

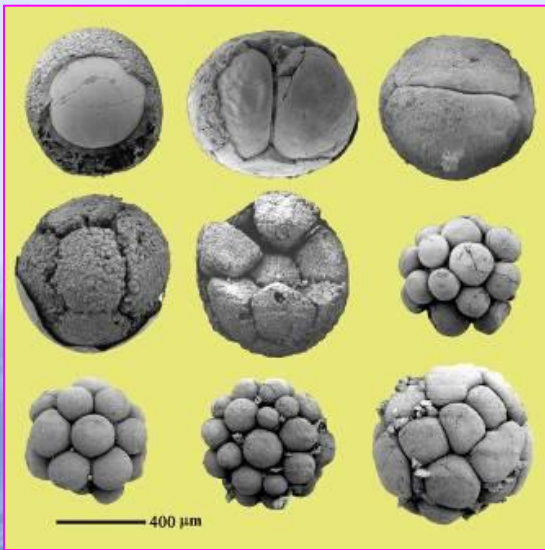
# Proteins as molecular fossils

**Hong-Yu Zhang**

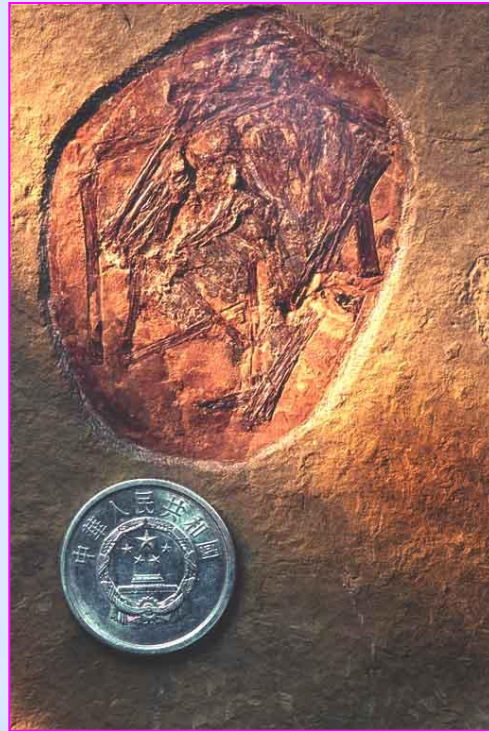
*College of Life Science and Technology  
Huazhong Agricultural University*

# Fossils

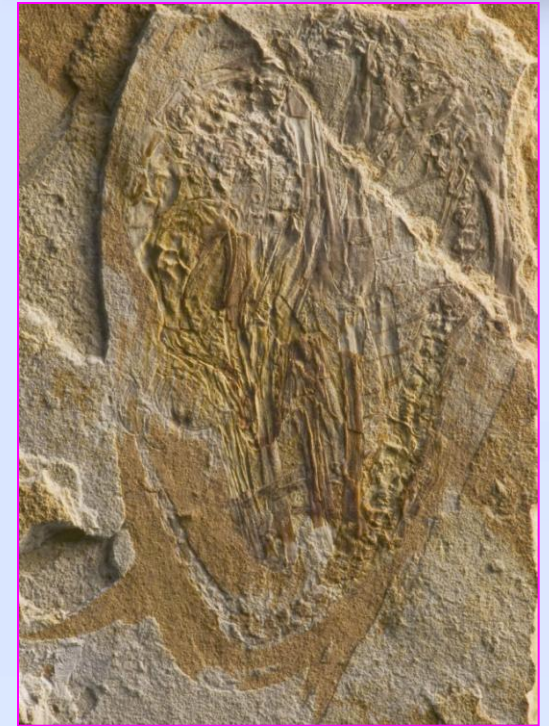
## Key players on the stage of evolution



前寒武的胚胎化石



翼龙的胚胎化石

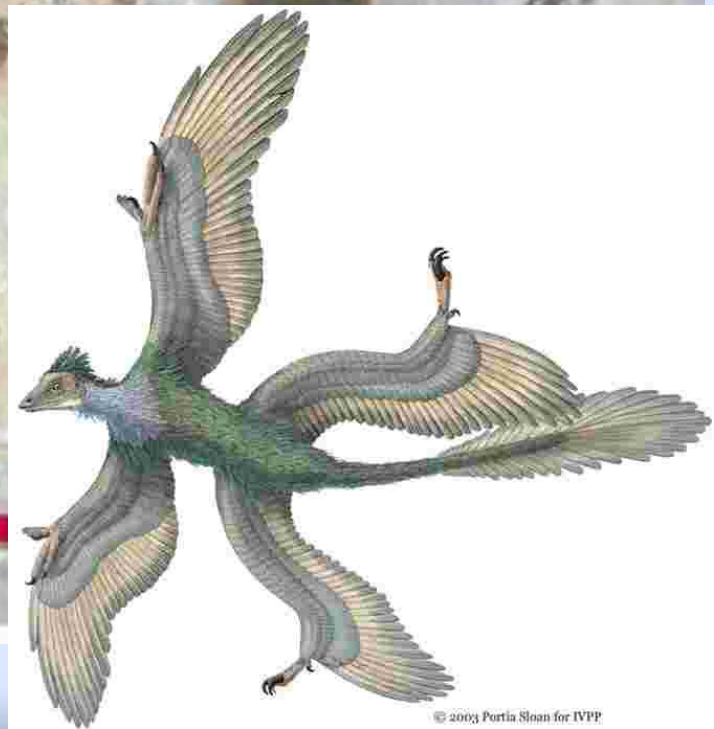
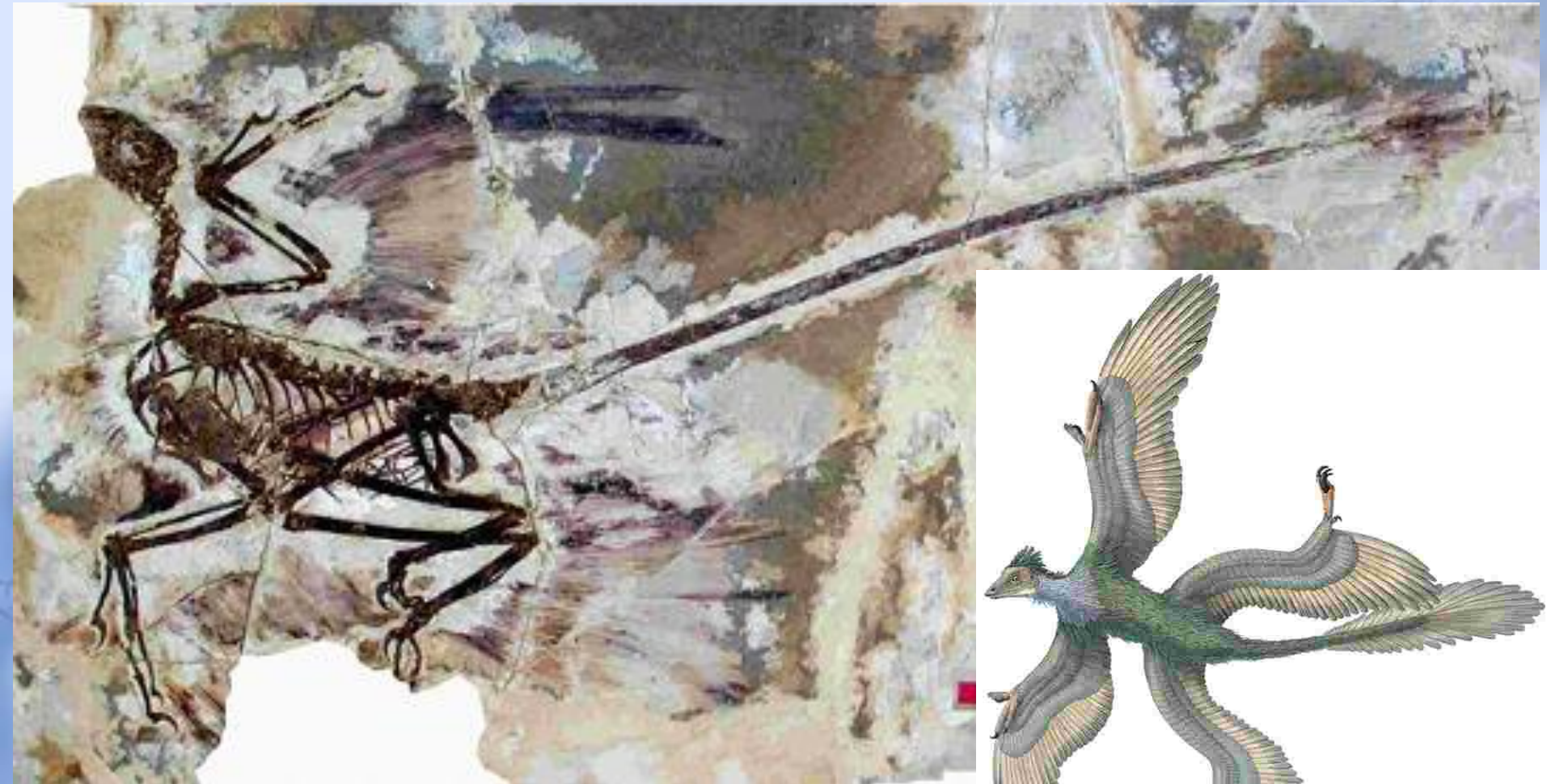


鸟的胚胎化石

# “中华龙鸟”



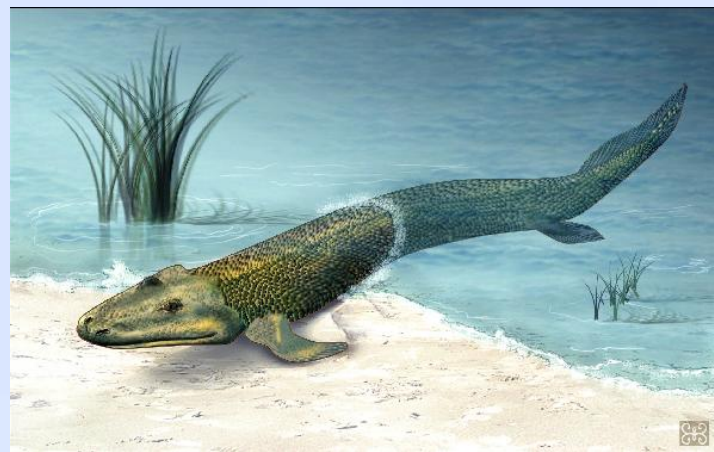
# 顾氏小盗龙





有鳃、鳍、鳞；  
也有颈部、强大的  
肋骨、少的肢骨。

## 提塔利克鱼



# 半甲齿龟

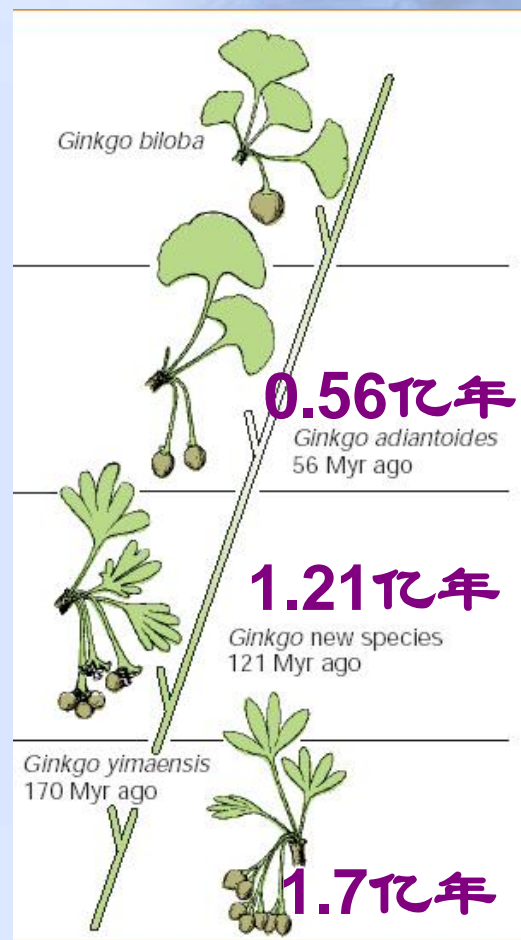


背面



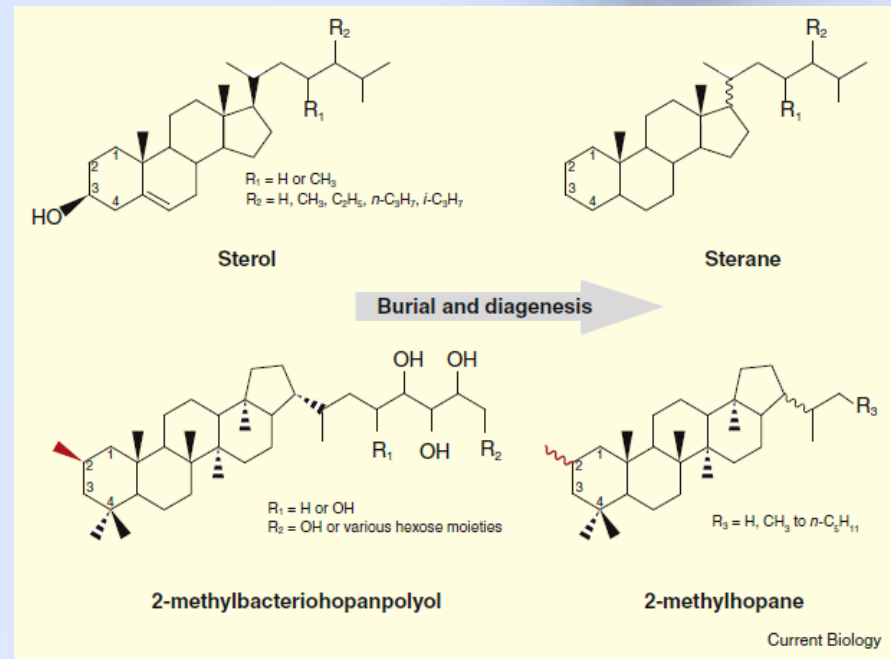
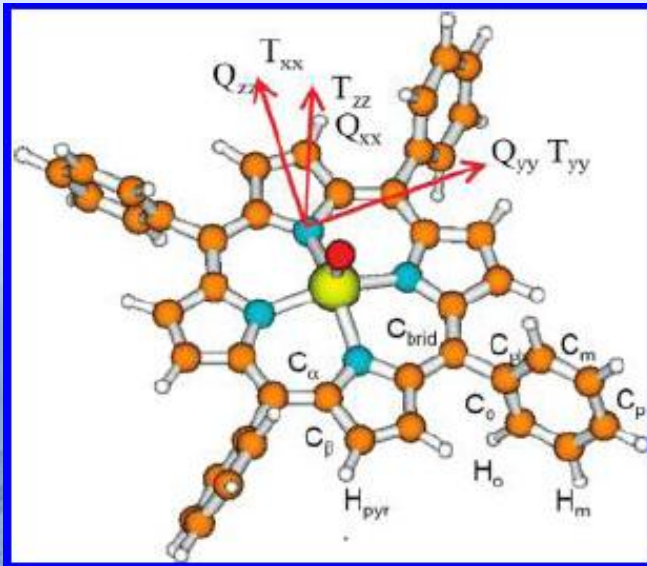
腹面

# 银杏的演化历程



# Molecular fossils

## Small molecules (real)

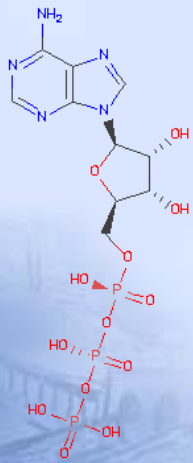


Gourier, D. et al. *J. Phys. Chem. B* 2010, 114: 3714-3725.  
 Sessions, A.L. et al. *Curr. Biol.* 2009, 19: R567-R574.

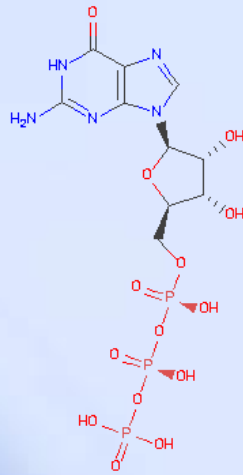


# Molecular fossils

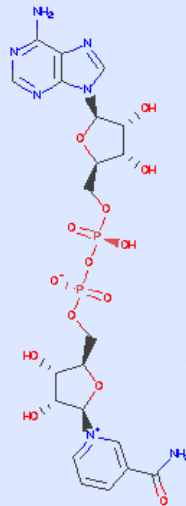
## Small molecules (virtual)



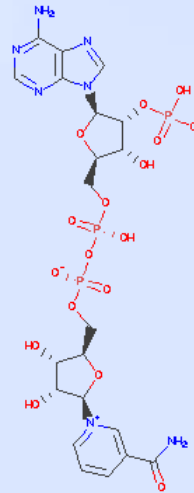
ATP



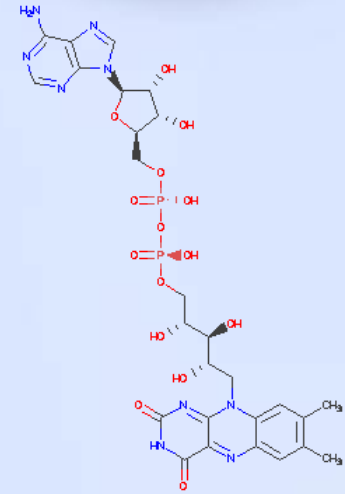
GTP



NAD



NADP

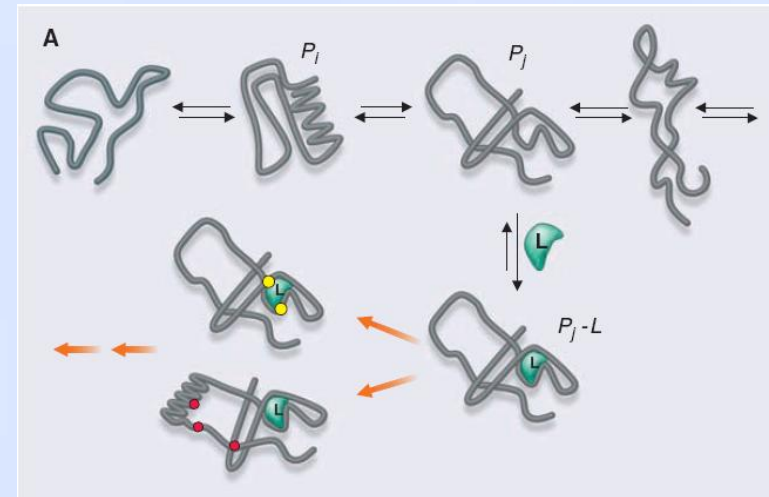
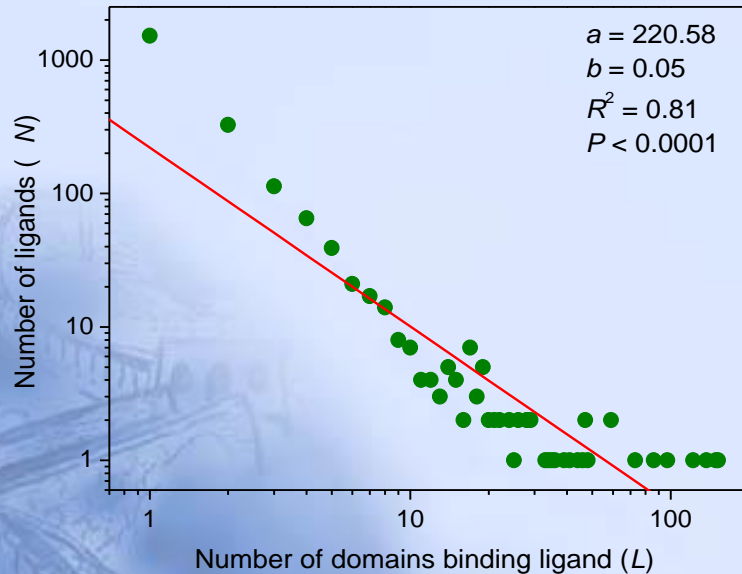


FAD

White, H.B. *J. Mol. Evol.* 1976, 7: 101-104.

# Application case

## Tracing protein origins



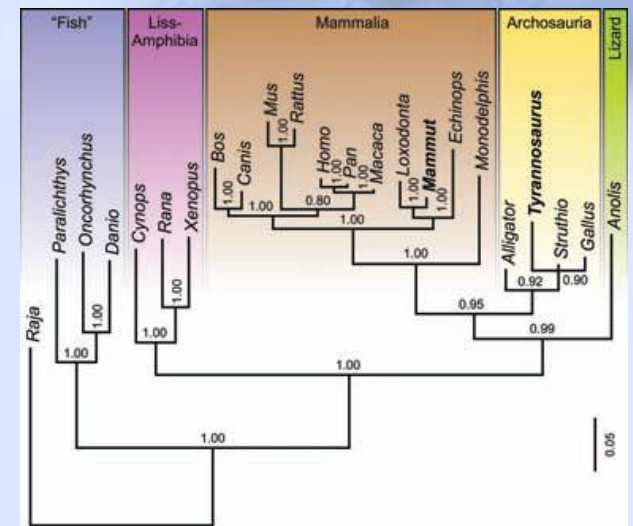
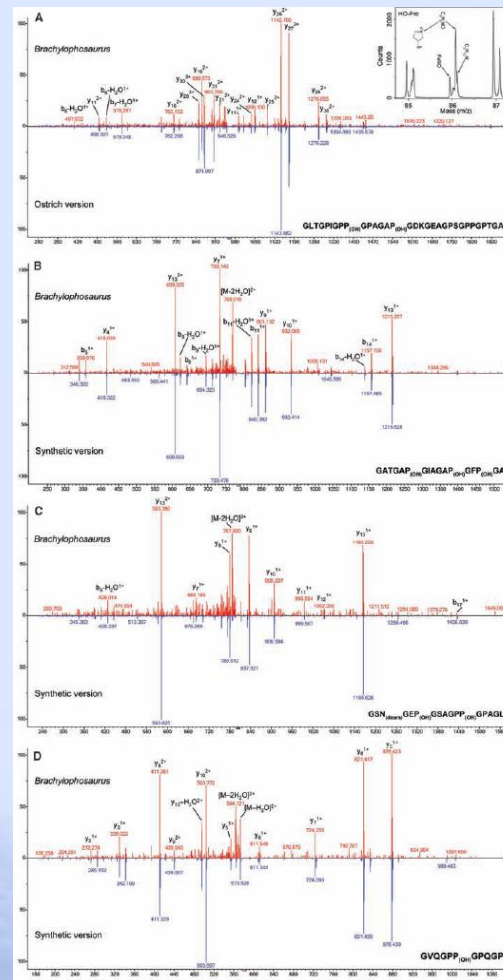
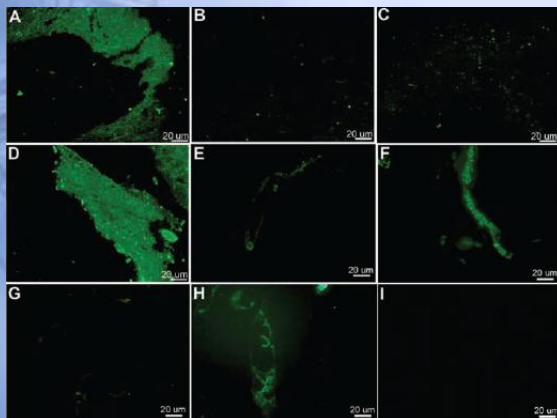
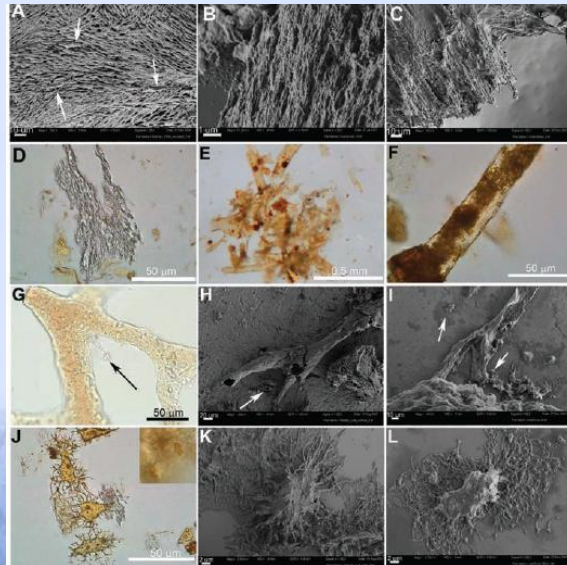
Ji, H.-F. *et al. Genome Biol.* 2007, 8: R176.

Ji, H.-F. *et al. BioEssays* 2009, 31: 975-980.

Tokuriki, N. & Tawfik, D. *Science* 2009, 324: 203-207.

# Molecular fossils

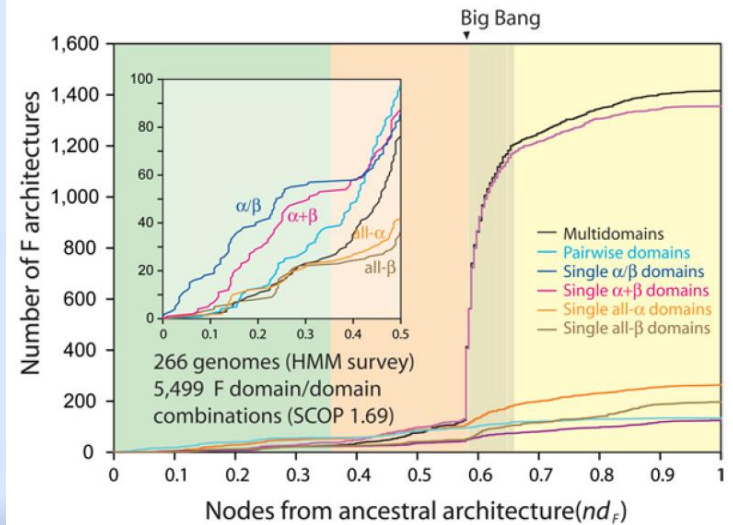
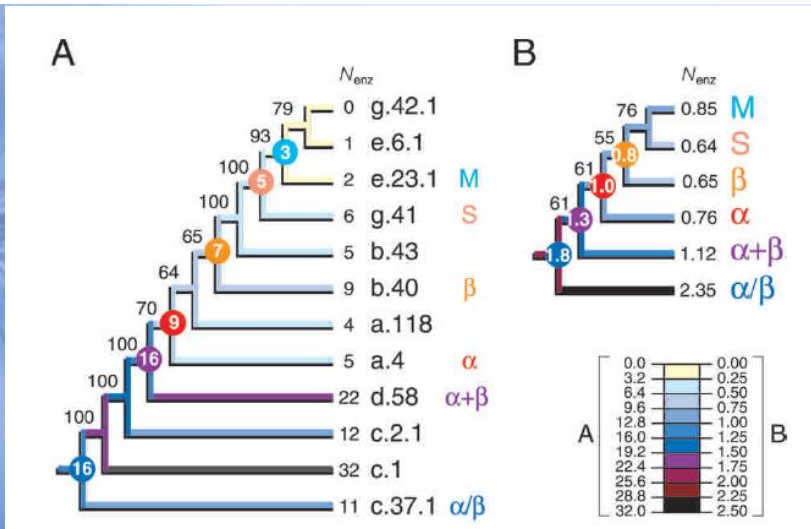
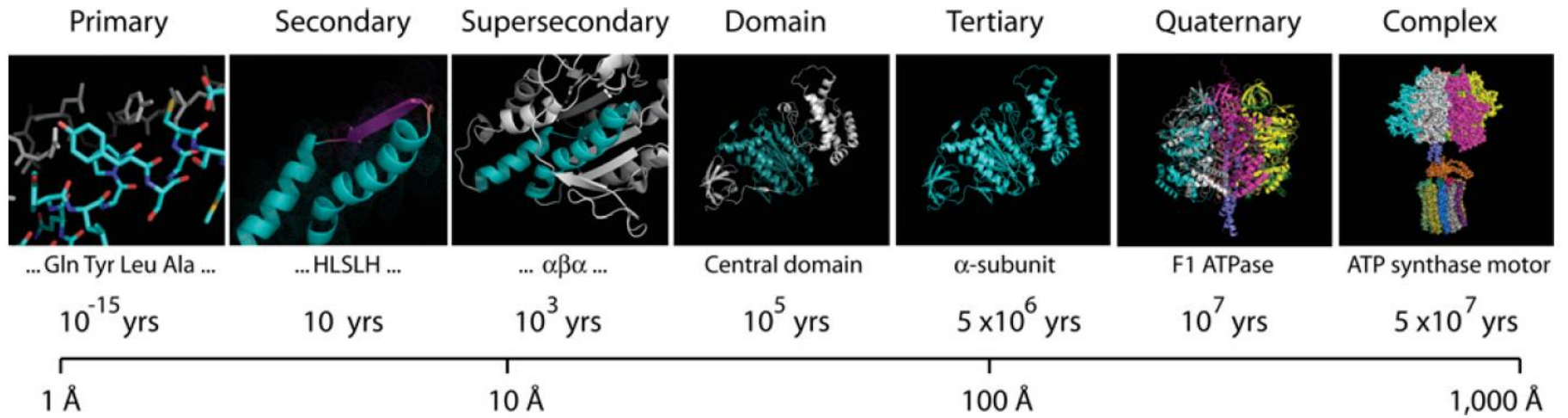
## Proteins (real)



Schweitzer, M.H. et al. Science 2009, 324: 626-631.

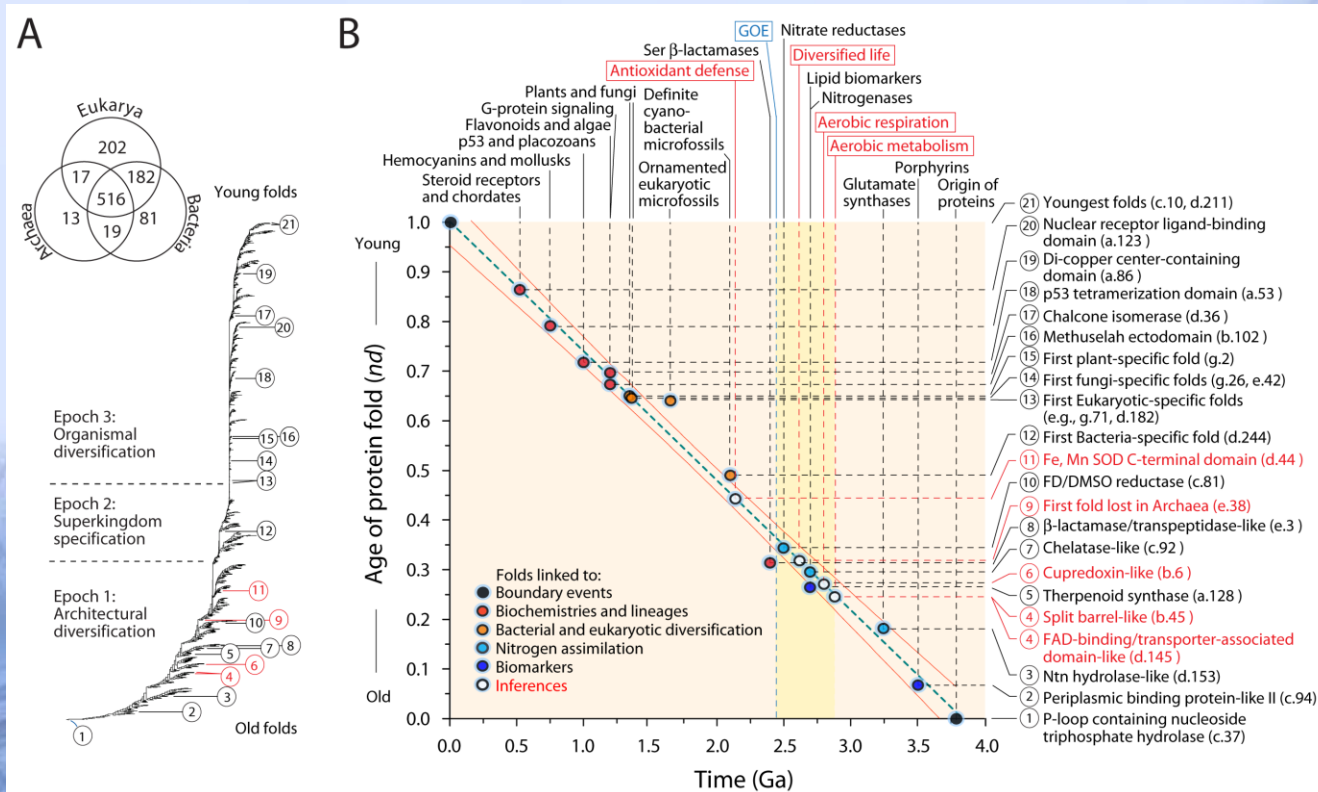
# Molecular fossils

## Proteins (virtual)



Caetano-Anollés G, et al. *Biochem. J.* 2009, 417: 621-637.

# Molecular clock of protein folds



Implications

Applications

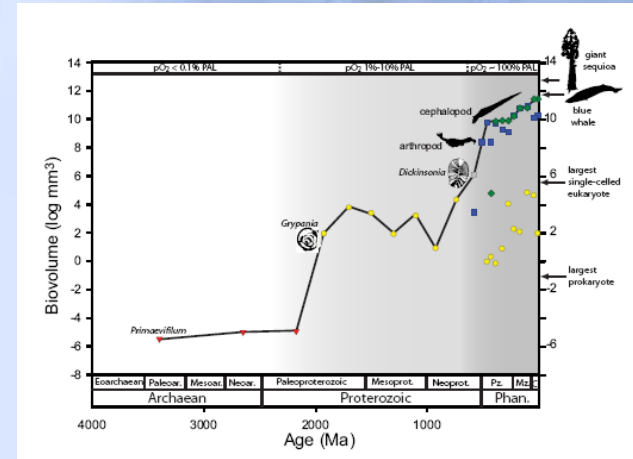
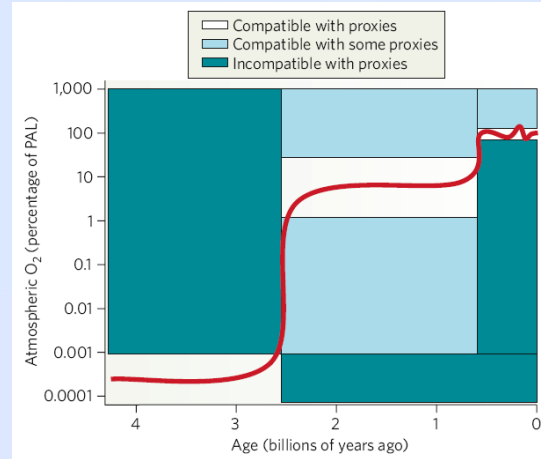
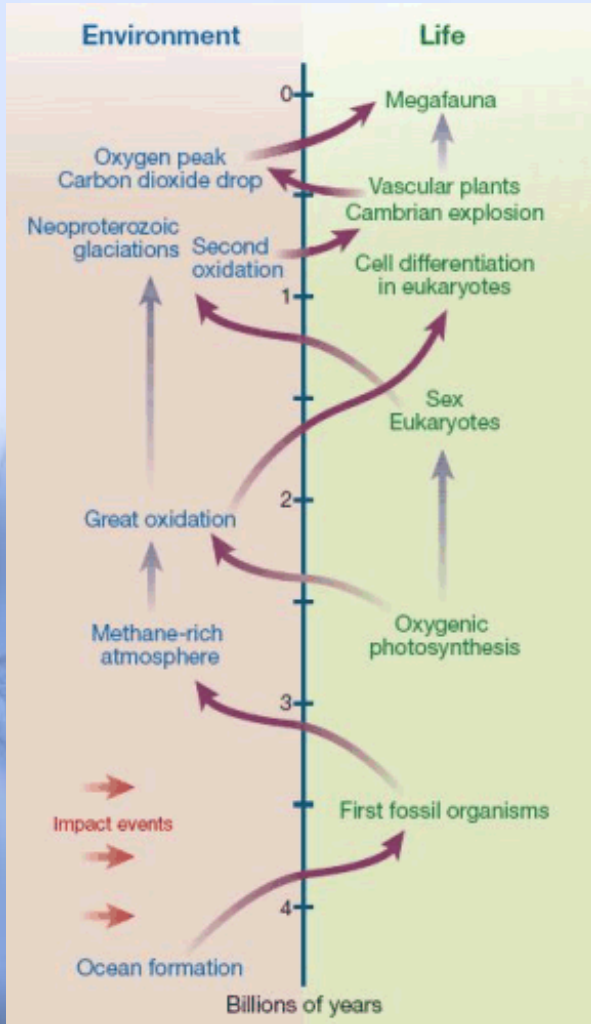
Advantages

A protein architectural chronology was established by a phylogenomic analysis of protein sequences in 749 organisms (52 archaeal, 478 bacterial, and 219 eukaryal species) and was calibrated by geological ages.

Wang, M.L. et al. *Mol. Biol. Evol.* 2010, 27: in press.

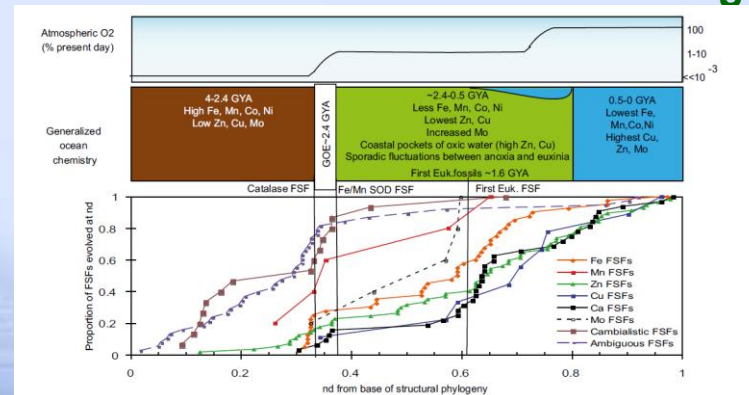
# Application case

## Tracing the rise of oxygen



Oxygen evolution over time

Sizes of the largest fossils through Earth history.



Kump, L.R. *Nature* 2008, 451: 277-278.

Payne, J.L. et al. *Proc Natl Acad Sci USA* 2009, 106: 24-27.



Contents lists available at ScienceDirect

## Earth and Planetary Science Letters

journal homepage: [www.elsevier.com/locate/epsl](http://www.elsevier.com/locate/epsl)



### Hematite formation by oxygenated groundwater more than 2.76 billion years ago

Yasuhiro Kato <sup>a,\*</sup>, Katsuhiko Suzuki <sup>b</sup>, Kentaro Nakamura <sup>c</sup>, Arthur H. Hickman <sup>d</sup>, Munetomo Nedachi <sup>e</sup>, Minoru Kusakabe <sup>f</sup>, David C. Bevacqua <sup>g</sup>, Hiroshi Ohmoto <sup>g</sup>



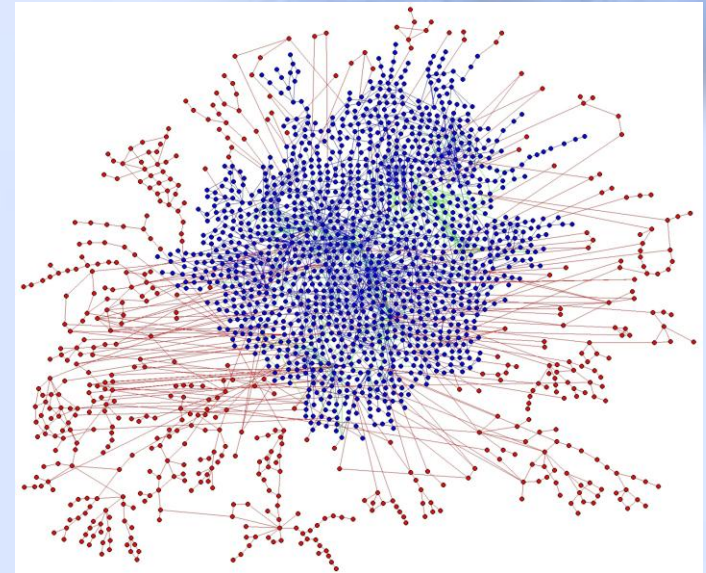
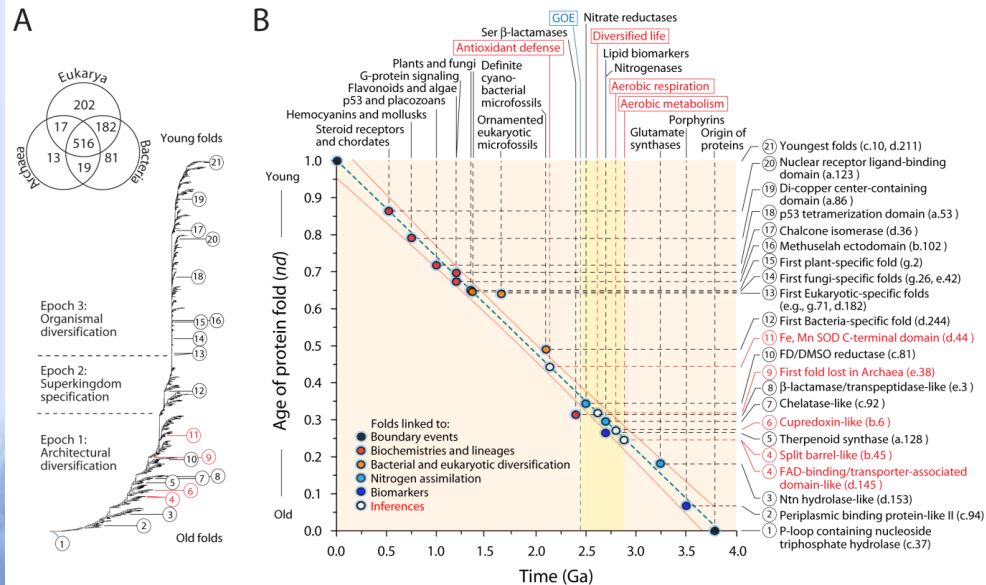
# Primary haematite formation in an oxygenated sea 3.46 billion years ago

Masamichi Hoashi<sup>1</sup>, David C. Bevacqua<sup>2</sup>, Tsubasa Otake<sup>2</sup>, Yumiko Watanabe<sup>2</sup>, Arthur H. Hickman<sup>3</sup>,  
Satoshi Utsunomiya<sup>4</sup> and Hiroshi Ohmoto<sup>2</sup>\*





# Tracing the rise of oxygen



Protein fold clock

Metabolic network simulation

Through identifying the initial protein folds associated with aerobic metabolism, we inferred that oxygen emerged 2.9 billion years ago, when the oxygen level reached 0.1% of PAL.

Raymond, J. & Segrè, D. *Science*, 2006, 311: 1764-1767.

Wang, M.L. et al. *Mol. Biol. Evol.* 2010, 27: doi: 10.1093/molbev/msq232.

# Conclusions

**Besides metabolites, proteins also serve as molecular fossils, which include protein remains of ancient organisms and extremely conserved protein features, such as protein architectures.**

# Acknowledgments

- Prof. Gustavo Caetano-Anollés (University of Illinois)
  - Ying-Ying Jiang (SDUT)
  - Ge Qu (SDUT)
  - Prof. Hong-Fang Ji (SDUT)
- 
- National Basic Research Program of China (2010CB126100)
  - National Natural Science Foundation of China (30870520)

The background of the slide is a blue-tinted sketch of the Great Wall of China. The wall is depicted as a long, winding stone structure that snakes across a range of mountains. The drawing uses fine lines to create texture and depth, showing the battlements and watchtowers. The overall color palette is a monochromatic blue, giving it a serene and historical feel.

**Thank you for your attention!**