Big-data for microbiome researches: Data integration, analysis and applications

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2018/08, Hayama, Japan

Microbiome Research

Key Challenge:

- Complexity of ecosystem
- Big-data

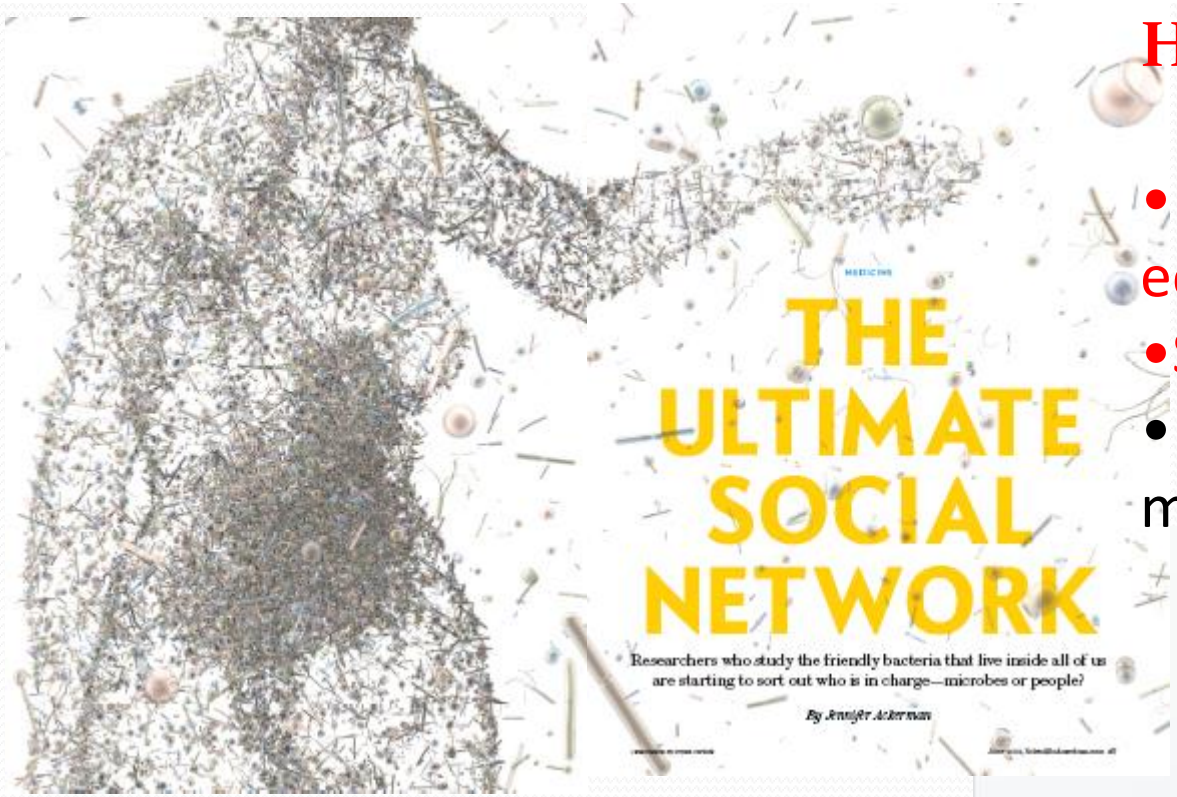
Microbiome Research

Key Challenge:

- Dynamics of ecosystem
- Big-data again!

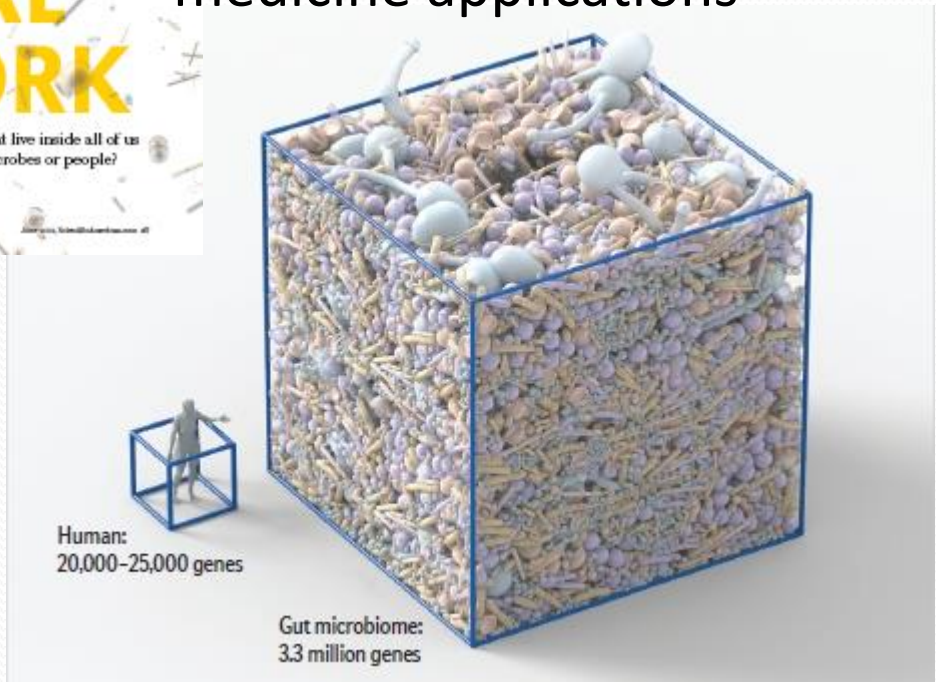
Microbiome Research

Key Challenge: “complexity and big-data”



Human microbiome:

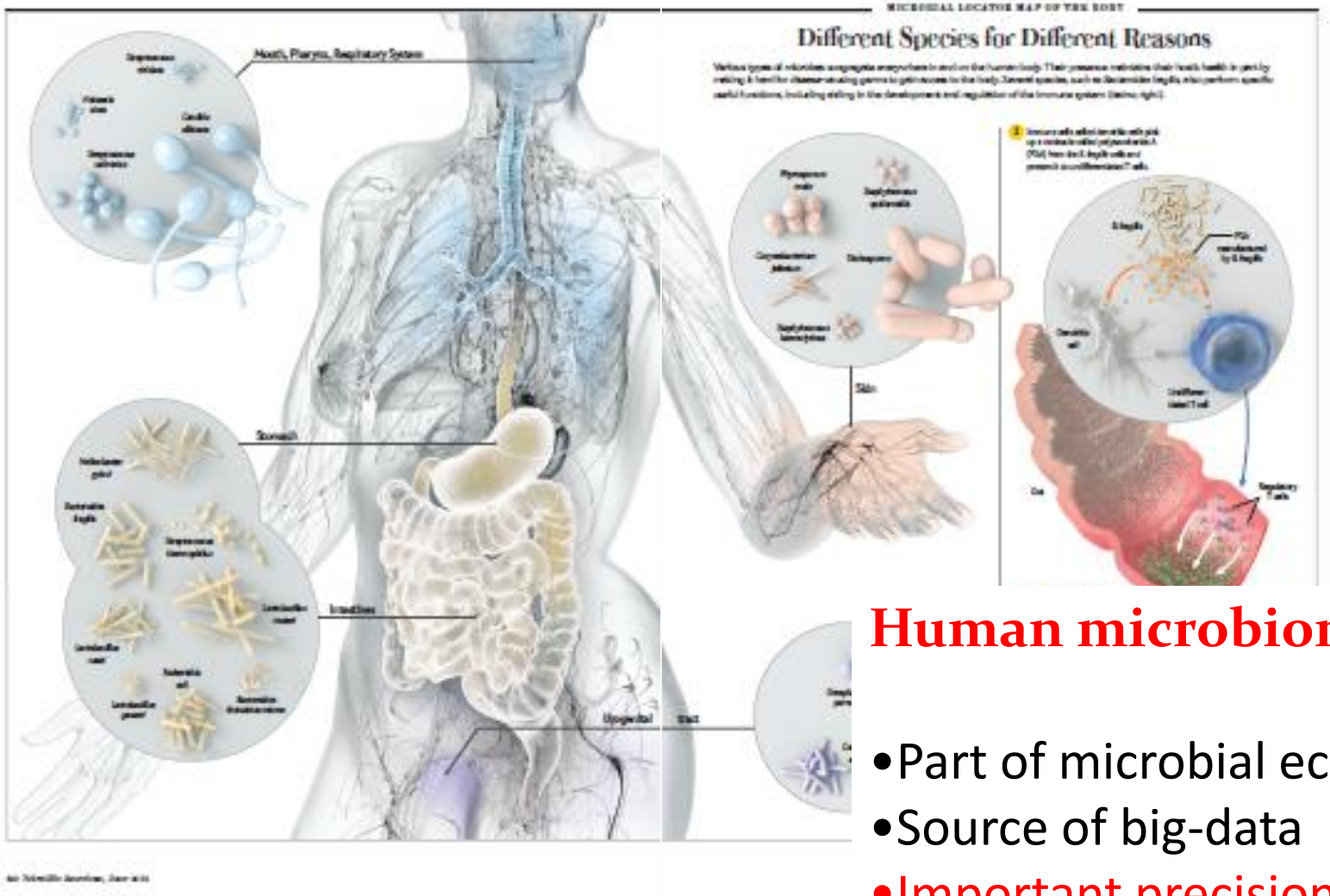
- Part of microbial ecosystem
- Source of big-data
- Important precision medicine applications



Ackerman, et al., *Scientific American*, 2012

Microbiome Research

Key Challenge: “un-culturable, complexity and big-data”



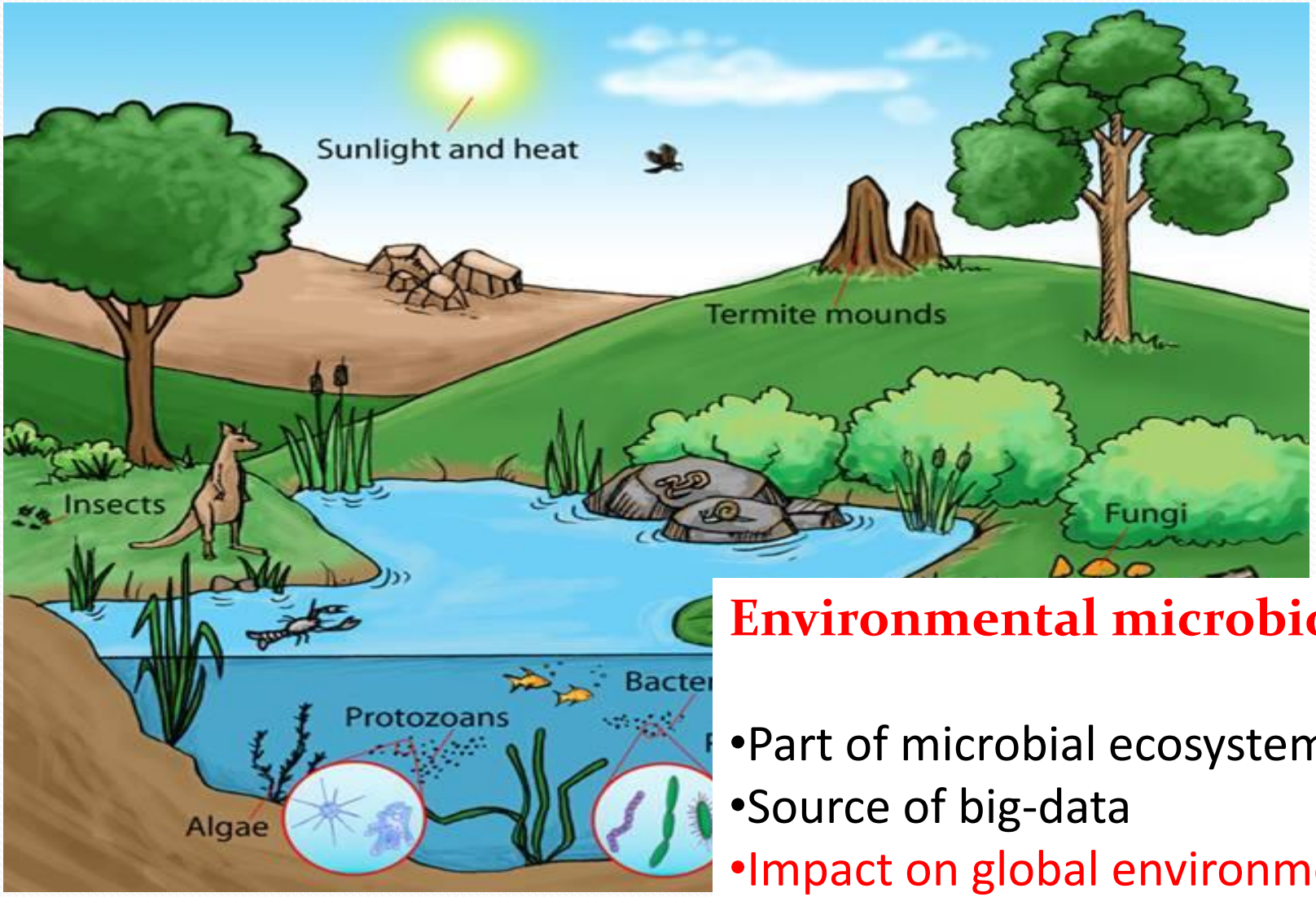
Ackerman, et al., *Scientific American*, 2012

Human microbiome:

- Part of microbial ecosystem
- Source of big-data
- Important precision medicine applications

Microbiome Research

Key Challenge: “un-culturable, complexity and big-data



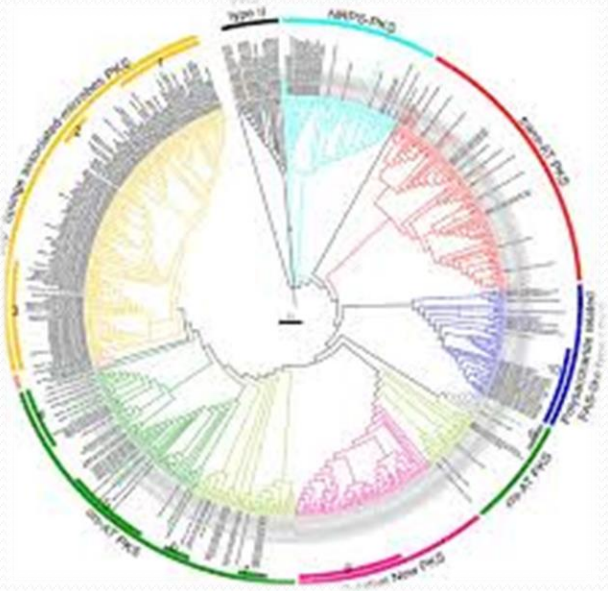
Environmental microbiome:

- Part of microbial ecosystem
- Source of big-data
- Impact on global environment

Microbiome Research

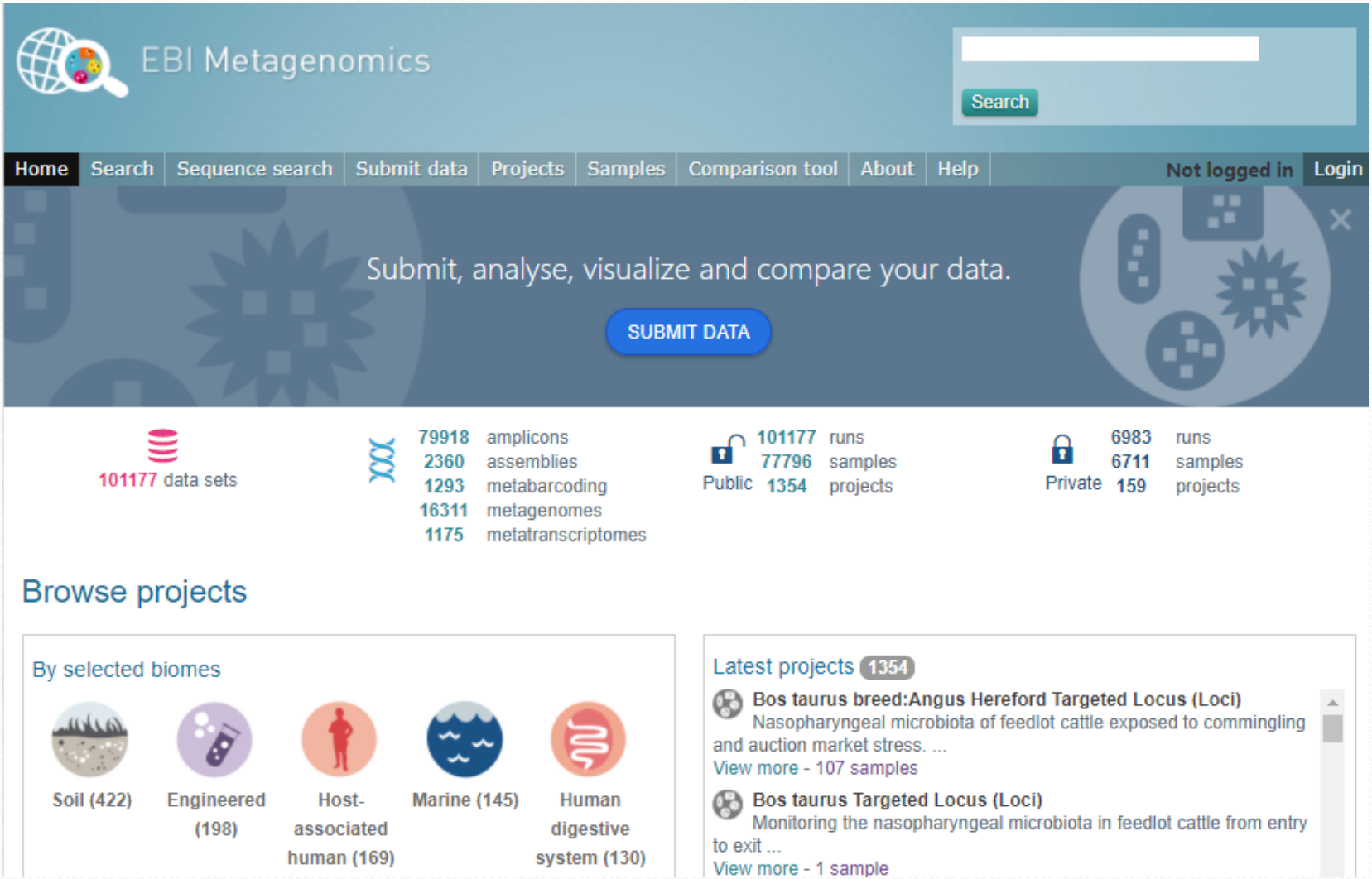
-- At present

From microbial communities to big-data…



EBI metagenomic portal (MGnify)

- https://www.ebi.ac.uk/metagenomics



NODE SysEcoKit portal

Bulletin of CAS, 2017

HUST & SIBS-CAS

Microbiome Research@HUST

微生物组大数据的4色
（4 colors for big-data towards healthy microbiome）

人体健康大数据（红色）
Human microbiome

高性能的生物计算（蓝色）
High Performance Computation

健康的生存环境（绿色）
Healthy environments

海量的健康大数据（褐色）
Big-data integration

From a sample to thousands of samples

I. Parallel-META

Parallel META

Su, et al, *BMC Sys. Bio.* 2012.
Su, et al, *PLoS ONE* 2014.
Zhou, et al, *Scientific Reports*, 2017

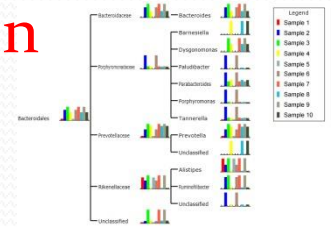
Sample analysis

II. MetaSee

Meta-See

Song, Su, et al, *PLOS ONE* 2012

Sample visualization

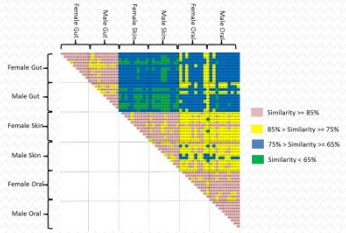


III. Meta-Storms

Meta-Storms

Su, et al, *Bioinformatics*, 2012;
Su, et al, *Bioinformatics*, 2014

Sample comparison

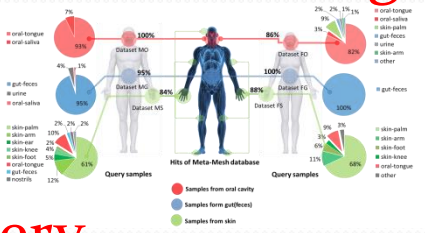


IV. Meta-Mesh

Meta-Mesh

Su, et al, *Scientific Reports*, 2014c, d

Sample search and data-mining



V. MetaBoot

Wang, et al, *PeerJ*, 2014
Gabriel , et al, *Bioinformatics*, 2016

Biomarker discovery

From structure to function

高性能的生物计算（蓝色）
HPC

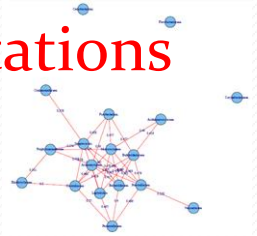
VI. Parallel-Prism

Sample indexing

Su, et al, *Scientific Reports*, 2017
Yu, et al, *Bioinformatics*, in revision

VII. Meta-Network

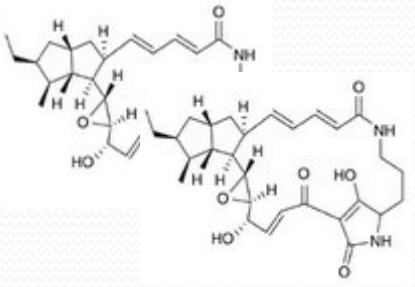
Species interaction interpretations



Yang, et al, *Bioinformatics*, in revision

VIII. Meta-BGC

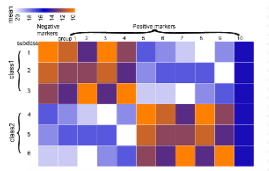
BGC interpretations



Zhang, et al, NAR, in revision
Chen, et al, in preparation

IX. Meta-Biomarker 2.0

Biomarker for noisy data



Tan, et al, *Bioinformatics*, in revision

X. Meta-Discover

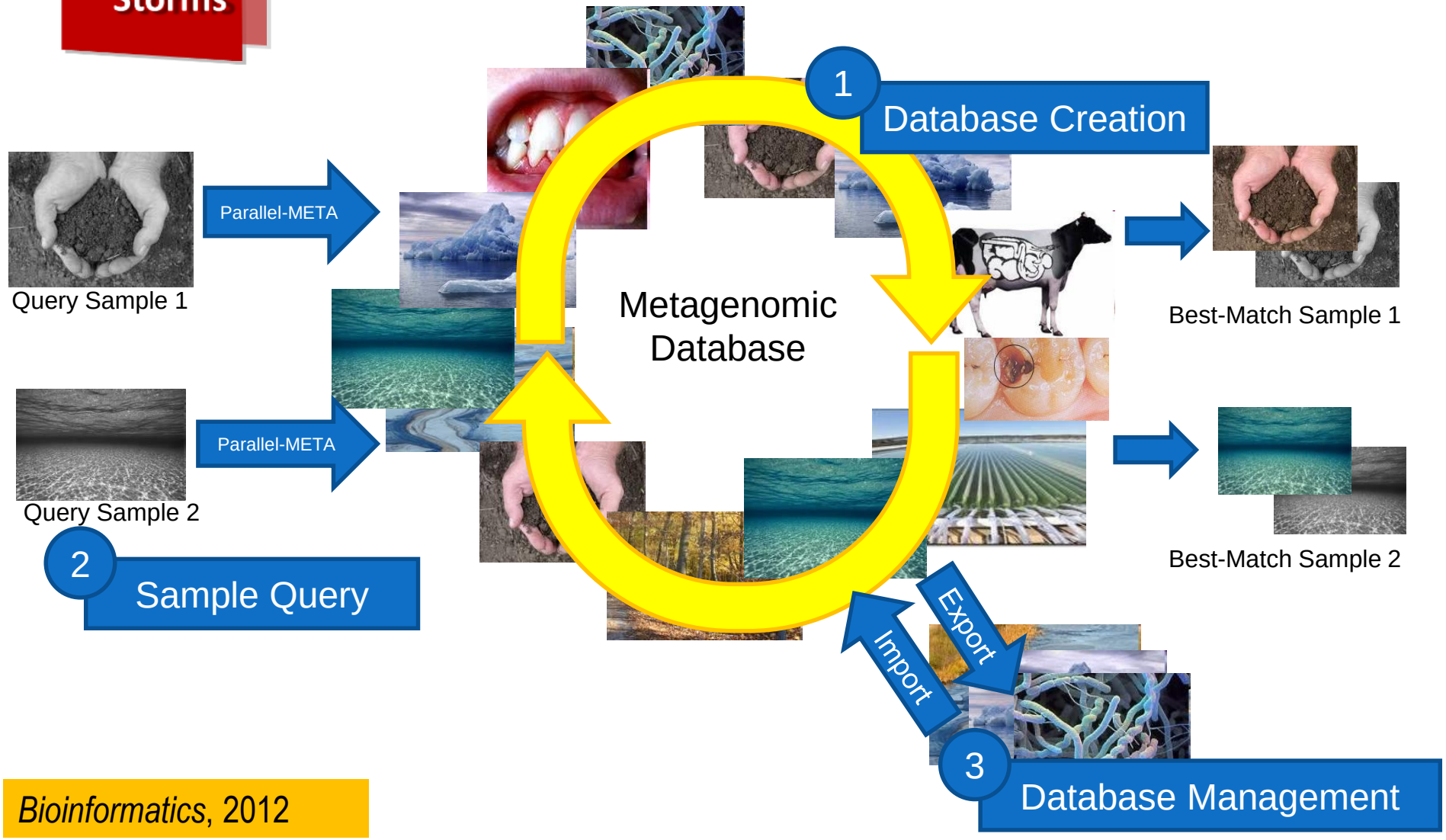
Integrated Metagenomic analysis

GPU and cloud computational platform…

Meta-Storms

高性能的生物计算（蓝色）
HPC

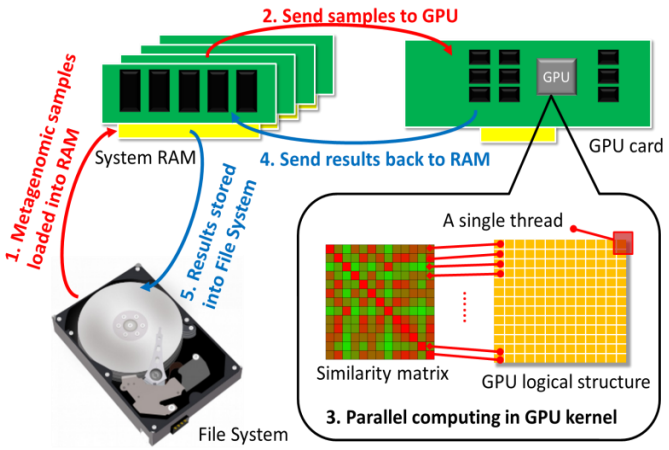
利用先进的数据库和索引技术处理群落比较和搜索



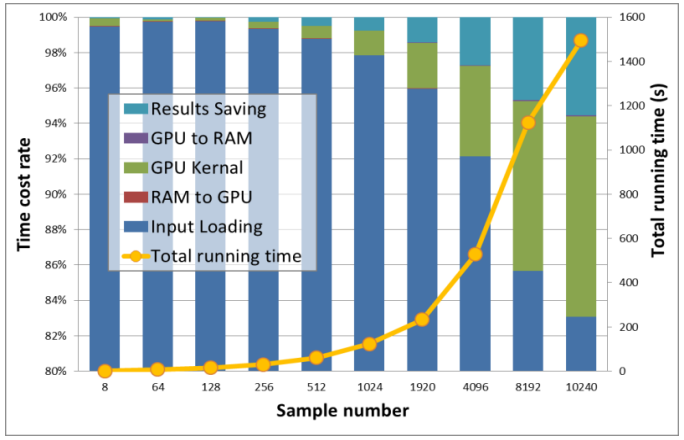
Bioinformatics, 2012

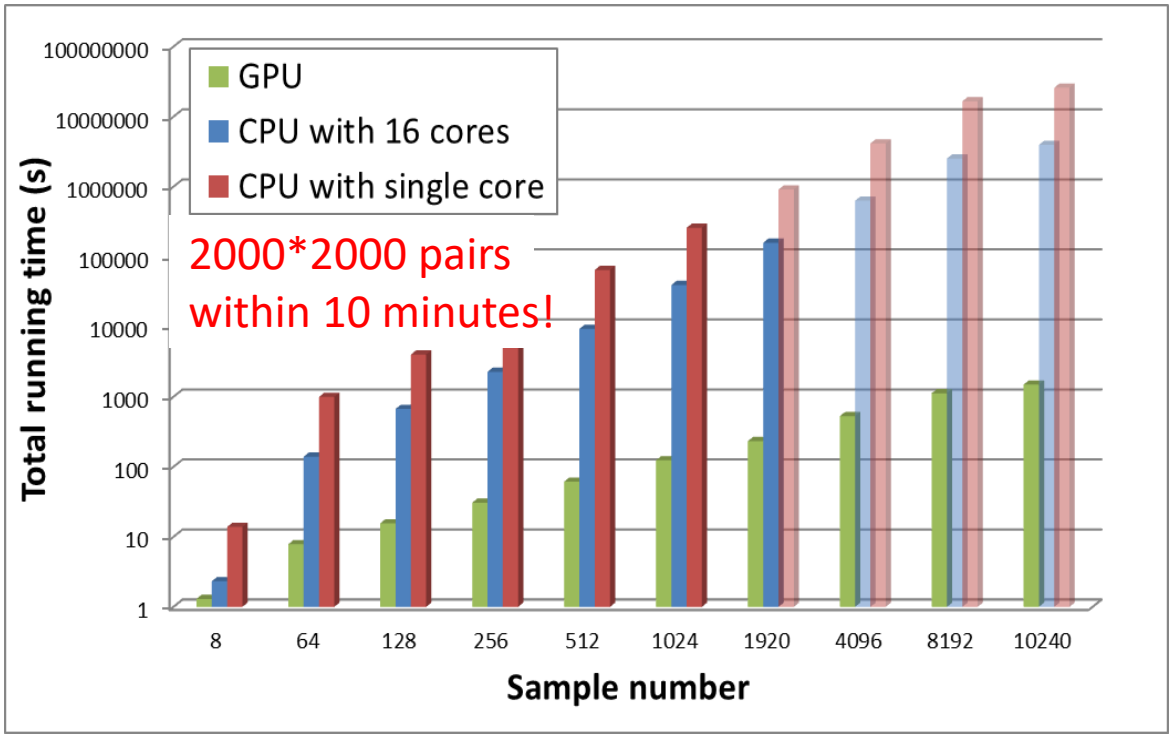
Meta-Storms

高性能的生物计算（蓝色）
HPC



利用并行计算技术
加速大规模群落比较和搜索





Data source: MG-RAST database

Bioinformatics, 2014
Scientific Reports, 2017

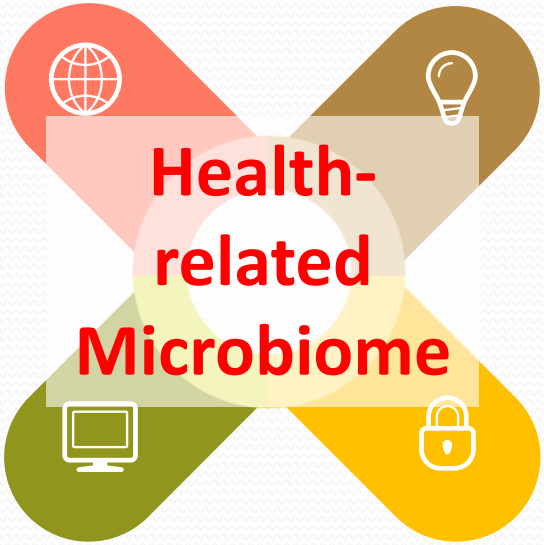
Microbiome for Health - Applications

1. Microbiome plasticity
（菌群可塑性）

应用：
水土不服的机制

3. Microbiome dysbiosis
（菌群失调）

应用：
ICU重症菌群失调



应用：
中国肠型的分类

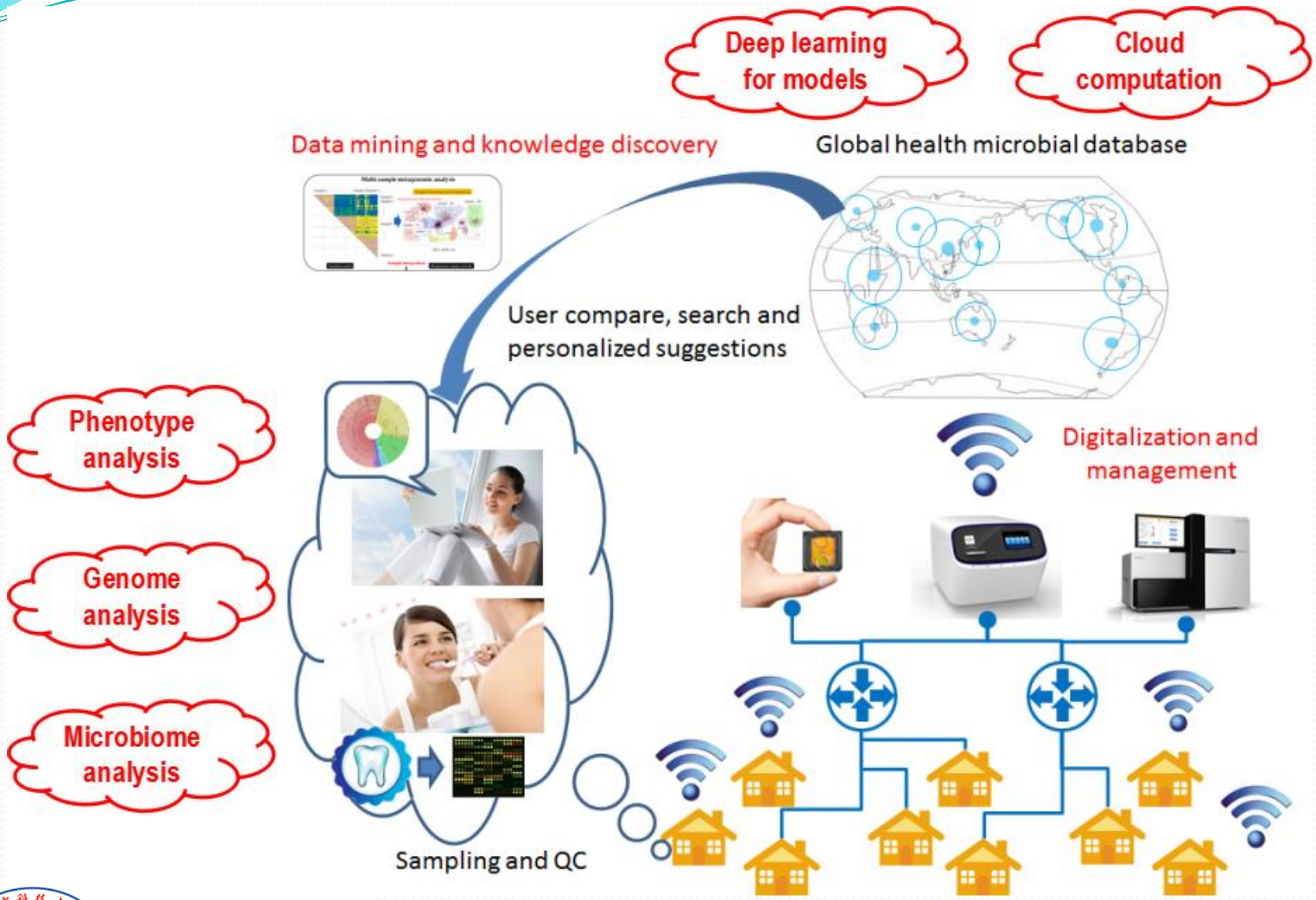
2. Microibome enterotype
（菌群分型）

应用：
益生菌干预治疗

4. Microbiome recovery
（干预性菌群恢复）

Microbiome for Health - Applications

人体健康大数据（红色）
Human microbiome



Ning, et al. (invited review), Science Bulletin

人体健康大数据（红色）
Human microbiome

Plasticity of gut microbiome

Gut microbiome plasticity

Inadaptability :

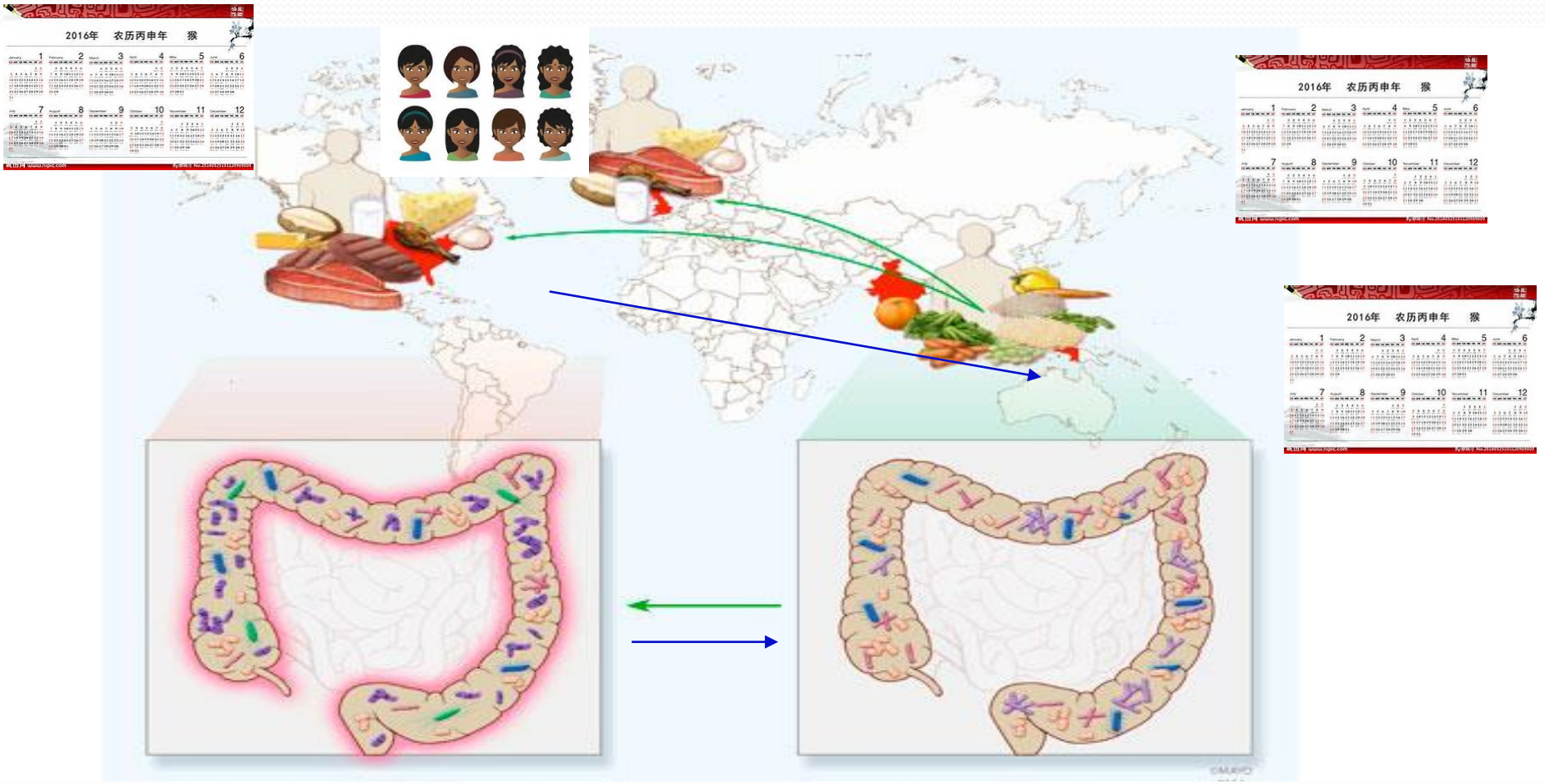
desynchronosis (time)

acclimatization (location)

Microbiome for Health - Applications

人体健康大数据（红色）
Human microbiome

Plasticity of gut microbiome



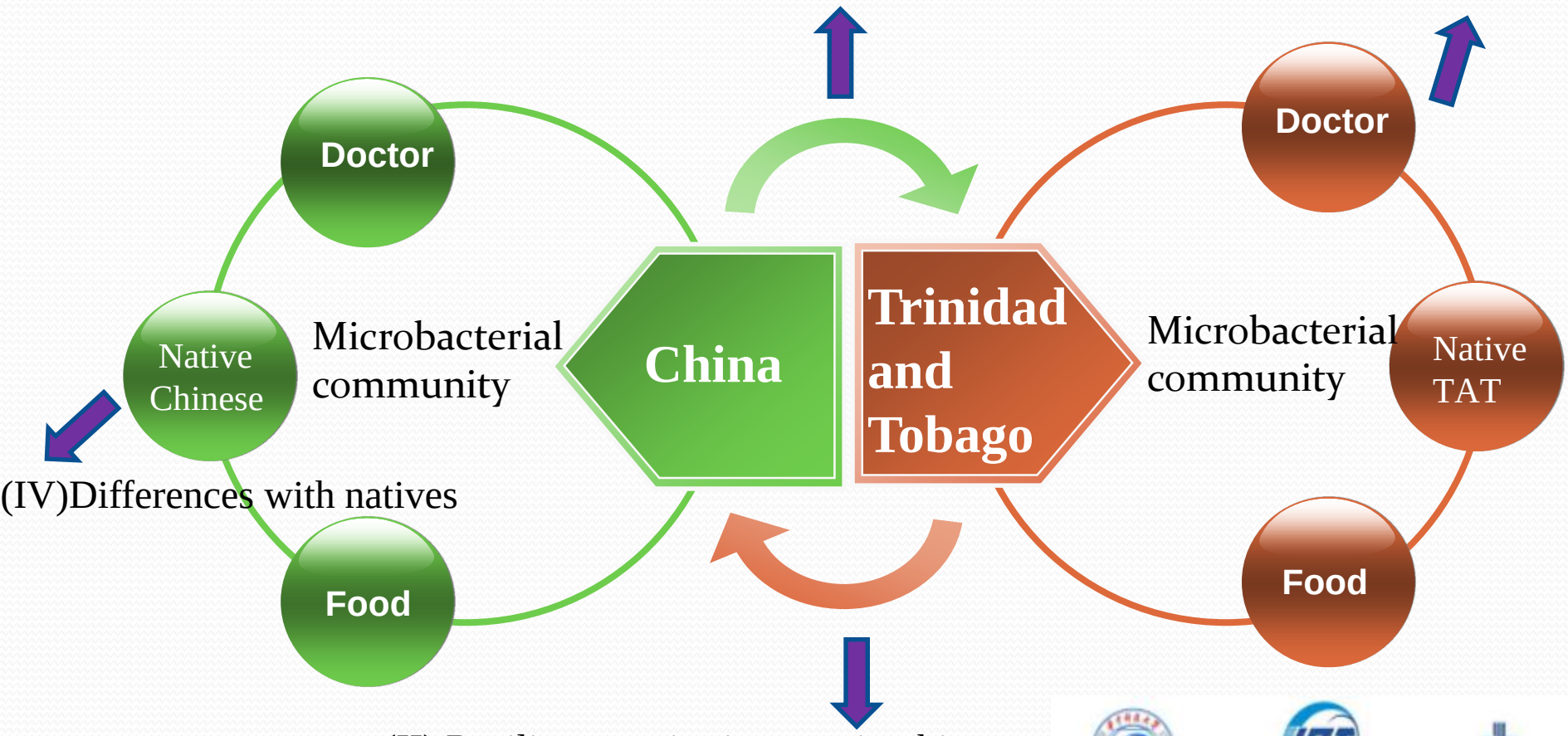
Microbiome for Health - Applications

人体健康大数据（红色）
Human microbiome

Plasticity of gut microbiome

(I) Immediate mirobiome change after dietar shift

(III) The realtionship with environment

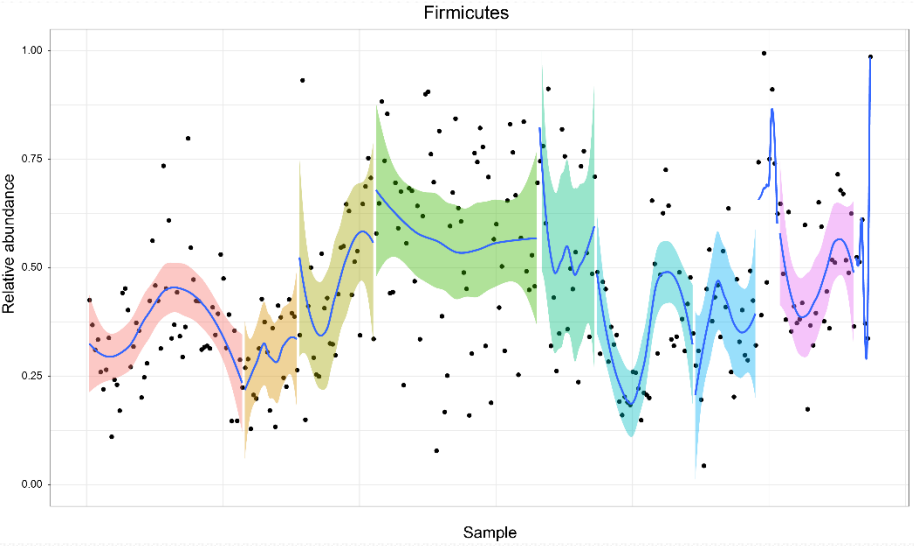


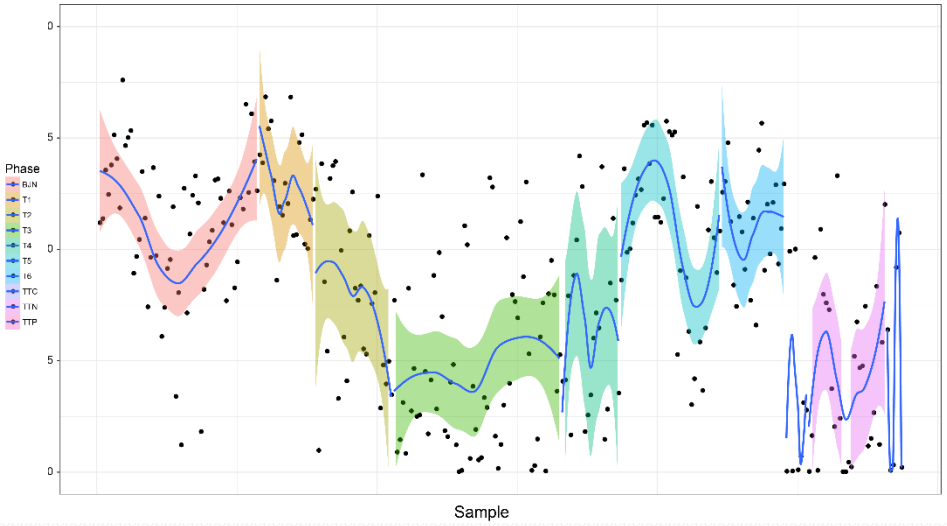
(IV)Differences with natives

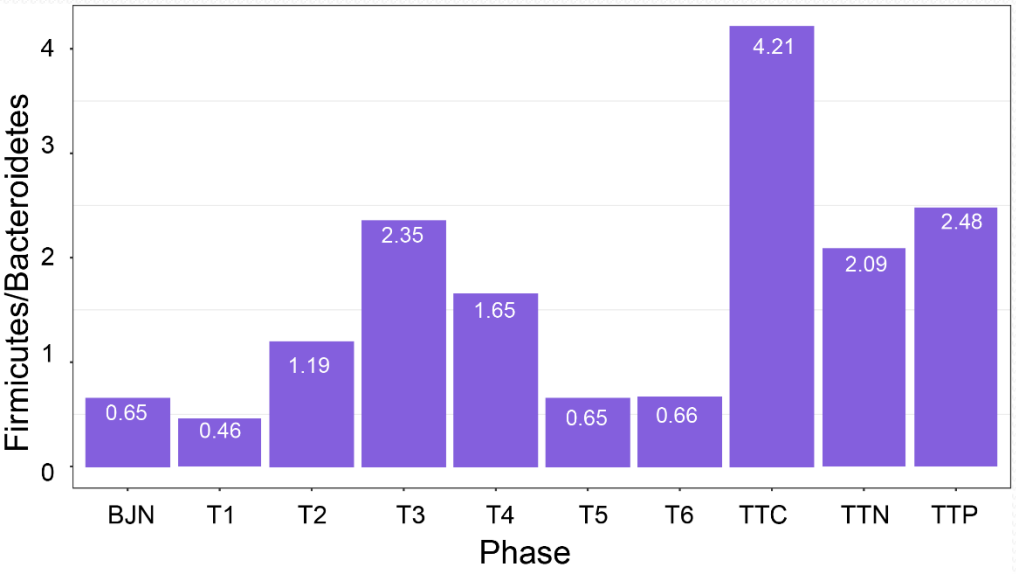
(II) Resilient species in gut microbiome

(V) Can these changes be reverted back to orginal status?

Trends of key genus





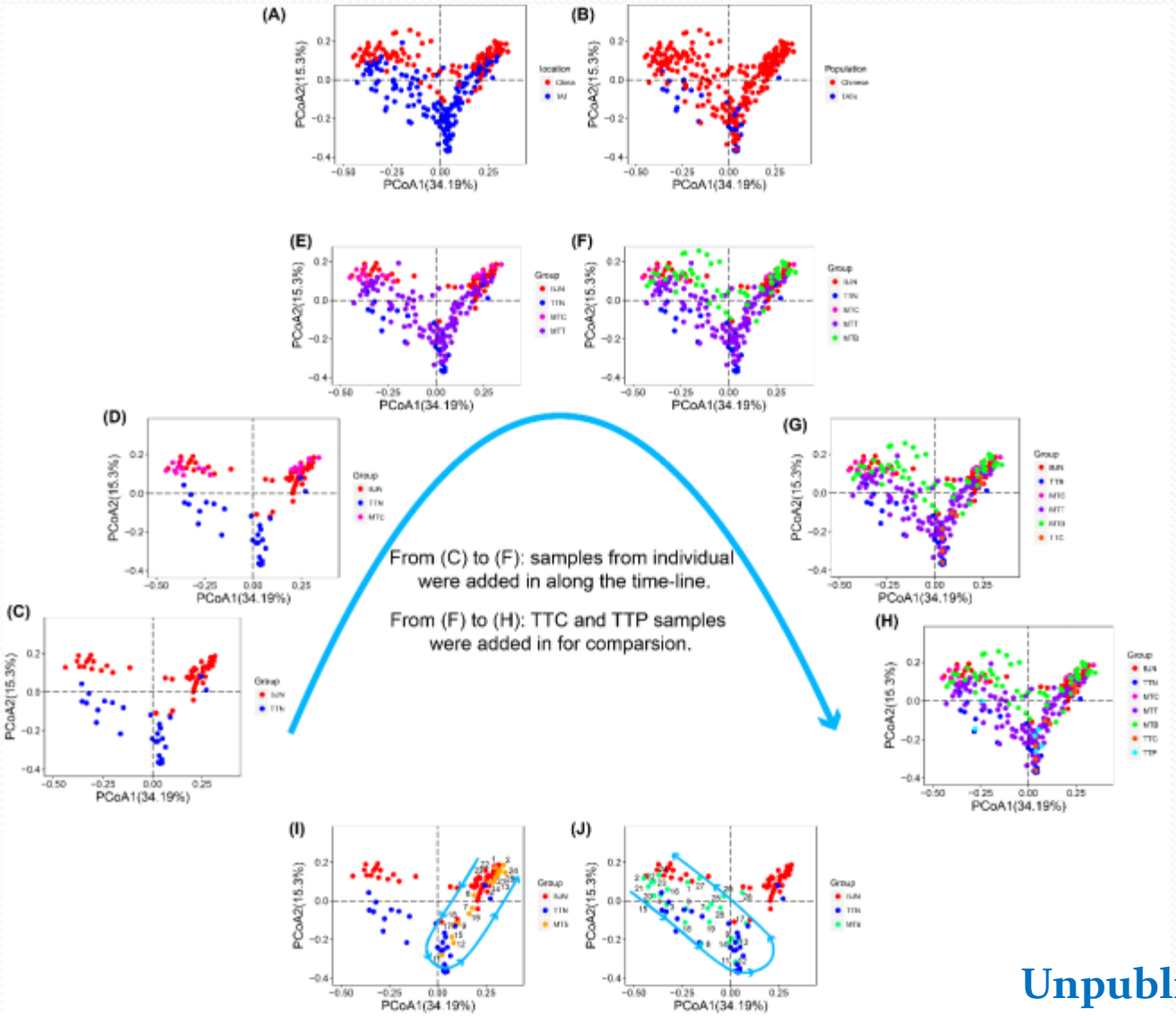


The ratio of *Firmicutes*: *Bacteroidetes*, considerable group-wise variations.

Unpublished data

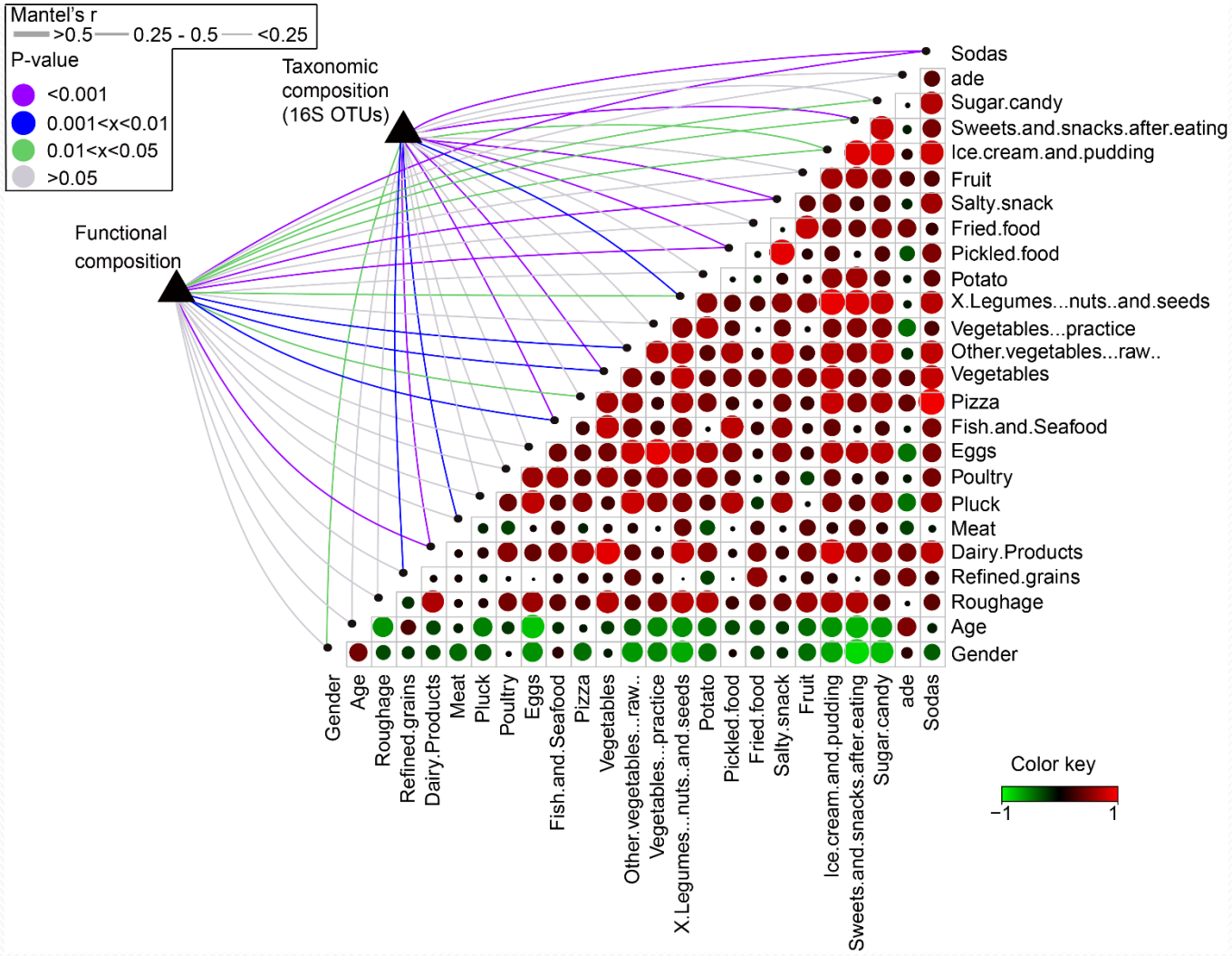
Sample similarity assessment

Clear separation of samples…



Unpublished data

Environmental drivers of community composition



Unpublished data

Plasticity of gut microbiome

Gut microbiome plasticity

Summary:

(I) Obvious differences in gut microbiota during Chinese groups stayed at TAT.

(i) The percentage of Top 6 phyla, shifted dramatically.

(ii) The ratio of *Firmicutes*: *Bacteroidetes*, considerable individual variations.

(iii) These changes might be associated with acclimatization.

(II) The stable states of the gut microbiota during stayed at TAT.

(i)70,544 OTUs, 18 OTUs, all samples and 68 OTUs, more than 90% samples.

(ii) Important: correlations between 18 core OTUs.

(III)The PCoA and CCA results also reveled the differences in gut microbiota.

(i) Taxonomical composition of samples from the same person with different time, immediate changes.

(ii)the samples from same person showed obvious clustering.

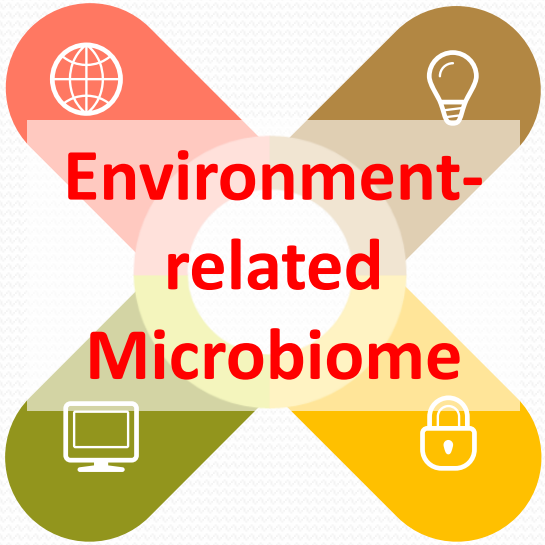
Microbiome for environment - Applications

1. Microbiome heterogenity
（菌群异质性）

应用：
淡水水体生态

3. Microbiome dynamics
（菌群动态特征）

应用：
校园微生物季节性



应用：
海洋抗性基因

应用：
城市环境微生物组

2. ARGs in microbiome
（菌群中的抗性基因）

4. Microbiome for cities
（菌群和健康中国）

Microbiome for environment - Applications

健康的生存环境（绿色）
Healthy environments

Freshwater lake data mining

Focusing on spatial differences!

We have more questions:

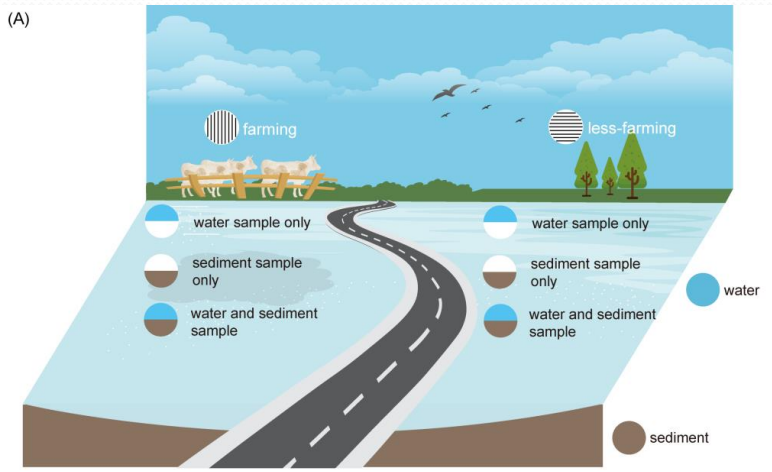
(i) The relationship of lake microbiome with eutrophication

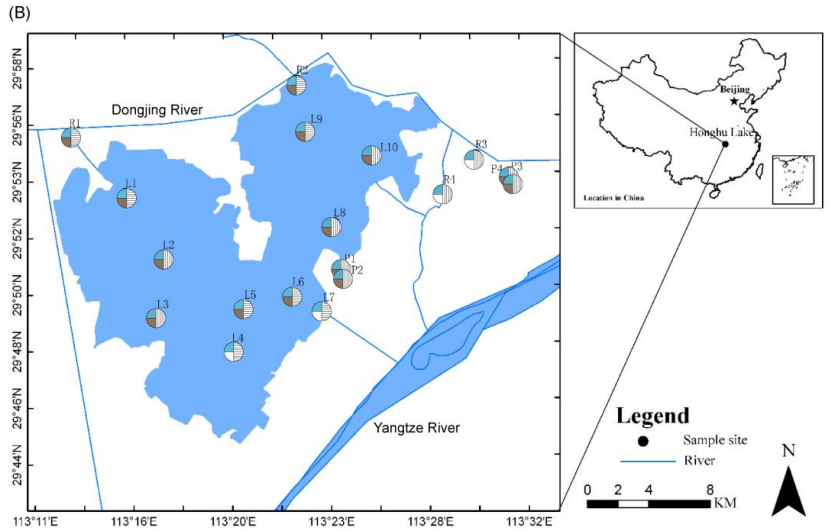
(ii) The relationship of lake microbiome with antibiotics

(iii) The relationship of lake microbiome with herbicides

(iv) The dynamics of lake microbial communities in time-series

(v) …





GPB, 2018

Microbiome for environment - Applications

健康的生存环境（绿色）
Healthy environments

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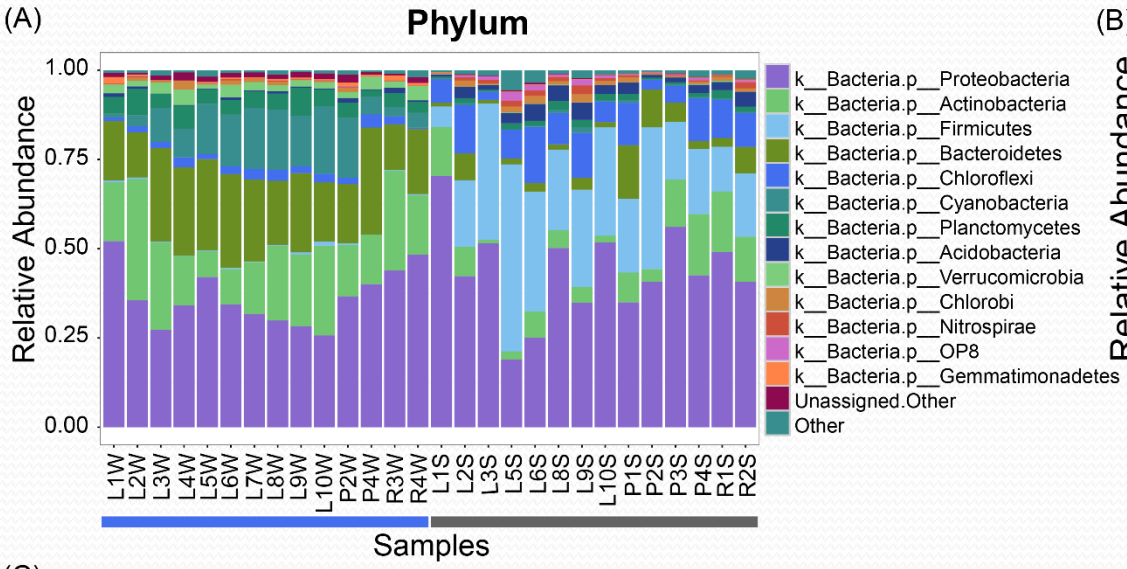
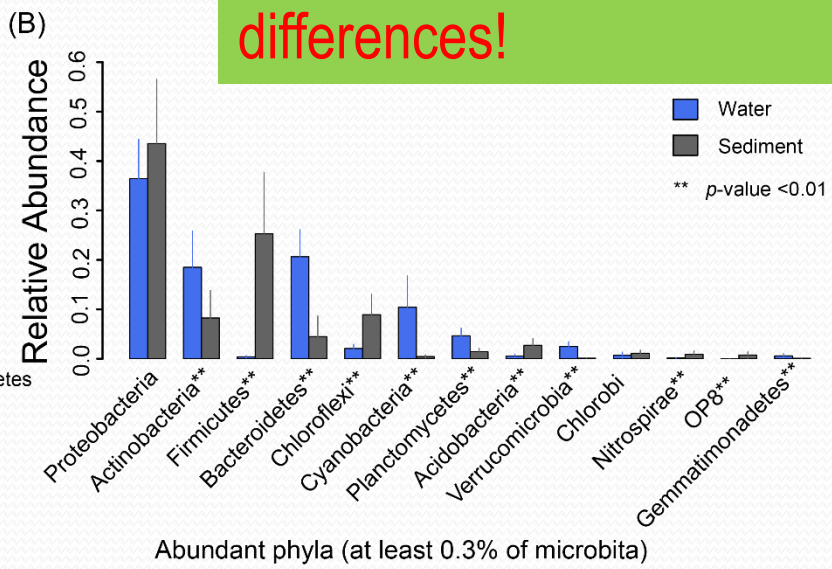
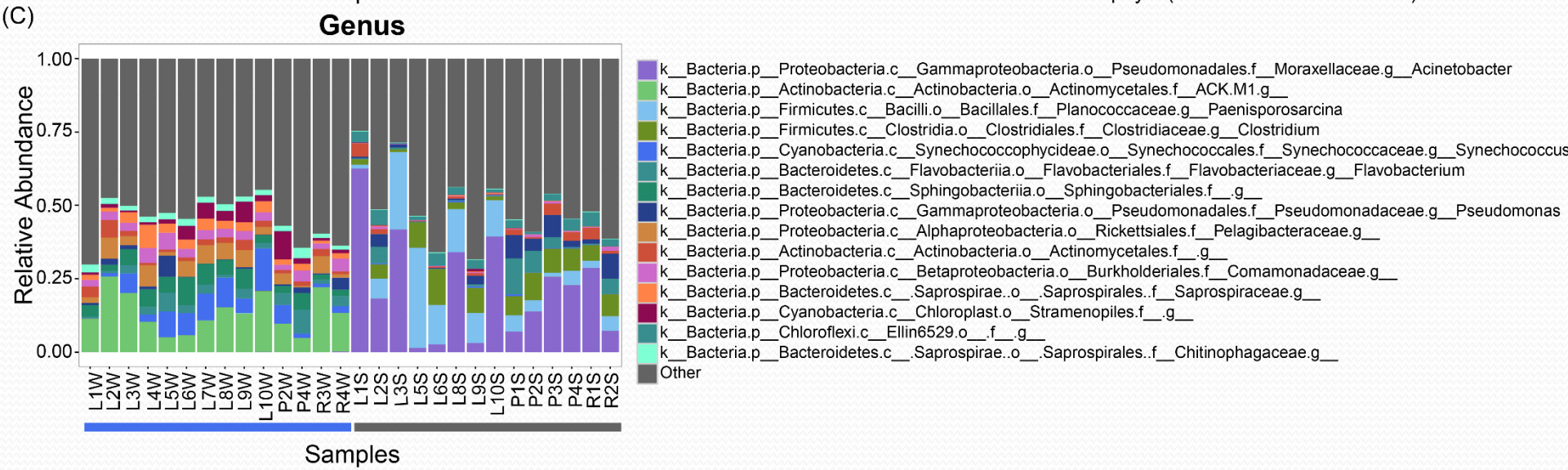
Focusing on spatial differences!







Microbiome for environment - Applications

健康的生存环境（绿色）
Healthy environments

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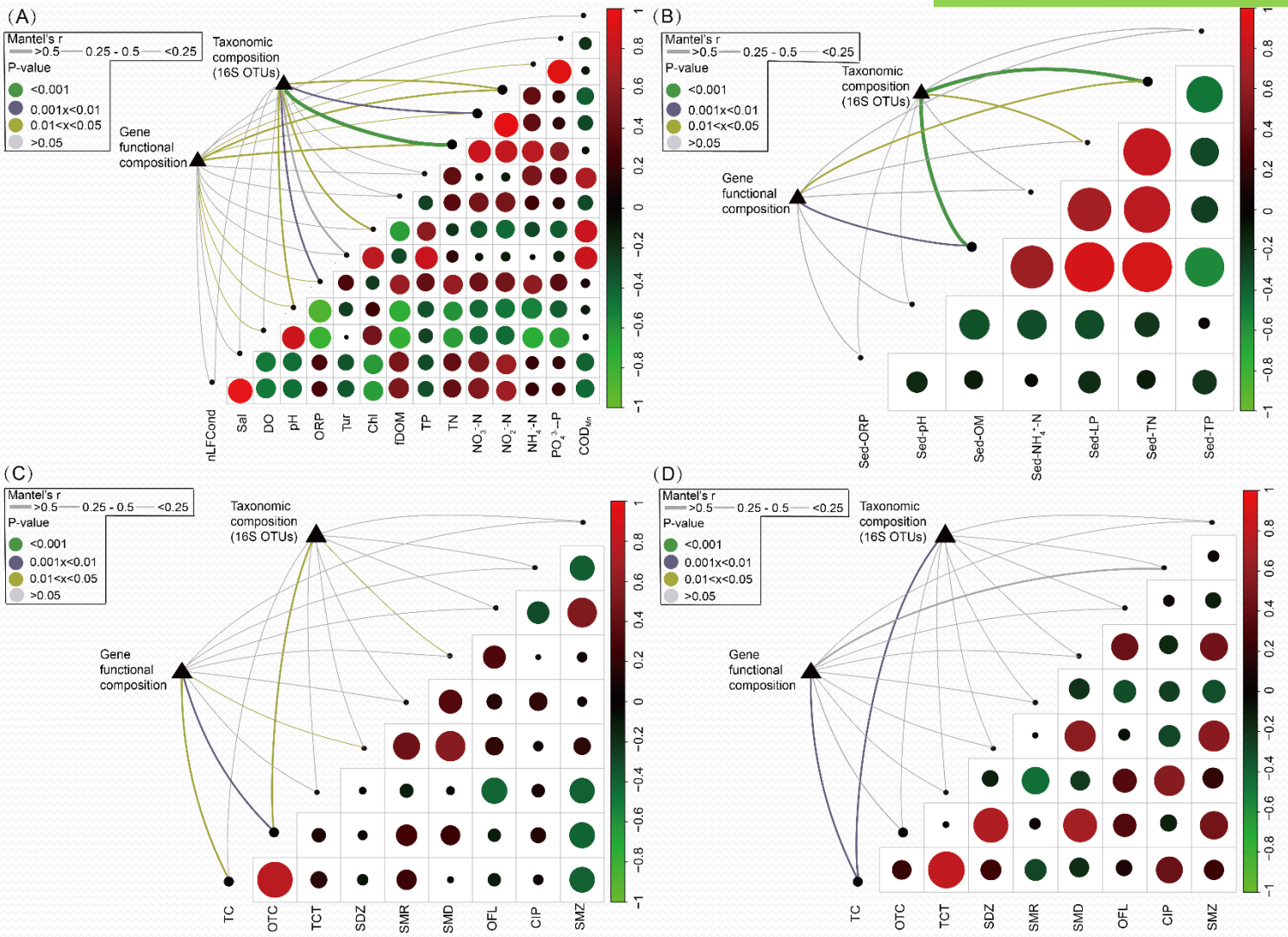
Focusing on spatial differences!



Microbiome for environment - Applications

健康的生存环境（绿色）
Healthy environments

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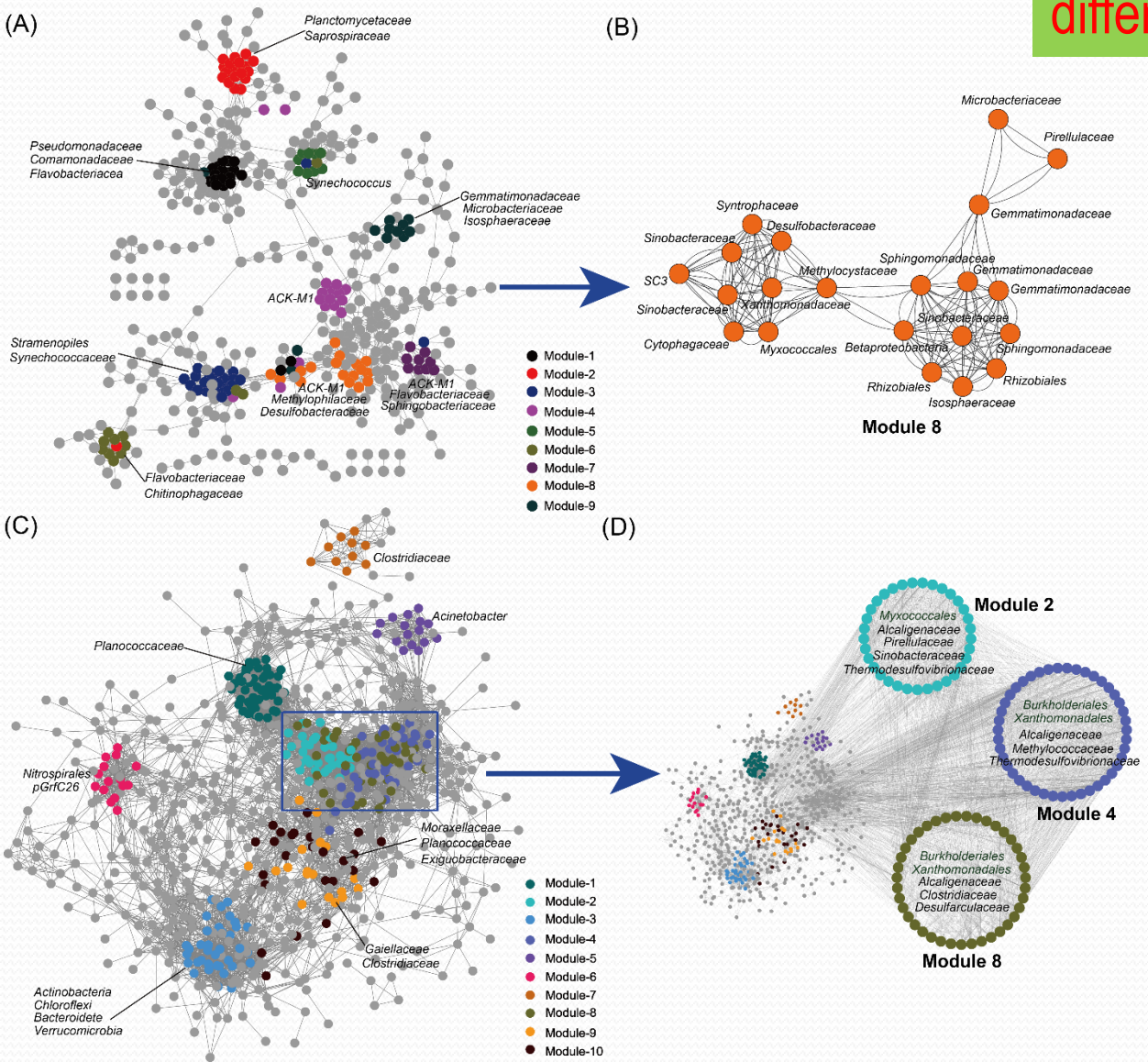


Microbiome for environment - Applications

健康的生存环境（绿色）
Healthy environments

Freshwater lake data mining

Focusing on spatial differences!

(i) The dynamics of microbial communities in Honghu: water-body and sediments

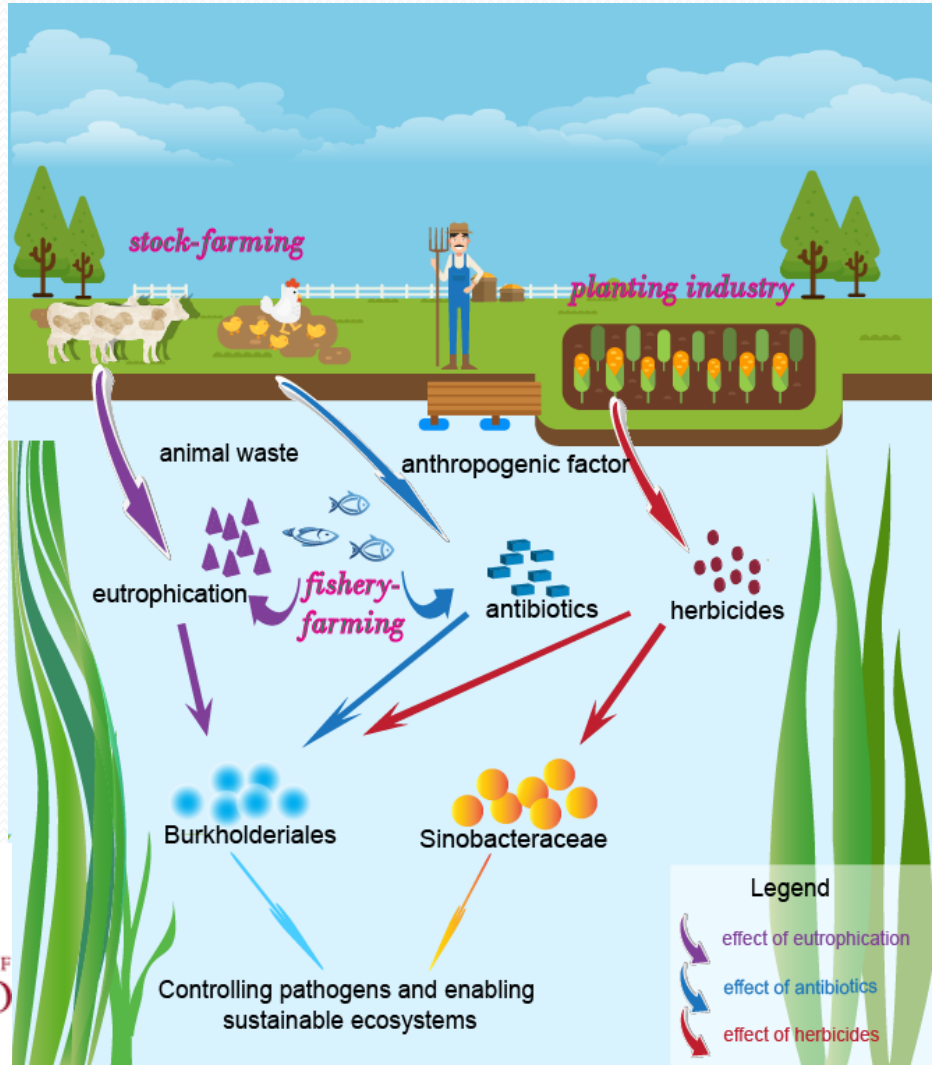
There are significant differences among them.

(i) The species-species co-occurrence ecological patterns

There exist core- and pan-microbiota in freshwater lake.

(ii) The relationship of microbial communities with environmental factors

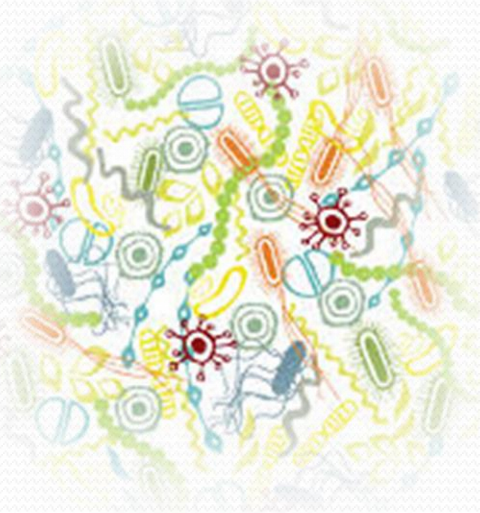
The relationships with eutrophication, herbiside, antibiotics.

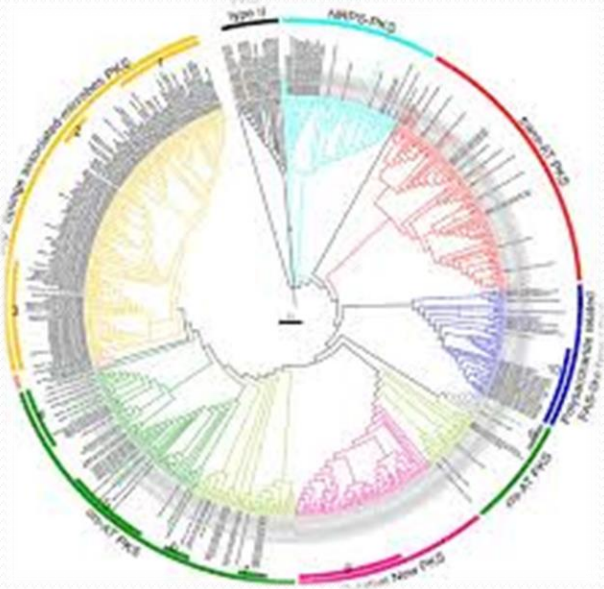


GPB, 2018

How to push them forward?

From microbial communities to big-data…





From data to knowledge and treatment

…

in which collaborations would be essential!

Modified based on:
Lauren Davis with sources via Shutterstock

Collaboration network

Acknowledgements

http://www.microbioinformatics.org/

- **Members:**
  - **Staff：** H Bai, YM Zhao
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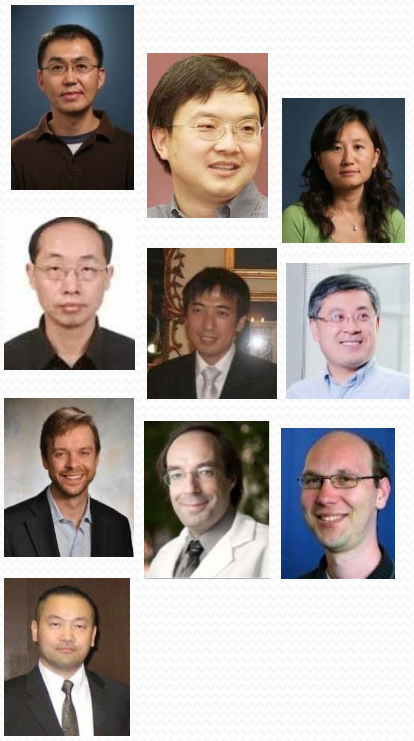
- **Collaborators:**
  - Jack Gilbert (U. Chicago) (on metagenomics)
  - JIANG Tao (UC riverside, USA; ACM Fellow) (on metagenomics)
  - WONG Limsoon (NUS, Singapore) (on omics)
  - CUI Xingping (UC riverside， USA) (on biostatistics and metagenomics)
  - BU DB(CAS-ICT) (on computational algorithems)
  - ZHANG Yang (U. Michgan) (on protein structure)
  - Alexey Nesvizhskii (U. Michigan, USA) (on proteomics)
  - Ansgar Poetsch (RUB, Germany) (on proteomics)



Thank you!


华中科技大学2018年新年音乐会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中国大学生马拉松联赛
CHINA UNIVERSITY MARATHON SERIES
START