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The reverse translation from English to DNA: the way how to encrypt messages in the genome



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SYNTHETIC BIOLOGY, SYNTHETIC CHROMOSOME, JCVI-syn1.0 clone sMmYCp235-1,
MOLECULAR BIOLOGY, MOLECULAR GENETICS, BIOTECHNOLOGY, GENE,
GENOME, BIOINFORMATICS, LINGUISTICS, ENGLISH LANGUAGE

THE FIRST EVER CREATED SPECIES, CONTROLLED BY A SYNTHETIC GENOME



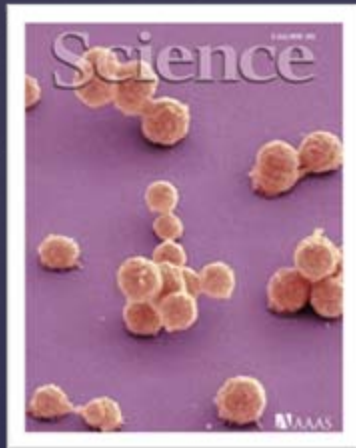
02.07.2010



ROCKWILL, MARYLAND, USA



INSTITUTE OF CRAIG VENTER



COVER of the SCIENCE journal:
Electron micrograph of synthetic cells
Mycoplasma mycoides JCVI-syn1.0
(magnification ~25,000×)

THE YEAR 2010 WAS SIGNIFICANT FOR BIOLOGY
IN THE LIGHT OF COMPLETE ARTIFICIAL
SYNTHESIS OF GENOME AND ITS
TRANSPLANTATION

[Gibson D. G., Glass J. I., Lartigue C., et al. Creation of a bacterial cell controlled by a chemically synthesized genome. *Science*. 2010;329:52–56. doi: 10.1126/science.1190719.]



A RESEARCH GROUP, LED BY THREE PROMINENT SCIENTISTS
TRANSPLANTED DE NOVO SYNTHESIZED CHROMOSOME OF
MYCOPLASMA MYCOIDES INTO MYCOPLASMA CAPRICOLUM



Hamilton Othanel Smith, Nobel prize laureate. Prominent for investigations of restriction enzymes. His studies revolutionized the methods of molecular biology and biotechnology

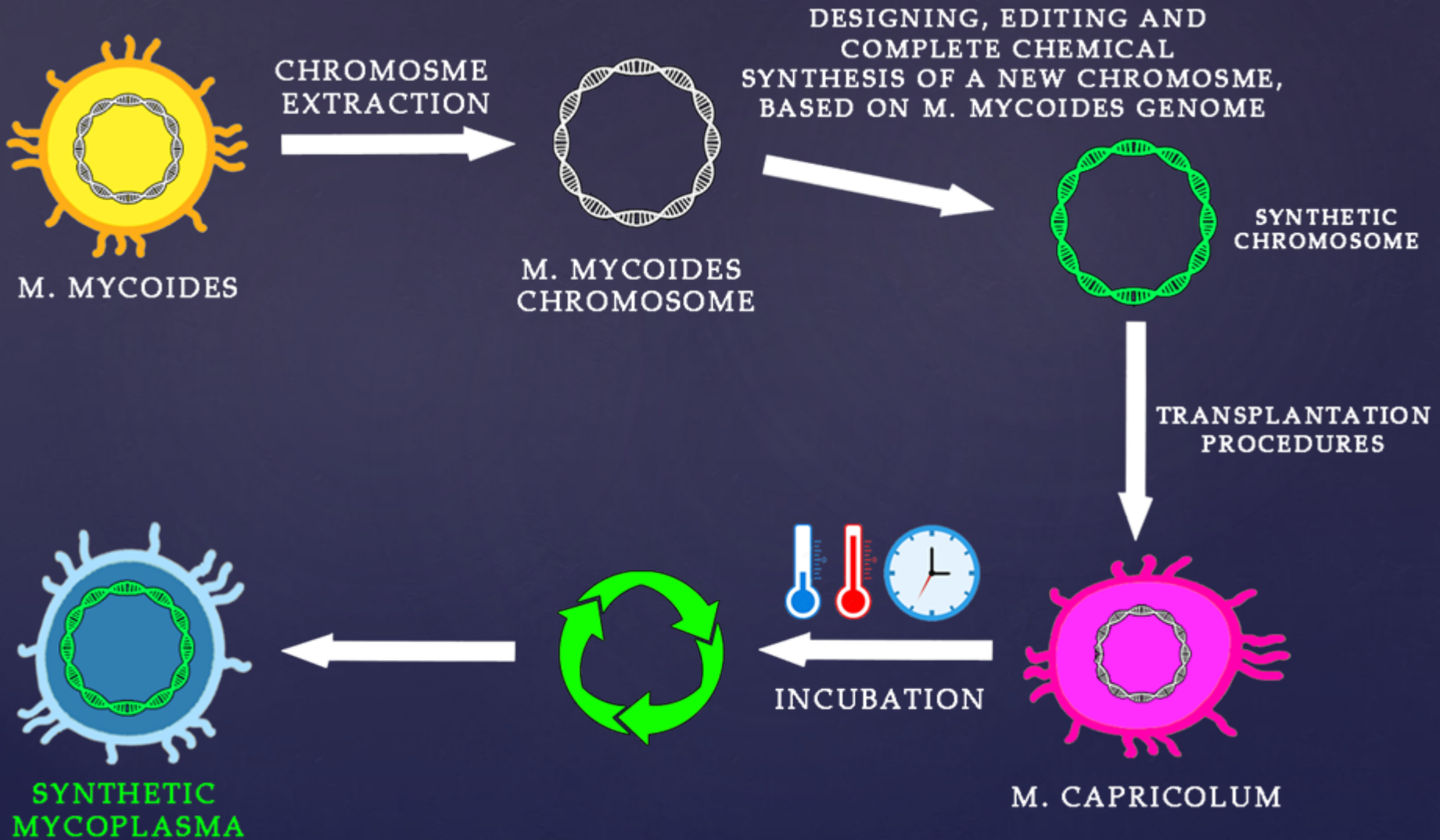


Clyde A. Hutchison III, prominent for investigations in sphere of site-directed mutagenesis. Participated in the determination of a complete genome sequence of phage Φ X174. Made a contribution to the polymerase chain reaction discovery

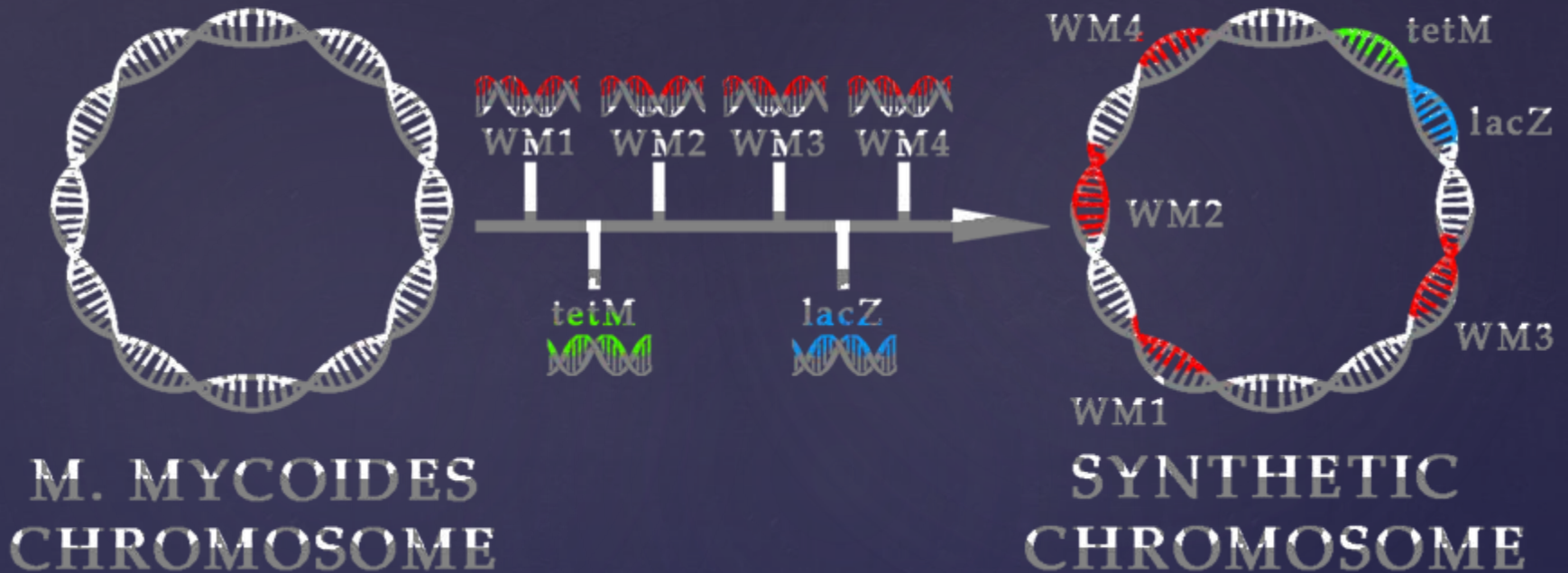


John Craig Venter, prominent for Human Genome Project and initial studies in synthetic biology

THE CONCEPTION OF EXPERIMENTAL WORK



DESIGN OF THE SYNTHETIC CHROMOSOME

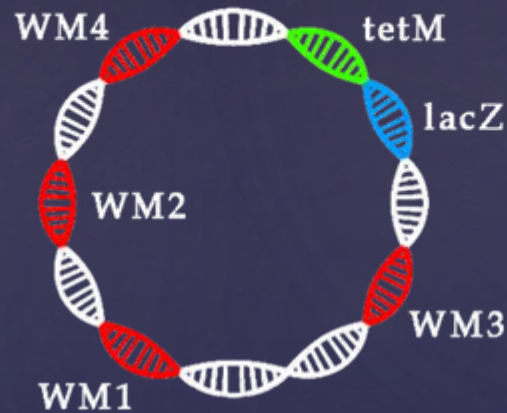
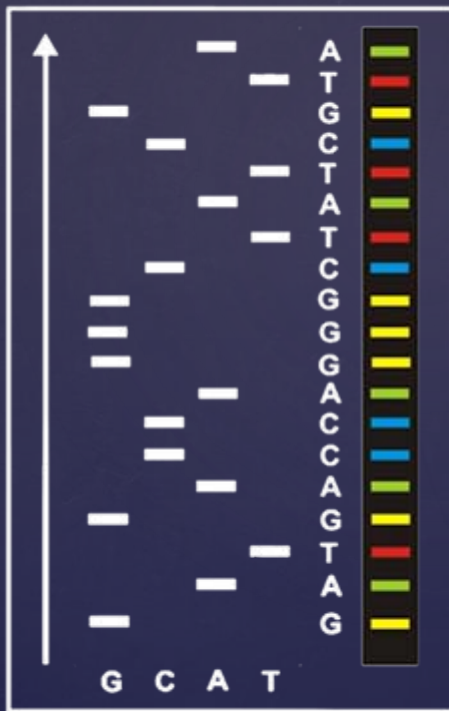


SYNTHETIC CHROMOSOME CONTAINS 6 EXTRA REGIONS: 4 WATERMARKS WITH DECODED MESSAGES IN ENGLISH LANGUAGE, TETRACYCLINE RESISTANCE GENE (**tetM**) AND BETA-GALACTOSIDASE GENE (**LacZ**)

In order to verify the success of the experimental work, the donor genome was edited by inserting the nucleotide sequence of **4 watermarks** into different loci of the genome, **antibiotic (tetracycline) resistance gene (tetM)** and **beta-galactosidase (lacZ) gene**. Thus, the efficiency of transplantation could be evaluated using three approaches:

1. Control sequencing of the synthetic genome and identification of watermarks
2. Testing viability of bacterial culture, treating their growth medium with antibiotic.
3. Turning the colony bright blue in the presence of an organic compound X-gal, metabolizing by a product of lacZ gene.

1. CONTROL SEQUENCING OF THE SYNTHETIC GENOME AND IDENTIFICATION OF WATERMARKS



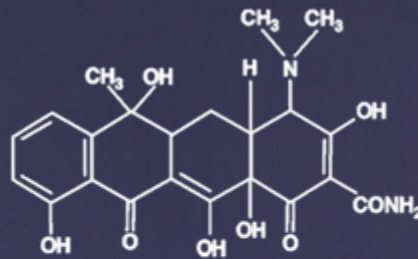
SYNTHETIC
CHROMOSOME
WITH WATERMARKS



INTACT CHROMOSOME
(NO WATERMARKS)



2. TESTING VIABILITY OF BACTERIAL CULTURE, TREATING THEIR GROWTH MEDIUM WITH ANTIBIOTIC



TETRACYCLINE
ANTIBIOTIC



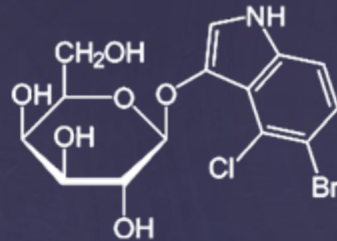
SYNTHETIC CELLS ARE
TETRACYCLINE-RESISTANT
(tetM-positive)



COLONY LYSIS
(tetM-negative INTACT CELLS)



3. TURNING THE COLONY BRIGHT BLUE IN THE PRESENCE OF AN ORGANIC COMPOUND X-GAL, METABOLIZING BY A PRODUCT OF *lacZ* GENE



X-gal, metabolized
by *lacZ* gene product
(beta-galactosidase)



SYNTHETIC CELLS METABOLIZE
X-gal (*lacZ*-positive),
THE COLONY BECOMES BLUE



INTACT CELLS (*lacZ*-negative)
DO NOT METABOLIZE X-gal,
THE COLONY DOES NOT TURN BLUE



These three approaches confirmed success in transplantation, proclaiming that the first ever species was created by human. The linguistic interest of this great scientific breakthrough lies in **watermarks**, which were inserted into the donor genome. Each additional sequence encodes a message in **English**.

THE AIM OF THE STUDY:

- To biologically and linguistically analyze the adapt of English alphabet to a genetic code
- Mapping the exact localization of 4 watermarks in synthetic genome (WMs loci have never been published)
- Deciphering encoded data (**complete nucleotide sequence of the watermarks has never been published**; decoded data is **partially** available)



MATERIALS AND METHODS

1. Analysis of C. Venter's book "**Life at the speed of light**" in order to get **cryptography** between English alphabet and a specific trinucleotide code, used to encipher it.
2. Building the **tagging sequences** (TSs) for pairwise alignment in order to identify **watermarks** in the synthetic chromosome. TSs were created without punctuation marks, except commas and spaces as .txt files and converted in FASTA format by **MEGA-X (Version: 10.1.7) tool**.
3. Dividing the sequence of synthetic chromosome in 5 fragments (Fs) in order to simplify and speed up the pairwise sequence alignment, using **DNASTAR Lasergene 17.01.1 (2020) MegAlign Pro**.
4. PSA (Pairwise Sequence Alignment) of Fs and TSs, completed by **DNASTAR Lasergene 17.01.1 (2020) MegAlign Pro** with **MAUVE** algorithm.
5. An extra PSA was completed by **DNASTAR Lasergene 17.01.1 (2020) MegAlign Pro**, using the **Smith-Waterman** DNA alignment algorithm [Matrix: "NUC44"; Gap penalty: 10; Gap extension penalty: 1].
6. Deciphering the watermarks codon by codon, moving to the 5'-end and 3'-end.
7. Overview of decoded watermarks.

1. ANALYSIS OF THE “LIFE AT THE SPEED OF LIGHT

The chapter 8 “**Synthesis of the M. mycoides Genome**” has a **key** for deciphering the nucleotide cryptography, used in watermarks. The series of characters, including complete English alphabet of 26 letters; newline; space; numbers (0-9); various punctuation marks, such as point, comma, hyphen etc; mathematical signs, such as plus, minus and some additional symbols were represented by the developed trinucleotide code.

THE CRYPTOGRAPHY BETWEEN WATERMARKS AND ENGLISH ALPHABET, PUNCTUATION MARKS AND ADDITIONAL CHARACTERS

- A is encoded by TAG trinucleotide; B – AGT; C – TTT; D – ATT; E – TAA; F – GGC; G – TAC; H – TCA; COMMA (,) – GTG; POINT (.) – CGA; SPACE () – ATA; 1 – CTT; 2 – ACT; 3 – AAT; @ - TCG etc.
- Total number of encoded characters – **64**, **corresponding to the real number of DNA-codons**.
- There is a **total mismatch** between codification of the English alphabet and one-letter code of amino acids. The only exception is in position **12**: letter L of JCVI-syn1.0 alphabet corresponds to leucine (Leu, L). Mismatch example: letter G in JCVI-syn1.0 alphabet is encoded by TAC, which in the real genetic code means M (Met, methionine) etc.
- **The table of cryptography** was created to make building the tagging sequences more convenient . It also was used for further decoding.

2. BUILDING THE TAGGING SEQUENCES (TSs) FOR PAIRWISE ALIGNMENT

Identification of watermarks in the synthetic genome required building the sequences to complete pairwise alignment. Because of the fact the whole sequences of watermarks remained **unpublished**, 4 specific tagging sequences (TSs) were created in order to identify corresponding fragments of each watermark in the chromosome. The TSs were built according to the only available data from “The life at the speed of light”. The chapter 8, “Synthesis of *M. mycoides* genome”, **fragmentally** provides some **insights** of what was encoded in each watermark. Thus, among encrypted data in WM₁ there is “Craig Venter Institute”; the quote from James Joyce: “To live, to err, to fall, to triumph, to recreate life out of life” in WM₂; the quote of Robert Oppenheimer: “See things not as they are, but as they might be” in WM₃ and Richard Feynman’s quote: “What I cannot build, I cannot understand” in WM₄. Considering these insights from the chapter 8 we hypothesized that “Craig Venter Institute” and the quotes above are suitable to be such tagging sequences for PSA. Using the cryptographic features from Table 1 TSs were created with no punctuation marks, except comas and spaces as .txt files and converted in FASTA format.



THE FILES CONVERTATION WAS
COMPLETED BY MEGA-X (V:10.1.7)

3. DIVIDING THE SEQUENCE OF SYNTHETIC CHROMOSOME

Complete sequence of synthetic *Mycoplasma mycoides* JCVI-syn1.0 clone sMmYCp235-1 was found in NCBI Nucleotide database (**GenBank: CP002027.1**) and downloaded in FASTA. The sequence was divided in 5 fragments, according to the schematic representation of watermarks in original paper “Creation of a bacterial cell controlled by a chemically synthesized genome”. There are:

- **F₀** (**1→200000** nucleotides)
- **F₁** (**200001→400000**)
- **F₂** (**400001→600000**)
- **F₃** (**600001→800000**)
- **F₄** (**800001→1078809**)

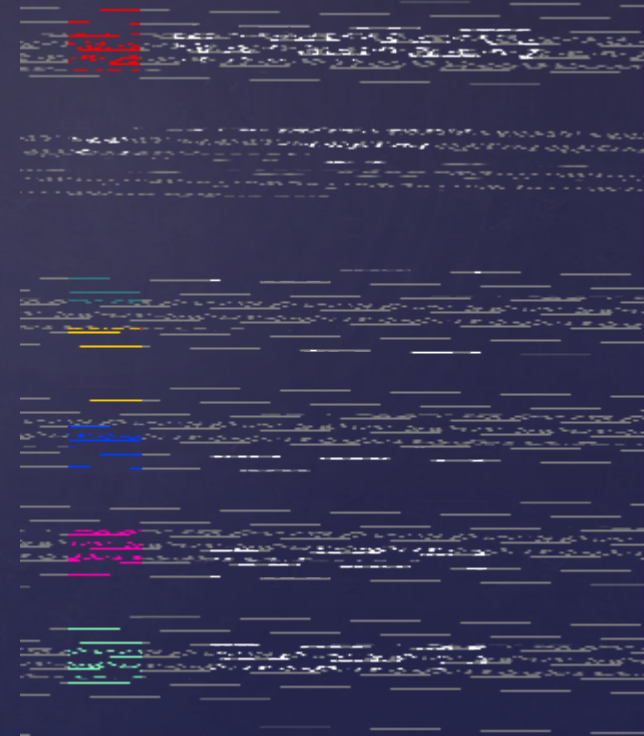
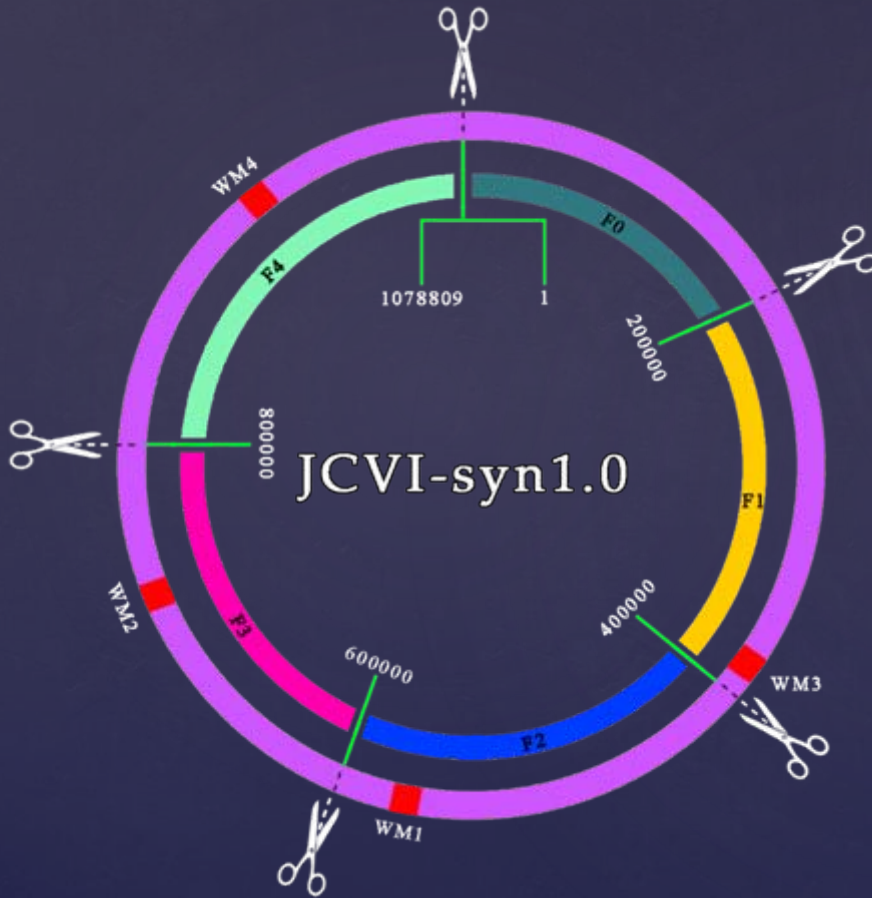


This manipulation was completed in order to simplify and speed up the pairwise sequence alignment.



The sequence was fragmented, using DNASTAR Lasergene 17.01.1 (2020) MegAlign Pro

Fragmentation of the complete sequence of synthetic *Mycoplasma mycoides* JCVI-syn1.0 clone sMmYCp235-1



F₀ (1→200000 nucleotides); **F₁** (200001→400000); **F₂** (400001→600000);
F₃ (600001→800000); **F₄** (800001→1078809)

4. PSA (MAUVE ALGORITHM); 5. CONTROL PSA (SMITH-WATERMAN ALGORITHM). COMPLETED BY

DNA STAR Lasergene 17.01.1 (2020) MegAlign Pro

1. The first WM was identified via alignment of F_2 and TS_1 :

5'-TTTCTATAGCTGTACATATTGTAATGCTGATAACTAATACTGTGCGCTTGACGTGAT
CCTGATAA-3' → "Craig Venter Institute" ([565527→565592](#)).



CONTROL PSA WAS
COMPLETED BY CLUSTAL
SOFTWARE

2. WM_2 was found via alignment of F_3 and TS_2 :

5'-

TGACGTAACCTGTTGTAATGACGTAACTACTATGACGTGGCTAGAACAACCTGACGT
TGACTACTGTCCCAAACATCATGACGTCTATAATTTCTATAATAGTGATAAAACCTGG
GCTAACGTTCTGACGTGGCAACCTGGGCTAA-3' → "To live, to err, to fall, to triumph,
to recreate life out of life", James Joyce ([726295→726492](#)).

3. WM_3 was identified via TS_3 :

5'-

GCTTAATAAATATGATCACTGTGCTACGCTATATGCCGTTGAATATAGGCTATATGATC
ATAACATATATAGCTATAAGTGATAAGTTCCTGAATATAGGCTATATGATCATAACAT
ATACAACCTGTACTCATGAATAAGTTAA-3' → "See things not as they are, but as they
might be", - the quote of Robert Oppenheimer ([390264→390407](#)).

4. The last watermark (WM_4) was detected via TS_4 :

5'-

GTCTCATAGTGAATACTGATATTTTAGTGCTGCCGTTGAATAAGTTCCTGAACATTGT
GATACTGATATTTTAGTGCTGCCGTTGAATATCCTGCATTAACTAGCTTGATAGTGCA

6. DECIPHERING THE WATERMARKS CODON BY CODON, MOVING TO THE 5'-END AND 3'-END



After WMs were identified, their complete sequences were decoded, moving to the 5'-end and to the 3'-end until the beginning of a senseless nucleotide context (?,?,fgjhdnf?>smkl31:":F or something like that)

RESULTS: 4 WMs IN JCVIsyn-1.0 WERE IDENTIFIED AND DECIPHERED

WATERMARK 1

5'-

TTAACTAGCTAAGTTCGAATATTTCTATAGCTGTACATATTGTAATGCTGATAACTAA
TACTGTGCGCTTGACTGTGATCCTGATAAATAACTTCTTCTGTAGGGGTAGAGTTTTATT
TAAGGCTACTCACTGGTTGCAAACCAATGCCGTACATTACTAGCTTGATCCTTGGTCG
GTCATTGGGGGATATCTCTTACTAATAGAGCGGCCTATCGCGTATTCTCGCCGGACCC
CCCTCTCCACACCAGCGGTGTAGCATCACCAAGAAAATGAGGGGAACGGATGAGG
AACGAGTGGGGGCTCATTGCTGATCATAATGACTGTTTATATACTAATGCCGTCAACT
GTTTGCTGTGATACTGTGCTTTTCGAGGGGCGGGAGATTTCGTTTTTTGACATACATAAATAT
CATGACAAAACAGCCGGTCATGACAAAACAGCCGGTCATAATAGATTAGCCGGTGA
CTGTGAAACTAAAGCTACTAATGCCGTCAATAAATATGATAATAGCAACGGCACTGA
CTGTGAAACTAAAGCCGGCACTCATAATAGATTAGCCGGAGTCGTATTCATAGCCGG
TAGATATCACTATAAGGCCCAGGATCATGATGAACACAGCACCCACGTCGTCGTCGCGA
GTTTTTTTGCTGCGACGTCTATACCACGGAAGCTGATCATAAATAGTTTTTTTGCTGCG
GCACTAGAGCCGGACAAGCACACTACGTTTGTAATAACATCGTTCCGAATTGTAAAT
AATTTAATTTTCGTATTTAAATTATATGATCACTGGCTATAGTCTAGTGATAACTACAAT
AGCTAGCAATAAGTCATATATAACAATAGCTGAACCTGTGCTACATATCCGCTATAC
GGTAGATATCACTATAAGGCCCAGGACAATAGCTGAACCTGACGTCAGCAACTACGTT
TAGCTTGACTGTGGTCGGTTTTTTTGCTGCGACGTCTATACGGAAGCTCATAACTATAA
GAGCGGCACTAGAGCCGGCACACAAGCCGGCACAGTCGTATTCATAGCCGGCACTC
ATGACAAAACAGCGGCGCGCCTTAAGCT-3'.

- oThe **largest** WM. It is localized in the region: **565506 → 566573**
- oConsisting of **1068** nucleotides
- oEncoding **356** characters

DECIPHERED WM1

Q2>EJ. CRAIG VENTER INSTITUTE 2009

[PARAGRAPH]

ABCDEFGHIJKLMNOPQRSTUVWXYZ

[PARAGRAPH]

0123456789#@)(-+ \ = / : < ; > \$ % { } *] ' [% ! ' . ,

[PARAGRAPH]

SYNTHETIC GENOMICS, INC.

[PARAGRAPH]

<!DOCTYPE HTML><HTML><HEAD><TITLE>GENOME

TEAM</TITLE></HEAD><BODY>THE JCVI<P>PROVE YOU'VE

DECODED THIS WATERMARK BY EMAILING US HERE!</P></BODY></HTML

>F5+ERS

ENCODED DATA

- Involved organizations and year of origin: Craig Venter institute, Synthetic Genomics, 2009
- Contains the key for deciphering (the series of used characters)
- HTML-code for emailing after decoding the watermark

WATERMARK 2

5'-TTAACTAGCTAACAACCTGGCAGCATAAAACATATAGAACTACCTGCTATAAGTGAT
ACAACCTGTTTTTCATAGTAAAACATACAACGTTGCTGATAGTACTCCTAAGTGATAGCTTA
GTGCGTTTAGCATATATTGTAGGCTTCATAATAAGTGATATTTTAGCTACGTAACCTAAATA
AACTAGCTATGACTGTACTCCTAAGTGATATTTTCATCCTTTGCAATACAATAACTACTAC
ATCAATAGTGCGTGATATGCCTGTGCTAGATATAGAACACATAACTACGTTTGCTGTTTTTC
AGTGATATGCTAGTTTTCATCTATAGATATAGGCTGCTTAGATTCCCTACTAGCTATTTCTG
TAGGTGATATACGTCCATTGCATAAGTTAATGCATTTAACTAGCTGTGATACTATAGCAT
CCCCATTCCTAGTGCATATTTTCATCCTAGTGCTACGTGATATAATTGTACTAATGCCTGT
AGATAATTTAATGCCTGGCTCGTTTGTAGGTGATAATTTAGTGCCTGTAAACATATACCT
GAGTGCTCGTTGCGTGATAGTTCGTTTCATGCATATACAACCTAGGCTGCTGTGATATGGTC
ACTGCCCTTACTGTGCTACATATTACTGCGAGGGGGGATGACGTATAAACCTGTTGTAAGT
GATATGACGTATATAACTACTAGTGATATGACGTATAGGCTAGAACAACGTGATATGAC
GTATATGACTACTGTCCCAAACATCAGTGATATGACGTATACTATAATTTCTATAATAGT
GATAAATAAACCTGGGCTAAATACGTTCCCTGAATACGTGGCATAAACCTGGGCTAACGA
GGAATACCCATAGTTTAGCAATAAGCTATAGTTCGTCATTTTTTAAGGCGCGCCTTAACCTA
GCT-3'

- o The smallest WM. It is localized in the region:

725653 → 726558

- o Consisting of **909** nucleotides

- o Encoding **303** characters

DECIPHERED WM2

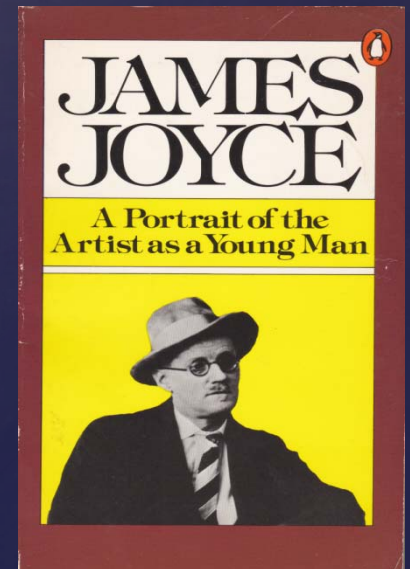
Q2>EMIKKEL ALGIRE, MICHAEL MONTAGUE, SANJAY VASHEE,
CAROLE LARTIGUE, CHUCK MERRYMAN, NINA ALPEROVICH,
NACYRA ASSAD-GARCIA, GWYN BENDERS, RAY-YUAN
CHUANG, EVGENIA DENISOVA, DANIEL GIBSON, JOHN GLASS,
ZHI-QING QI.

[PARAGRAPH]

“TO LIVE, TO ERR, TO FALL, TO TRIUMPH, TO RECREATE LIFE
OUT OF LIFE.” – JAMES JOYCE

ENCODED DATA

- Names of the scientists, participated in the project (n=13)
- The quote from the James Joyce's
- “**A Portrait of the Artist as a Young Man**”



COVER OF THE BOOK

3

5'-

TTAACTAGCTAATTTAACCATATTTAAATATCATCCTGATTTTCACTGGCTCGTTGCGTGA
TATAGATTCTACTGTAGTGCTAGATAGTTCTGTACTAGGTGATACTATAGATTTCATAGAT
AGCACTACTGGCTTCATGCTAGGCATCCCAATAGCTAGTGATAGTTTAGTGCATACAACG
TCATGTGATACAACGTTGCTGGCTGTAGATACAACGTCGTATTCTGTAAGTGATACAATA
GCTATTGCTGTGCATAGGCCTATAGTGGCTGTAAGTGTGATATCACGTAACAACCATAT
AAGTTAGATTTAATGCCCCCTGACTGAACGCTCGTTGCGTGATAGTTTAGGCTCGTTGCAT
ACAAGTGTGATTTTCATAAAACAACGTGATAATTTAGTGCTAGATAAGTTCCGCTTAGCA
AGTGATAGTTTCCGCTTGACTGTGCATAGTTCGTTTCATGCGCTCGTTGCGTGATAAACTAG
GCAGCTTCACAAGTGTGATAATTTAATTGCTGATATTGCTGGCTGTCTAGTGCTAGTGATCAT
AGTGCGTGATAGTTTAAGCTGCTCTGTTTTAGATATCACGTGCTTGATAATGAACTAACT
AGTGATACTACGTAGTTAACTATGAATAGGCCTACTGTAAATTCAATAGTGCGTGATATT
GAACTAGATTCTGCAACTGCTAATATGCCGTGCTGCACGTTTGGTGATAGTTTAGCATGC
TTCAGTATAATAAATATGGTAGTTGTAAGTACTGCGAATAGGGGGAGCTTAATAAATATG
ATCACTGTGCTACGCTATATGCCGTTGAATATAGGCTATATGATCATAACATATATAGCT
ATAAGTGATAAGTTCCTGAATATAGGCTATATGATCATAACATATACAAGTGTACTCATG
AATAAGTTAACGAGGA-3'

- oLocalized in the region: **389493 → 390413**
- oConsisting of **921** nucleotides
- oEncoding **307** characters

DECIPHERED WM3

Q2>ECLYDE HUTCHISON, ADRIANE JIGA, RADHA KRISHNAKUMAR, JAN MOY, MONZIA MOODIE, MARVIN FRAZIER, HOLLY BADEN-TILSON, JASON MITCHELL, DANA BUSAM, JUSTIN JOHNSON, LAKSHMI DEVI VISWANATHAN, JESSICA HOSTETLER, ROBERT FRIEDMAN, VLADIMIR NOSKOV, JAYSHREE ZAVERI.

[PARAGRAPH]

“SEE THINGS NOT AS THEY ARE, BUT AS THEY MIGHT BE.”

ENCODED DATA

- Names of the scientists, participated in the project (n=15)
- Robert Oppenheimer's qoute

WATERMARK 4

5'-

TTAACTAGCTAATTTTCATTGCTGATCACTGTAGATATAGTGCATTCTATAAGTCGCTCC
CACAGGCTAGTGCTGCGCACGTTTTTCAGTGATATTATCCTAGTGCTACATAACATCAT
AGTGCGTGATAAACCTGATACAATAGGTGATATCATAGCAACTGAACTGACGTTGCAT
AGCTCAACTGTGATCAGTGATATAGATTCTGATACTATAGCAACGTTGCGTGATATTTT
CACTACTGGCTTGACTGTAGTGCATATGATAGTACGTCTAACTAGCATAACTAGTGAT
AGTTATATTTCTATAGCTGTACATATTGTAATGCTGATAACTAGTGATATAATCCAAC
AGATAGTCCTGAACTGATCCCTATGCTAACTAGTGATAAACTAACTGATACATCGTTC
CTGCTACGTGATAGCTTCACTGAGTTCCATACATCGTCGTGCTTAAACATCAGTGATAA
CACTATAGAGTTCATAGATACTGCATTAAGTGTGATATGACTGCAAATAGCTTGACG
TTTTGCAGTCTAAAACAACGTGATAATTCTGTAGTGCTAGATACTATAGATTTCCCTGCT
AAGTGATAAGTCTACTGATTACTAATGAATAGCTTGGTTTTGGCATACACTGTGCGCT
GCACTGGTGATAGCTTTTCGTTGATGAATAATTTCCCTAGCACTGTGCGTGATATGCTA
GATTCTGTAGATAGGCTAAATTCGTCTACGTTTGTAGGTGATAGTTTAGTTGCTGTAAC
TAATATTATCCCTGTGCCGTTGCTAAGCTGTGATATCATAGTGCTGCTAGATATGATAA
GCAAATAATAGAGTCGAGGGGGAGTCTCATAGTGAATACTGATATTTTAGTGCTGCC
GTTGAATAAGTTCCCTGAACATTGTGATACTGATATTTTAGTGCTGCCGTTGAATATCC
TGCATTAACTAGCTTGATAGTGCATTGAGGAATACCCATACTACTGTTTTTCATAGCT
AATTATAGGCTAACATTGCCAATAGTGCGGCGCGCCTTAACTAGCT-3'

- oLocalized in the region: **958641 → 959684**
- oConsisting of **1044** nucleotides
- oEncoding **348** characters

DECIPHERED WM4

Q2>ECYNTHIA ANDREWS-PFANNKOCH, QUANG PHAN, LI MA, HAMILTON SMITH, ADI RAMON, CHRISTIAN TAGWERKER, J CRAIG VENTER, EULA WILTURNER, LEI YOUNG, SHIBU YOOSEPH, PRABHA IYER, TIM STOCKWELL, DIANA RADUNE, BRIDGET SZCZYPINSKI, SCOTT DURKIN, NADIA FEDOROVA, JAVIER QUINONES, HANNA TEKLEAB.

[PARAGRAPH]

“WHAT I CANNOT BUILD, I CANNOT UNDERSTAND.” – RICHARD FEYNMANF5+ERS

ENCODED DATA

- Names of the scientists, participated in the project (n=18)
- Richard Feynman's quote

CONCLUSION

THIS STUDY REVEALED:

- EXACT LOCI OF WATERMARKS (WM1: 565506 → 566573; WM2: 725653 → 726558; WM3: 389493 → 390413; WM4: 958641 → 959684).

As far as we know, this data is absolutely exclusive and it has been never published before.

- COMPLETE NUCLEOTIDE SEQUENCE OF THE WMs

WATERMARKS WERE FULLY DECODED. THEY CONTAIN:

- THE **KEY** FOR DECIPHERING AND HTML CODE FOR EMAILING
- **46** NAMES OF SCIENTIST, INVOLVED IN THE PROJECT
- **4** QUOTATIONS
- TOTAL NUMBER OF NUCLEOTIDES, COMPOSING 4 WATERMARKS = **3942**
- THE LARGEST IS WM1 (**1069** NTs), THE SMALLEST IS WM2 (**909** NTs)



ON THE 90TH ANNIVERSARY
OF THE DEPARTMENT OF
FOREIGN LANGUAGES
**THANK YOU FOR
ATTENTION!**



ON THE 10TH
ANNIVERSARY OF
SYNTHETIC MYCOPLASMA

ABCDEFGH 

К 90-ЛЕТИЮ КАФЕДРЫ ИНОСТРАННЫХ ЯЗЫКОВ. ON THE 90TH ANNIVERSARY
OF THE DEPARTMENT OF FOREIGN LANGUAGES. ZUM 90-JÄHRIGE JUBILÄUM
DER FAKULTÄT FÜR FREMDSPRACHEN. DEBIDO AL 90 ANIVERSARIO DEL
DEPARTAMENTO DE LENGUAS EXTRANJERAS. SUR LE 90^E ANNIVERSAIRE DE LA
FACULTÉ DES LANGUES ÉTRANGÈRES.