

WHAT IS LIFE ?

LIFE CANNOT BE SEPARATED FROM FOUR FONDAMENTAL PROCESSES

**METABOLISM
COMPARTMENTALIZATION**

**MEMORY
MANIPULATION**

THE FIRST TWO HAVE THE SCALE OF SMALL MOLECULES, THE OTHER ONES CORRESPOND TO MACROMOLECULES

MEMORY AND MANIPULATION ARE LINKED BY A FUNDAMENTAL LAW THAT GIVES ITS RECURSIVE CHARACTER TO LIFE TRANSMISSION THIS LAW IS THE GENETIC CODE

LIFE CONCERNS RELATIONSHIPS BETWEEN OBJECTS RATHER THAN OBJECTS (THE DELPHIAN BOAT)

Origin



 MICROSCOPIC

 MESOSCOPIC

A THEORY OF THE ORIGIN OF LIFE MUST EXPLAIN :

- **HOW COMPARTMENTS ARE MADE**
- **HOW ARE CONSTRUCTED THE FIRST REPLICATING MOLECULES**
- **HOW IS GENERATED THE CORRESPONDENCE RULE BETWEEN MEMORY AND MANIPULATION**

A PRIMITIVE METABOLISM PROVIDES A SOLUTION

Origin



**J'AI LA PRÉTENTION DE DÉMONTRER AVEC RIGUEUR QUE
DANS TOUTES LES EXPÉRIENCES OU L'ON A CRU RECONNAÎTRE
L'EXISTENCE DE GÉNÉRATIONS SPONTANÉES, CHEZ LES ÊTRES
LES PLUS INFÉRIEURS, OU LE DÉBAT SE TROUVE AUJOURD'HUI
RELÉGUÉ, L'OBSERVATEUR A ÉTÉ VICTIME D'ILLUSIONS OU DE
CAUSES D'ERREUR QU'IL N'A PAS APERÇUES OU QU'IL N'A PAS
SU ÉVITER.**

LOUIS PASTEUR

Origin



**ARGUMENTS THAT ATTEMPT TO EXTRAPOLATE FROM
MODERN BIOCHEMISTRY BACK TO THE ORIGIN OF LIFE
ARE FUTILE**

S. BENNER

**THE METHOD USED IS THAT OF A RECONSTRUCTION OF
PRECURSOR PATHWAYS BY RETRODICTION FROM EXTANT
PATHWAYS**

Origin



G. WÄCHTERSCHÄUSER

IN THE USUAL MODEL OF A PREBIOTIC "SOUP" A VAST NUMBER OF VARIANTS OF A SET OF SMALL MOLECULES IS PRODUCED. BUT FAR FROM BEING A FEATURE FAVORABLE TO THE THEORY THIS ACTS AS A POISON WHICH FREEZES THE FUTURE OF THE BROTH.

IN A MODEL OF A PRIMITIVE METABOLISM, ONE MUST TAKE INTO ACCOUNT A SELECTIVE MECHANISM. THIS IMPLIES :

- THE EXISTENCE OF AN UPPER LIMIT IN THE NUMBER OF SPECIES PRODUCED AT A GIVEN TIME.**
- FOR EACH SPECIES A MEASURE OF ITS FITNESS.**
- THAT THE PROGENY OF THE BEST ADAPTED SPECIES INCREASES WITH TIME.**
- THAT AS LONG AS A SPECIES IS NOT ON THE VERGE OF DISAPPEARING IT PRODUCES A SET OF SIBLINGS SOME OF WHICH ARE SLIGHTLY BETTER ADAPTED THAN THEIR PARENTS.**

Origin



FREEMAN DYSON PROPOSED THAT LIFE BEGAN TWICE, TO ACCOUNT FOR THE TWO SPACE SCALES OF BIOMOLECULES.

BERNAL, GRANICK, CAIRNS-SMITH, WÄCHTERSCHÄUSER, ... HAVE STRESSED THE INADEQUACY OF A PRIMITIVE PREBIOTIC SOUP, AND HAVE PUT FORWARD THE LIKELINESS OF THE INVOLVEMENT OF MINERAL SURFACES IN THE GENESIS OF BIOMOLECULES.

AMONG THE MANY REACTIONS THAT OCCUR AT THE SURFACE OF MINERALS, THOSE INVOLVING GROUP-TRANSFER ON A SMALL FAMILY OF UNIVERSAL CARRIER MOLECULES IS PLACED IN THE LIMELIGHT. THE CORRESPONDING PROCESS CAN BE TERMED HOMEOTOPIC TRANSFORMATION.

Origin



ANOTHER ASPECT OF METABOLISM MUST BE TAKEN INTO CONSIDERATION : IT MUST FAVOR SYNTHESIS OF MACROMOLECULES IN WATER.

IN 3-DIMENSIONS THE INCREASE OF ENTROPY DISFAVOURS POLYMERIZATION, BUT IN 2-DIMENSIONS, IF A WATER MOLECULE IS LIBERATED DURING POLYMERIZATION, FORMATION OF MACROMOLECULES IS FAVOURED.

Origin



**CHARGED MOLECULES INTERACTING WITH SURFACES
CAN PERMIT BUILDING UP OF A SELECTIVE PROCESS.**

**MANY AUTHORS HAVE IN THE PAST PROPOSED
HYPOTHESES TO TAKE IT INTO ACCOUNT :**

- | | | |
|--------|-----------------------------------|--|
| • 1951 | BERNAL | CLAYS |
| • 1957 | GRANICK | Fe₂O₃ + FeO + S |
| • 1975 | CAIRNS-SMITH & HARTMAN | CLAYS |
| • 1988 | WÄCHTERSCHÄUSER | FeS (PYRITE) |

Origin



**BEFORE CONSIDERING THE GENETIC CODE AND DNA
ONE MUST ACCOUNT FOR THE CORRESPONDING SYNTHESIS
INSIDE A COMPARTMENTALIZED ORGANELLE.**



SYNTHESIS OF LIPIDS

SYNTHESIS OF COENZYMES

SYNTHESIS OF NUCLEOTIDES

Origin



WHAT IS EASY :

**SYNTHESIS OF SOME AMINO-ACIDS
(ASSUMING NITROGEN REDUCTION)**

**SYNTHESIS OF MOLECULES WITH A THREE
CARBON ATOM BACKBONE**

Origin



WHAT IS DIFFICULT :

SYNTHESIS OF BASIC AMINO-ACIDS

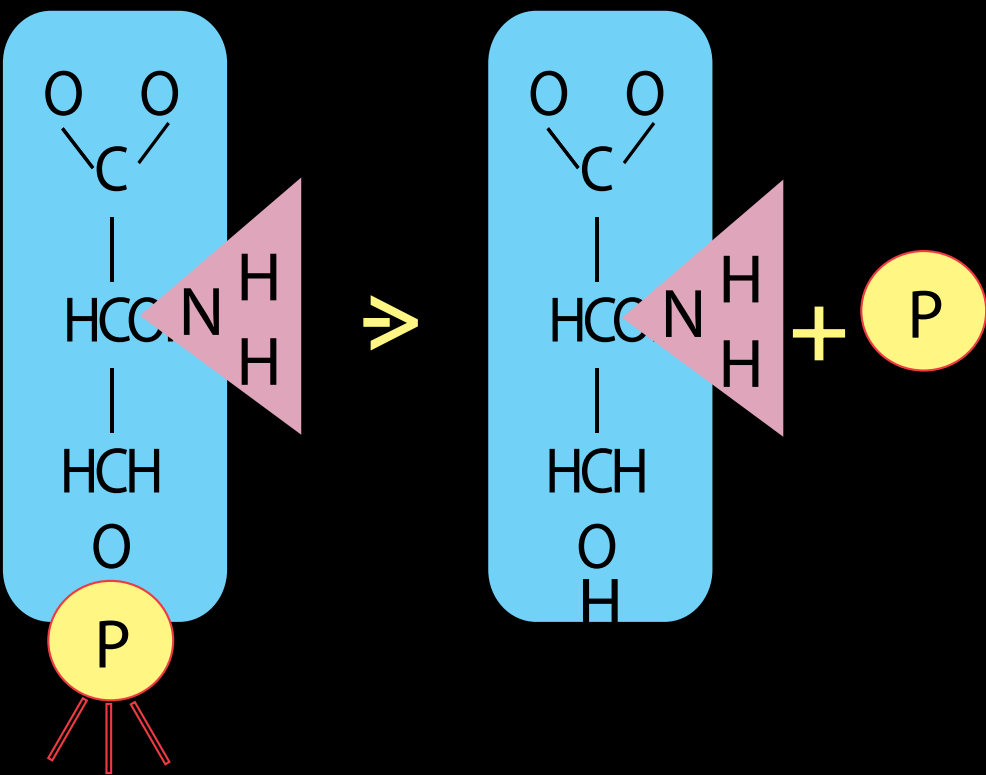
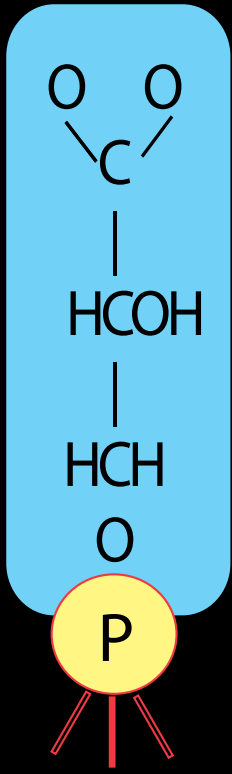
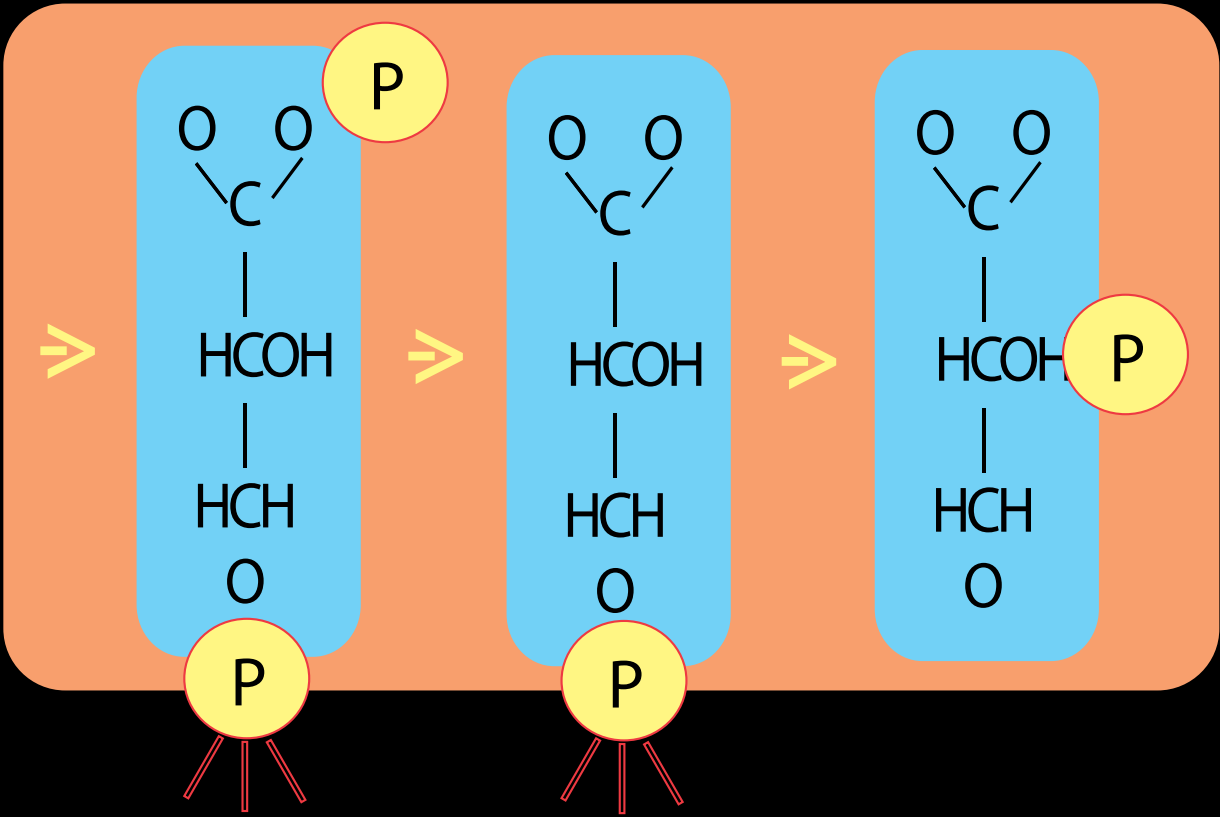
SYNTHESIS OF COENZYMES

SYNTHESIS OF LIPIDS

**SYNTHESIS OF NUCLEOTIDES (ESPECIALLY
PYRIMIDINE NUCLEOTIDES)**

Origin





Origin



PATHWAYS UTILIZING UNEXPECTED PHOSPHATE RESIDUES :

**SERINE (SERINE~PHOSPHATE)
PYRIDOXAL PHOSPHATE
ISOPRENYL ~ PYROPHOSPHATE
4-PHOSPHOPANTETHEINE
THIAMINE ~ PYROPHOSPHATE**

CONTAINING NUCLEOTIDES :

**CYTIDYLATE (LIPIDS)
ADENYLATE, GUANYLATE, URIDYLATE (SUGARS)
COENZYMES (NAD, CoA...)**

Origin



tRNA OUTSIDE TRANSLATION

FORMATION OF A PEPTIDIC LINK

Gly~ARNtGly murein

Phe~ARNtPhe N-terminal

Leu~ARNtLeu N-terminal

Arg~ARNtArg Ubiquitine

HOMEOTOPY

Met~ARNtFMet → FMet~ARNtFMet

Glu~ARNtGln → GlnARNtGln

Ser~ARNtseCys → SeCys~ARNtseCys

DIVERSE

Lys~ARNtLys Lipides

Glu~ARNtGlu Aminolevulinate

OTHER

Base modification

Origin



AMINO-ACIDS IN THE SYNTHESIS OF NUCLEOTIDES AND COENZYMES

PURINES Q G (S) Q D (S)

PYRIMIDINES D

GLUTATHION E C G

4-PHOSPHOPANTETHEINE V A C

NICOTINAMIDE D (Q)

PYRIDOXAMINE S (Q)

PYRROLLOQUINOLONE QUINONE E Y (PEPTIDE)

ETC...

Origin



ORIGIN OF tRNA SYNTHETASES

IF HOMEOTOPIC TRANSFORMATION IS AT THE ROOT OF METABOLISM ON tRNA MOLECULES, tRNA SYNTHETASES MUST DERIVE FROM AMINO ACID BIOSYNTHESIS :
GATTI & TZAGOLOFF HAVE FOUND THAT ASPARTYL-tRNA SYNTHETASE IS RELATED TO ASPARAGINE SYNTHETASE, AND DI GIULIO (1993) HAS SHOWN THAT GLUTAMINE tRNA SYNTHETASE IS RELATED TO GLUTAMINE AMIDO-TRANSFERASES

Origin



GRANICK (1957), YCAS (1974) AND JENSEN (1976) PROPOSED THAT ENZYME SPECIFICITY EVOLVED FROM RECRUITMENT OF PREEXISTING PROTEINS THAT CATALYSE SIMILAR REACTIONS

THIS HAS BEEN OFTEN VERIFIED

pabB trpE
pabA trpG guaA

GONCHAROFF & NICHOLS 1984
KAPLAN & NICHOLS 1983
ZALKIN et al. 1985

thrC dsdA ilvA trpB
metB metC
cysK trpB

PARSOT 1986, 1987
PARSOT et al. 1988
LÉVY & DANCHIN 1988

Origin

pdxB serA
umk thrA lysC gltK carK

SCHOENLEIN et al. 1989
SERINA et al. 1995



A PRESENT-DAY ILLUSTRATION OF RECURSIVE HOMEOTOPY IS REPRESENTED BY THE GENERATION OF PEPTIDIC ANTIBIOTICS OR BY THE SYNTHESIS OF FATTY ACIDS.

IT IS FASCINATING TO REMARK THAT THE GENES NECESSARY FOR BOTH TYPES OF SYNTHESSES CODE FOR VERY SIMILAR ENZYMES AND THUS STEM FROM A COMMON ANCESTOR.

AN OTHER REMARKABLE FEATURE IS THE FORMATION OF PEPTIDES CATALYZED BY A PHOSPHORYLATED PEPTIDE (PHOSPHOPANTETHEINE) FOLLOWING A PROCESS INDEPENDENT OF TRANSLATION.

AS A CONSEQUENCE, PEPTIDES OR REACTIONS USING PEPTIDES SHOULD BE TAKEN INTO CONSIDERATION FOR THE SYNTHESIS OF COENZYMES AS WELL AS OF NUCLEOTIDES (AS IT IS INDEED OBSERVED IN PRESENT DAY METABOLISM).

Origin



AS AN EXAMPLE, ONE SHOULD REMARK THE PRESENCE OF PEPTIDES LEADING TO INTRA-MOLECULAR REARRANGEMENTS, SUCH AS BACTERIOCINS WHICH PRODUCE LANTHIONINE AND THE LIKE FROM AMINO ACIDS SUCH AS SERINE AND CYSTEINE.

**A TWO-DIMENSION STRUCTURE FAVORS POLYMERISATION
THROUGH ELIMINATION OF A WATER MOLECULE IN THE MEDIUM**

**IN THE PRESENCE OF AN ELEMENTARY SET OF AMINO-ACIDS
THIS PERMITS SYNTHESIS OF FERREDOXINS
(WHICH INCORPORATE AN IRON-SULFUR NUCLEUS)**

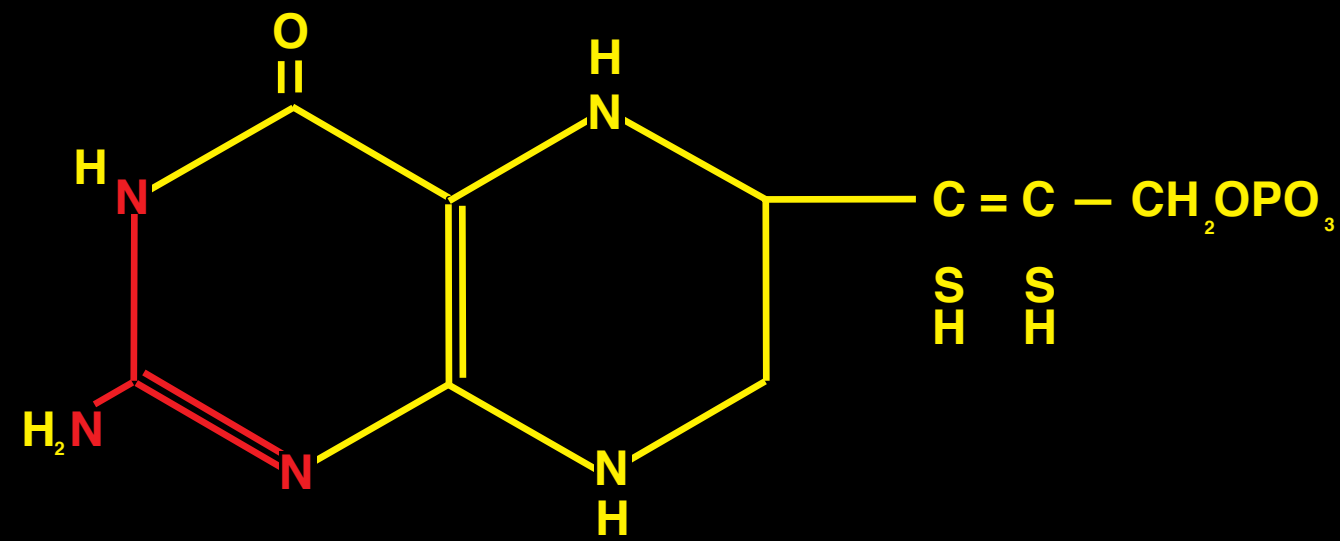
**NITROGEN FIXATION IS A PREREQUISITE
IT REQUIRES Fe-Mo-Co :**

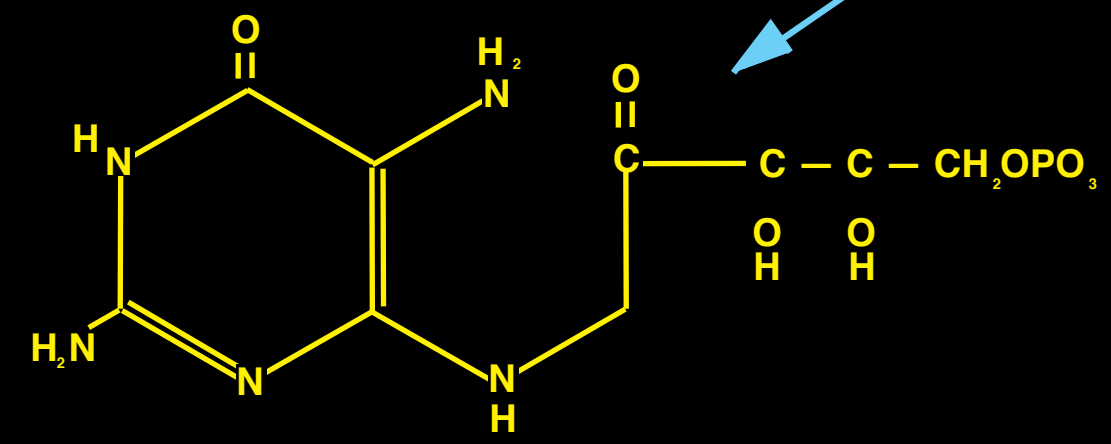
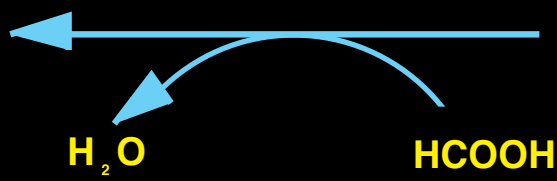
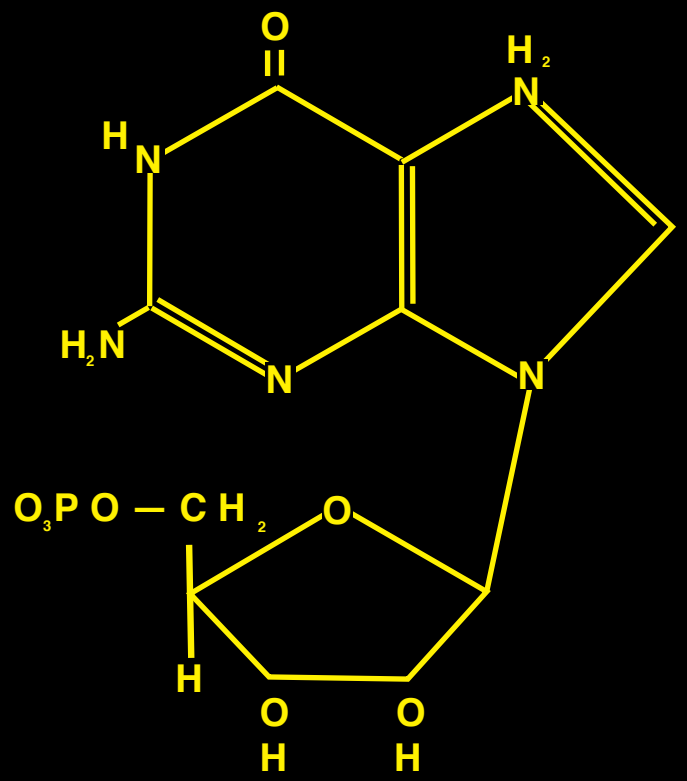
**FERREDOXIN
MOLYBDENE AND MAY HAVE BEEEN ASSOCIATED TO
MOLYBDOPTERIN AS A COFACTOR**

Origin

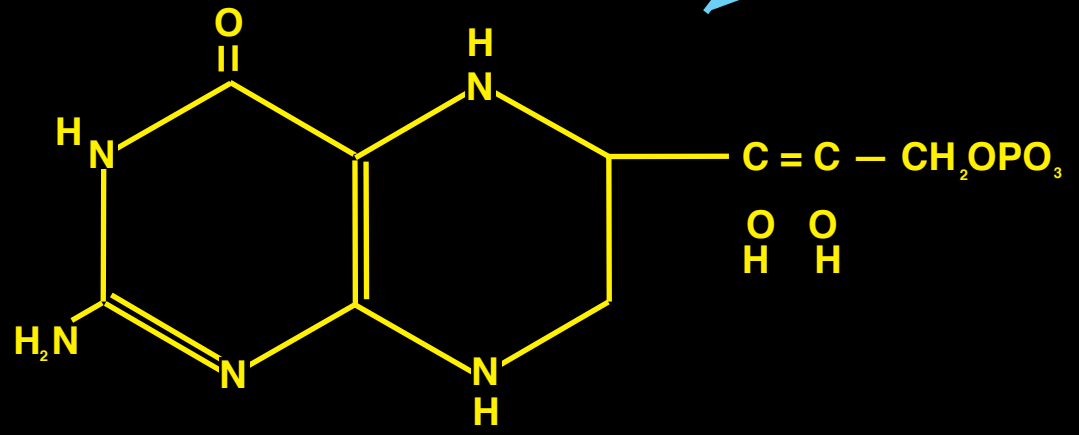


Molybdopterin





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Origin

