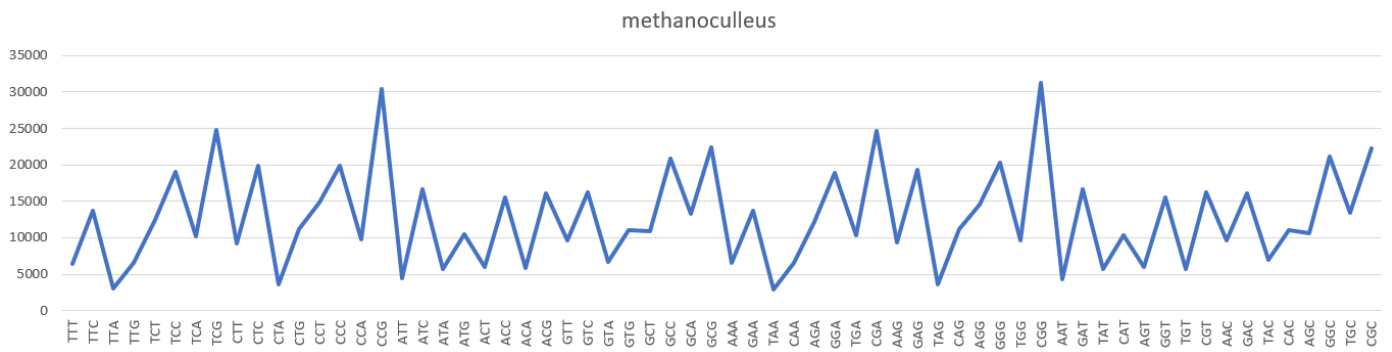
If we divide the codons into two groups each of 32 codons, then the first 32 codon frequencies match the last 32 codon frequencies.

To achieve this symmetrical balance whilst coding for functional proteins is remarkable.

Correlation between frequency of any codon, and frequency of its reverse compliment (methanococcus)

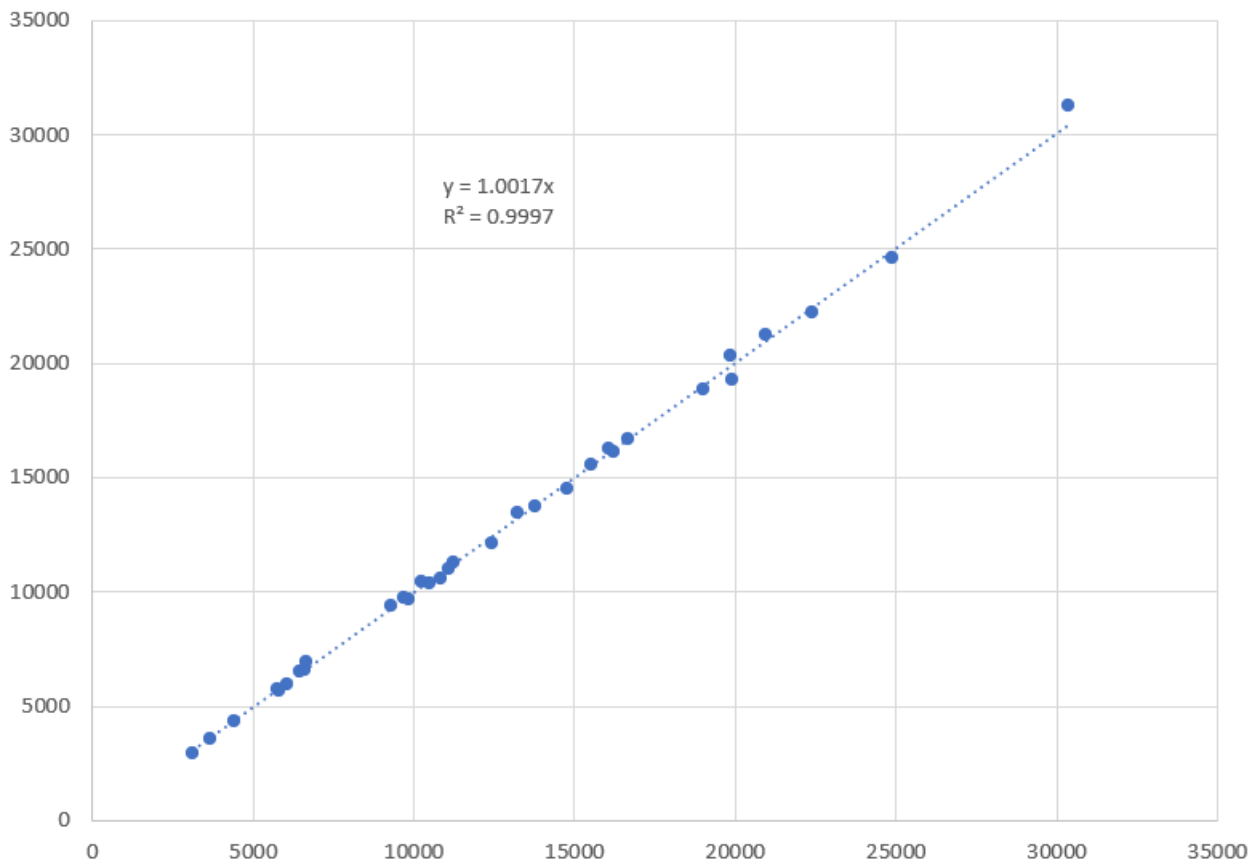


*Methanoculleus* is another methanogen. Its genome is GC rich and AT poor, so its codon profile is the inverse of that for *methanococcus*



Once again, there is a perfect symmetry between the frequency of any codon, and the frequency of its reverse compliment.

Correlation between frequency of any codon, and frequency of its reverse compliment (methanoculleus)



Maintaining codon function across 80% of its genome, whilst maintaining this degree of symmetry is a remarkable feat of engineering.



## ATP Production in Methanogens

### Methanogenesis: ATP Production in Methanogens

Methanogens are **anaerobic archaea** that thrive in oxygen-free environments like wetlands, animal guts, and sediments. Their energy metabolism revolves around converting simple substrates into methane (CH<sub>4</sub>), and this process is tightly coupled to ATP synthesis.

### Key Substrates

Methanogens use a few main substrates:

- CO<sub>2</sub> + H<sub>2</sub> (most common)
- Formate
- Methanol
- Acetate
- Methylamines

### Core Pathway Steps

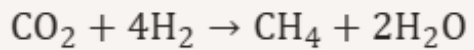
1. **Reduction of CO<sub>2</sub> to methane:**
  - CO<sub>2</sub> is reduced stepwise using electrons from H<sub>2</sub>.
  - This involves coenzymes like **methanofuran**, **coenzyme M (CoM)**, and **coenzyme B (CoB)**.
2. **Electron transport and proton gradient:**
  - Electrons from H<sub>2</sub> are transferred via **ferredoxin** and **F420** (a unique electron carrier).
  - This drives a **proton or sodium ion gradient** across the membrane.
3. **ATP synthesis:**
  - The ion gradient powers **ATP synthase**, producing ATP from ADP and inorganic phosphate.
  - This is the only ATP-generating mechanism in methanogens [Wikipedia Biology LibreTexts](#).

### Unique Features

- Methanogenesis is **exergonic** (releases energy), but only marginally — so methanogens are extremely efficient.
- They use **unusual cofactors** like F420 and methanopterin.
- The final step involves **methyl-CoM reductase**, which releases methane and regenerates CoM and CoB.

## Chemical Equation: CO<sub>2</sub> Reduction by H<sub>2</sub>

The overall reaction used by hydrogenotrophic methanogens is:



This is an exergonic reaction — it releases energy, which methanogens harness to produce ATP.

### Role of Coenzymes

In nature, this reaction **does not occur spontaneously** at biologically useful rates without the help of specialized enzymes and coenzymes. Methanogens use a suite of unique cofactors to catalyze and regulate each step:

- **Methanofuran (MFR)**: binds and activates CO<sub>2</sub>
- **Coenzyme F420**: electron carrier
- **Methanopterin**: carries intermediate methyl groups
- **Coenzyme M (CoM)** and **Coenzyme B (CoB)**: involved in the final step of methane release

These cofactors stabilize intermediates, lower activation energy, and couple the reaction to ion gradients for ATP synthesis.

### Without Coenzymes?

Without these coenzymes and their associated enzymes:

- The reaction would be **thermodynamically favorable** but **kinetically inert** — meaning it wouldn't proceed at a meaningful rate.
- No ATP would be generated, and methane wouldn't form under physiological conditions.

So, the reaction is chemically possible, but biologically **non-viable** without the full enzymatic machinery.

CO<sub>2</sub> is a **very stable molecule**, and its reduction requires both **activation** (via binding) and **electron input**. Methanofuran **lowers the activation energy** and **stabilizes the intermediate**, making the reaction biologically feasible. Without methanofuran, CO<sub>2</sub> would remain inert under physiological conditions.

#### CO<sub>2</sub> Binding:

- CO<sub>2</sub> is initially captured by **methanofuran (MFR)**, forming a **carbamate intermediate**.
- This binding occurs at the **aminomethyl group** of methanofuran, which acts as a nucleophile.

#### Formation of Formyl-MFR:

- The enzyme **formyl-methanofuran dehydrogenase (Fmd)** catalyzes the **reduction of the bound CO<sub>2</sub>** to a **formyl group**.
- This step uses **electrons from reduced ferredoxin** or **F<sub>420</sub>H<sub>2</sub>**, depending on the organism.

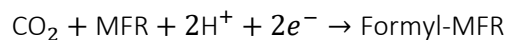
#### Transfer to Methanopterin:

- The formyl group is then transferred from methanofuran to **methanopterin**, another coenzyme, continuing the methanogenesis pathway.

### Stepwise Equations in Methanogenesis (CO<sub>2</sub> + H<sub>2</sub> → CH<sub>4</sub>)

#### Step 1: CO<sub>2</sub> Activation

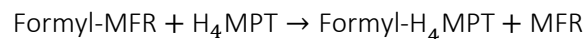
CO<sub>2</sub> binds to methanofuran (MFR), forming formyl-MFR:



Catalyzed by **formylmethanofuran dehydrogenase**, using electrons from reduced ferredoxin.

#### Step 2: Transfer to Methanopterin

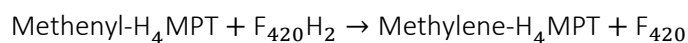
Formyl group is transferred to methanopterin (H<sub>4</sub>MPT):



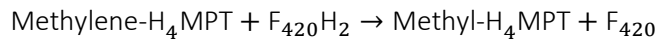
#### Step 3: Cyclization to Methenyl-H<sub>4</sub>MPT



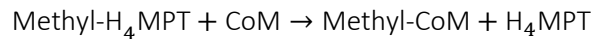
#### Step 4: Reduction to Methylene-H<sub>4</sub>MPT



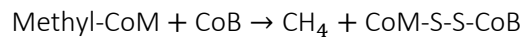
#### Step 5: Reduction to Methyl-H<sub>4</sub>MPT



### Step 6: Transfer to Coenzyme M

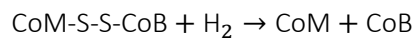


### Step 7: Methane Formation



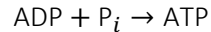
Catalyzed by **methyl-CoM reductase**, the final step releasing methane.

### Step 8: Regeneration of CoM and CoB



### ATP Synthesis

Ion gradients ( $\text{H}^+$  or  $\text{Na}^+$ ) generated during electron transfer drive **ATP synthase**:



If any of the key enzymes in the methanogenesis pathway are absent or nonfunctional, **ATP synthesis is disrupted or halted entirely**.

Methanogenesis is a **stepwise cascade**, and each enzyme:

- Catalyzes a specific transformation (e.g.,  $\text{CO}_2 \rightarrow \text{formyl-MFR} \rightarrow \text{methyl-CoM} \rightarrow \text{CH}_4$ )
- Couples redox reactions to ion gradients
- Enables ATP generation via membrane-bound ATP synthase

If any enzyme is missing:

- The pathway **stalls at that step**
- **No methane is produced**
- **No ion gradient forms**
- **ATP synthase remains inactive**

### Bottlenecks

- **Missing formylmethanofuran dehydrogenase**  $\rightarrow$   $\text{CO}_2$  can't be reduced, so the cycle never starts.
- **Missing methyl-CoM reductase**  $\rightarrow$  methane isn't released, and the final redox step fails.
- **Missing ATP synthase**  $\rightarrow$  even if methane is made, no ATP is generated.

Methanogens are exquisitely tuned — they operate near thermodynamic limits, so **every enzyme is mission-critical**. You could think of it as a symbolic relay: drop the baton anywhere, and the energy never reaches the finish line.

In this short note, we have seen the importance of methanogens for enabling the decomposition of organic matter, and the fermentation and digestion of foods by ruminant animals. There is ample reason to not subject animals to experimental drugs that suppress methanogenesis, not least of which is the suffering imposed on the animals for their entire lives, and the loss of productive healthy livestock. Widespread use of these suppressive drugs would result in global hunger and poverty.

We have also seen that even the least of creatures embody

1. complex pathways of multiple steps with irreducible complexity
2. unique pathways with no known lineage
3. a symmetry in codon usage.

These creatures embody not just ingenious function, but a striking symmetry of form. Did they evolve? If each step is useless without all of the steps being in place, then can it have evolved step by step, or must the steps have appeared all at once? How can it have evolved when its functions are unique – meaning no other creature possesses this mechanism? Why add the additional constraint of near-perfect symmetry?

Such abrupt beginnings, such wonderful symmetry and such irreducible complexity are signs that these creatures were created - the product of intelligent design- by our Father in Heaven.

As of late 2025, **Bovaer is registered for use in over 65 countries worldwide**. Here's a diagnostic snapshot of its global rollout:

### Countries Using Bovaer

- **Early adopters:** Brazil and Chile (2021)
- **Major approvals:**
  - **European Union**
  - **United Kingdom**
  - **Australia**
  - **Canada** (approved January 2024)
  - **United States** (approved May 2024)
  - **Mexico**
  - **Much of Latin America**
  - **China** (implementation underway with China Modern Dairy Holdings)

As of now, **precise uptake percentages of Bovaer by farmers in each country are not publicly available**. While Bovaer has been approved in over 65 countries—including the EU, UK, US, Canada, Australia, Brazil, and China—most sources report **pilot programs, partnerships, and early-stage rollouts**, not full adoption metrics.

### Known Adoption Highlights

- **Brazil & Chile:** First to approve Bovaer in 2021; used in select dairy and beef operations.
- **EU & UK:** Approved and promoted via large dairy cooperatives like Arla, but uptake remains **limited to pilot farms**.
- **Australia & Canada:** Approved in 2024; adoption is **growing but not yet widespread**.
- **United States:** Approved in May 2024; **early-stage implementation** in some feedlots and dairies.
- **China:** Partnering with China Modern Dairy Holdings; **scaling underway**, but no public uptake data.

### Diagnostic Insight

The lack of transparent uptake data suggests:

- **Centralized control:** Adoption may be driven by large agribusinesses or cooperatives, not individual farmers.

In Australia, the actual uptake of Bovaer among farmers is currently very low—likely under 1%, and there are no known instances of its use on Australian dairy farms as of late 2024.

### Current Status in Australia

- **Beef feedlots:** Bovaer has been trialed in select feedlot operations, primarily for methane reduction research.
- **Dairy sector:** Despite regulatory approval, **Bovaer is not in use** due to high costs, limited supply, and logistical challenges.
- **Public statements:** The Australian Dairy Farmers association confirmed that Bovaer has not been adopted in commercial dairy farming.

### Diagnostic Insight

This suggests that Bovaer's presence in Australia is **symbolic rather than systemic**—approved but not embedded.