





**SCElse**  
Singapore Centre for  
Environmental Life Sciences Engineering

**Singapore Centre for  
Environmental Life Sciences Engineering**

Prof. Staffan Kjelleberg  
Centre Director

9th September, 2015


 **NANYANG  
TECHNOLOGICAL  
UNIVERSITY**  **NUS**  
National University of Singapore  **NATIONAL  
RESEARCH  
FOUNDATION**  **Ministry of Education  
SINGAPORE**

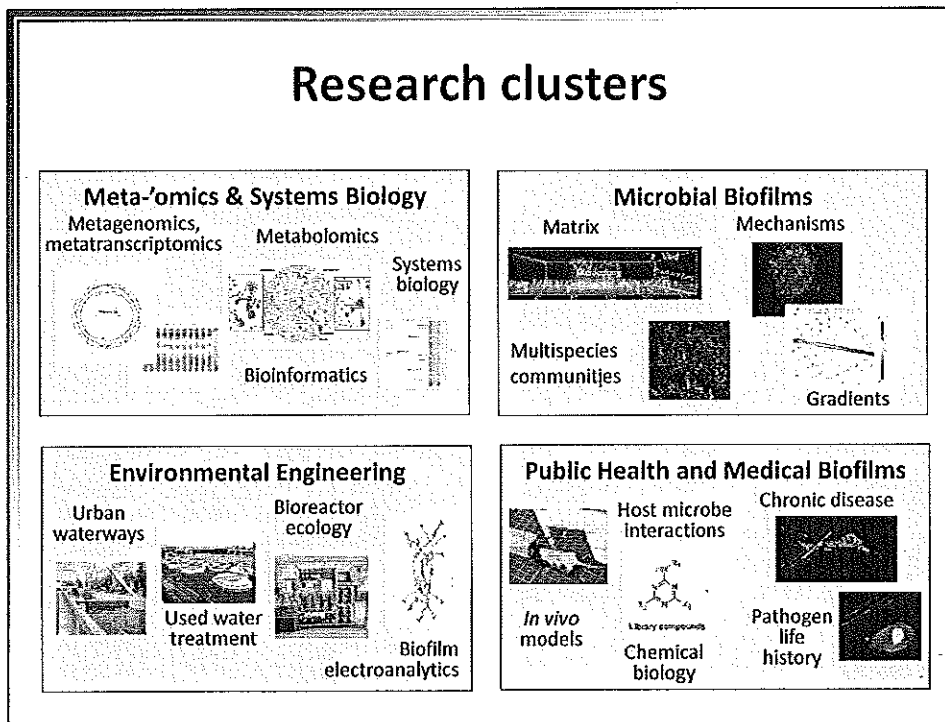
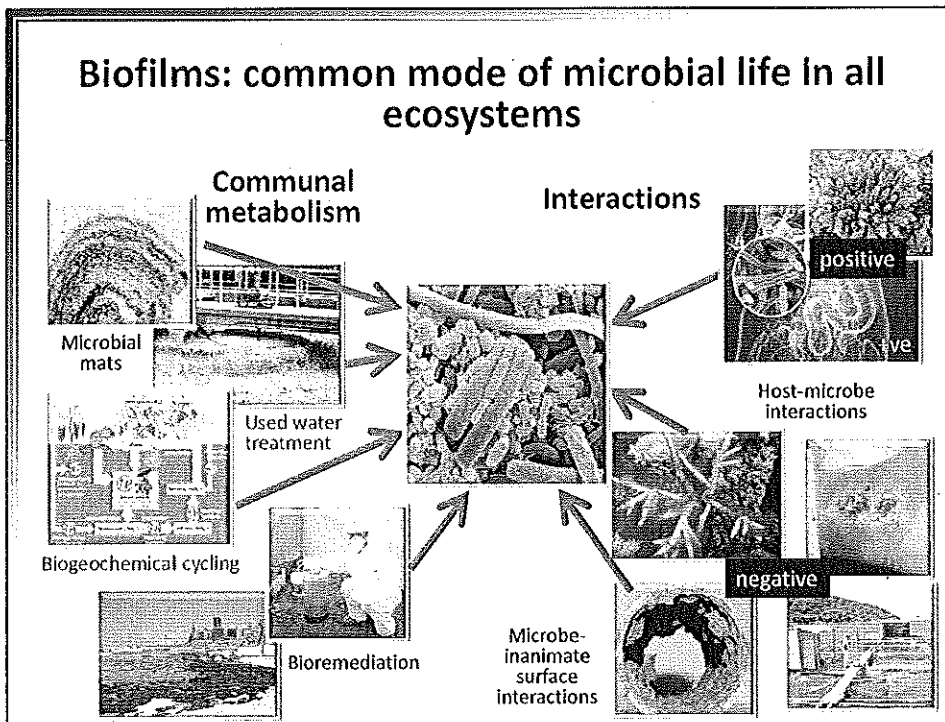
**Environmental Life  
Sciences Engineering**

- Understanding the universality of microbial biofilm communities in all habitats.
- A new approach & discipline for sustainable natural, engineered and medical systems.

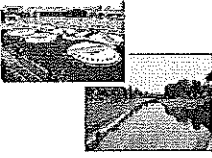
**SCElse's Mission**

*To discover, control and direct the behaviour of microbial biofilm communities for sustainable environmental, engineering, public health and medical applications.*







## Integrated Research Programmes




(i) Urban Water Cycle



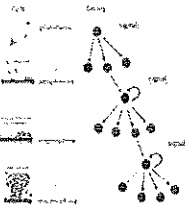
(ii) Bioreactor Community Ecology



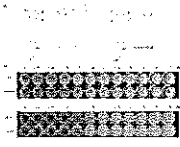
(iii) Experimental Biofilm Communities




(iv) Biofilm Matrix




(v) Developmental Biology of Biofilms



(vi) Antibiofilm Drugs



(vii) Host Microbiome Interactions



(viii) Air Microbiomes

## Integrated programs

**Urban water cycle**

Focuses on biofilms in used water treatment and engineered waterways

**Bioreactor community ecology**

Uses reactors of different scales/dimensions to test and formulate ecological theories and predictive models for process engineering performance

**Singapore's Urban Water Cycle**

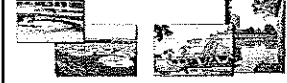
SWSM employs the 'source-to-sewer' paradigm to reduce natural and engineered wetland loss associated with Singapore

**Ulu Pandan Water Reclamation Plant**


• world's first water reclamation plant with a 100% biofilm-based treatment process

**Ulu Pandan Sewerage Treatment Plant**

• world's first large-scale biofilm-based wastewater treatment plant



**Detection by FISH of *Candidatus Akkermansia* clade B4**



Sample: 18 December 2013, Singapore, wastewater treatment plant, Ulu Pandan

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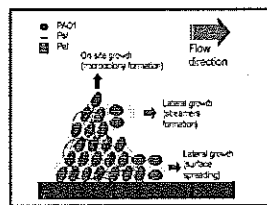
## Integrated programs

### Biofilm matrix

To explore a range of novel matrix components and their structure/function contribution to biofilms

### Developmental biology of biofilms

Specific mechanisms at the various developmental stages of the biofilm lifecycle



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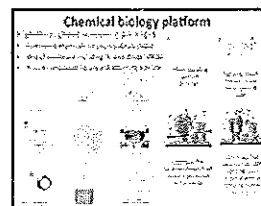
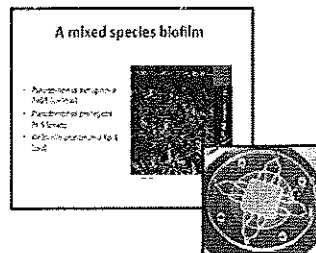
## Integrated programs

### Experimental biofilm communities

Uses both defined and complex community systems to understand biofilm mechanisms and ecology in communities rather than populations

### Antibiofilm drugs

Using identification of new biofilm targets and biofilm-specific assays to develop biofilm control drugs

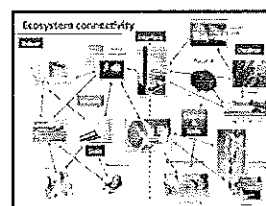
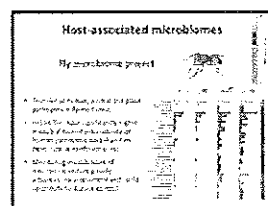


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## Integrated programs

**Host-microbiome interactions**  
 Novel host-associated biofilm  
 microbiomes, including marine,  
 insects and human hosts

**Air microbiomes**  
 Sources, function and  
 ecology of urban air  
 microbiomes



## SCELSSE within and across NTU/NUS



Schools of:

- Biological Sciences
- Materials Science & Engineering
- Civil & Environmental Engineering
- Mechanical & Aerospace Engineering
- Chemical & Biomedical Engineering
- Lee Kong Chian Medical School (NTU/Imperial College)
- Chemistry and Biological Chemistry
- Asian School of the Environment

Singapore Membrane Technology Centre  
 Energy Research Institute  
 Earth Observatory of Singapore  
 Nanyang Institute for Structural Biology  
 Complexity Institute  
 NTU Integrated Medical, Biological, &  
 Environmental Life Sciences

Departments of:

- Biological Sciences
- Biochemistry
- Computational Science & Engineering
- Chemistry

Bioimaging Institute  
 Life Sciences Institute  
 Mechanobiology Institute  
 NUS Environmental Research Institute  
 Singapore Eye Research Institute  
 Tropical Marine Science Institute  
 Lee Kong Chian Natural History Museum

## SCELSE@NTU

- Bioreactor engineering
- Bioengineering
- Analytical microbiology
- Molecular microbiology
- Experimental biofilms
- Analytical instrumentation
- Sequencing and high performance compute cluster
- Advanced Biofilm Imaging Facility

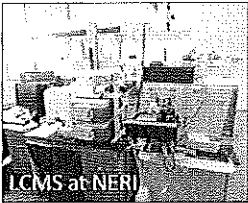
## NIMBELS

NTU Integrated for Medical, Biomedical and Environmental Life Sciences (NIMBELS)

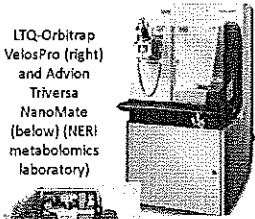
- Strategic collaborative consortium for integrated and coordinated research in life sciences
- Foster innovative expertise, capacities and facilities:
  - Singapore Phenome Centre
  - NTU Genomics
  - Imaging
  - Bioinformatics
- Co-localised on campus from early 2016

## SCELSE@NUS


- Systems Biology
- Van Kleef Aquatic Science Centre
- Metabolomics
- Chemical Biology Programme
- TMSI St John's Island Marine Laboratory



LCMS at NERI



LTQ-Orbitrap VelosPro (right) and Advion Triversa NanoMate (below) (NERI metabolomics laboratory)



Orbitrap Exactive Plus for high throughput sequencing






Plate reader for small molecule screening assays (LSI chemical biology laboratory)




Van Kleef Aquatic Science Centre




TMSI St John's Island Marine Laboratory

## Graduate program, Summer Course and outreach

- SCELSE Graduate Program across NTU & NUS
- Offers a spectrum of research activities from both universities to strengthen and complement the interdisciplinary research
  - International joint PhD programs

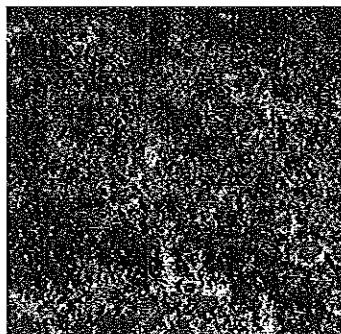


- Annual international graduate Summer Course on Environmental Life Sciences Engineering already conducted since 2011
- Series of hands-on workshops



2015 Summer Course participants

**Thank you**



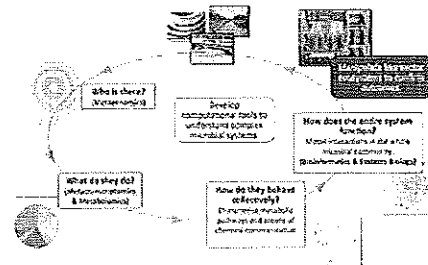
**Highlights from SCELSE's  
integrated research programmes  
for Q&A**

- Urban water cycle
- Experimental biofilm communities
- Biofilm matrix & biophysics
- Antibiofilm drugs
- Microbiomes



## Urban water cycle: used water treatment

Understanding used water treatment functioning and performance.

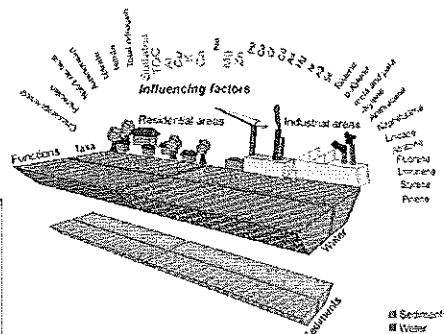


Meta-omics & systems biology approach

- Extremely high microbial diversity: > 2000 genera; mostly unclassified
- Identified metabolic pathways to track whole community gene expression; metabolic junctions as targets for controlling bioprocesses
- Anaerobic Digestion Ecosystem Microbial Observatory to optimise system performance for complete degradation and energy production
- Enhanced biological phosphorus removal – understanding community dynamics of clusters of key “species” (subspecies/variants)

## Urban water cycle: engineered waterways

Ecogenomics of engineered waterways: Identifying key drivers of microbial communities and their functions at the catchment scale.



- Microbial functions are influenced by pressures from land-use rather than habitat
- Of entire metadata set three elements (K, Cu, Al) explain 30% of variation in taxa and function
- Findings are used by PUB for enhanced microbial services and development of ecologically friendly urban waterways
- Experimental approach now adopted by government agencies for marine and aquatic research

## Experimental biofilm communities

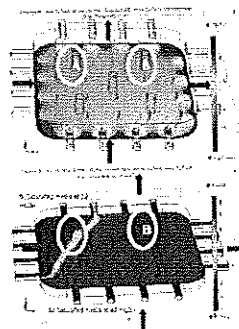
Moving from single species (population) studies to multi-species biofilm communities that exist in all habitats.

### Biofilm communities

- Model mixed species communities – simple (2 to 3 species) and highly diverse (granular communities). Establishes how:
  - Pathogenic strains colonise and exhibit virulence
  - Biofilms resist stressors and antimicrobial treatment
  - Microbes interact via signalling to achieve true community effect
  - Ecological theory explains microbial communities

### Spatial/temporal resolution in biofilms at relevant scales

- Next generation biofilm growth chamber developed to address the relationship of micro-environmental conditions to biofilm behaviour
- Combined data on shear force and chemical gradients reveal how microscale conditions drive biofilm lifecycle and development
- To understand co-metabolism between microbial species

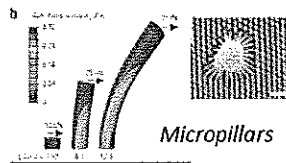
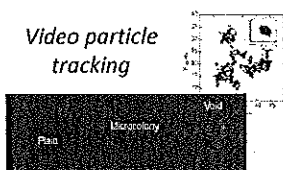


## Matrix & biophysics

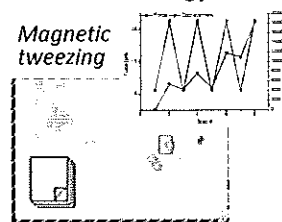
Many biofilm emergent properties are due to matrix structure/function.

### Biophysics analyses for tracking matrix mechanics and microrheology

Video particle tracking



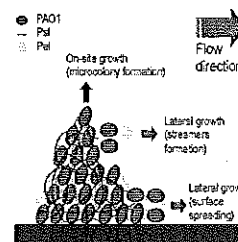
Magnetic tweezing



### Understanding matrix components

Exopolysaccharide, eDNA and protein polymers and their interaction with soluble information rich molecules

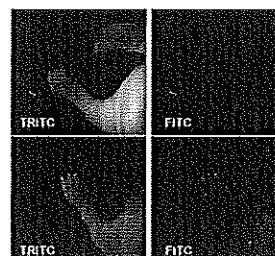
- Exopolysaccharides (Psl and Pel) dynamically remodel biofilms and determine mechanical properties
- Amyloids & bound shuttles/signals affect biofilm structure/function
- Biofilm community members benefit from shared matrix polymers



## Antibiofilm drugs

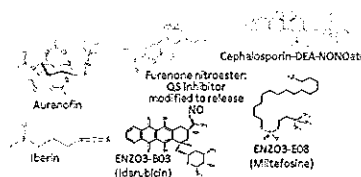
SCELS identifies chemical compounds for detecting and dismantling biofilms

- Biofilm control: Screen for biofilm dispersing compounds, using many targets within each system (quorum sensing (QS) system, secondary messenger system, biofilm structures – amyloids etc))
- Biofilm detection: Using biofilm-unique targets, e.g. amyloids



### High-throughput screening

- Fluorescent chemical compounds library
- Med-Chem libraries incl. "known drugs"
- Natural product-based libraries
- Synthetic chemical-based libraries
- *In silico* compounds library



- Novel compounds targeting biofilm specific traits for detection/control

## Microbiomes

### Air

Sources, function & ecology of urban air microbiomes

- Environmental genomics
- Ecological connectivity
- Adaptive responses



### Host-associated

- Insects – biological and mechanical vectors for transmission (fly and mosquito)
- Human
  - Gut – link between microbiome and early development, metabolites and organ-development/function
  - Atherosclerosis
  - Skin – scalp and wound
  - Microbiome biofilms and cancer
- Marine
  - Coral holobiont

