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Centre for Invasive and Transitional Sciences  
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**Roscoff (France), 25-29 juin 2011**

**Aspects évolutifs des maladies émergentes chez les animaux et chez les plantes dues à des champignons pathogènes, dans le contexte des changements globaux**

*New and emerging fungal diseases of animals and plants: evolutionary aspects in the context of global changes*

Président : **Matthew FISHER**

Faculty of medicine, Imperial college London, Londre, Royaume Uni

Vice-Présidente : **Tatiana GIRAUD**

Laboratoire écologie, systématique et évolution. Université Paris Sud, Orsay, France

**Rapport sur la Conférence**

*Conference Report*

## **RESUME DU RAPPORT**

### **Conférence Jacques Monod intitulée : Aspects évolutifs des maladies émergentes chez les animaux et chez les plantes dues à des champignons pathogènes, dans le contexte des changements globaux Roscoff, 25-29 juin 2011**

Les environnements du monde entier se retrouvent profondément modifiés par les activités humaines. De plus, la globalisation croissante entraîne l'introduction d'espèces exotiques dans des nouveaux écosystèmes. Certaines de ces espèces, parfois pathogènes, deviennent envahissantes. Cette Conférence Jacques Monod se focalisait dans ce cadre sur les champignons, un règne qui est de plus en plus reconnu comme ayant un impact majeur sur les écosystèmes naturels, les agro-écosystèmes et la santé humaine. De nombreuses maladies émergentes apparaissent qui sont dues à des champignons, aussi bien chez les plantes, les animaux que chez l'homme. Les conférenciers ont présenté leurs travaux et idées qui contribuent à comprendre les mécanismes à l'origine de ces maladies, en s'appuyant en particulier sur biologie évolutive, qui fournit un cadre théorique indispensable, en particulier pour comprendre les processus d'invasion et l'adaptation des pathogènes aux nouveaux environnements ou aux nouveaux hôtes. Des idées importantes ont émergé, comme l'identification d'adaptations clefs permettant les émergences de maladies, les similitudes et différences entre champignons pathogènes de plantes et animaux, la nécessité d'études interdisciplinaires à la frontière entre les études théoriques, génomiques, et expérimentales, mais impliquant également le public. Il est apparu essentiel d'entreprendre des actions pour sensibiliser le public et les politiques, et les conférenciers se sont engagés à écrire un article contenant les objectifs clés qui semblent indispensables pour permettre de limiter l'émergence de maladies fongiques. Les participants ont considéré que la conférence était d'un niveau et d'un intérêt exceptionnels et ont voté unanimement pour une demande de renouvellement d'ici 3 ou 4 ans, avec Tatiana Giraud en Présidente et Bruce McDonald comme Vice-Président.

## **CONFERENCE REPORT**

### **Final report from the Jacques-Monod Conference entitled: New and emerging fungal diseases of animals and plants: evolutionary aspects in the context of global changes Roscoff, June 25-29, 2011**

#### **GENERAL ASPECTS**

The world is changing rapidly as environments are modified by human activity. Superimposed upon this background of environmental change are signatures of 'Globalisation' as species are introduced into non-native, ecosystems. Many of these species are invasive, often pathogenic, organisms, and this conference Jacques Monod focuses on a Kingdom that is increasingly being recognised as having a widening impact on ecosystem, agricultural and human health, the Fungi. Pathogenic fungi are known to cause great impacts on animal and plant species, and devastating new fungal diseases are emerging. Increasingly, there is a focus on identifying the factors that drive the emergence of new fungal diseases and evolutionary theory provides a framework for considering the adaptability and match between new invaders and new host/environment combinations. Generally, the conference will focus on three main questions;

- 1) Are disease emergences due to the introduction of a pathogen into a new environment? In such cases, how has the invasion taken place? What are the regions of origin? Were there multiple introductions, or is a single introduction sufficient? Have host shifts occurred between geographically overlapping host species?
- 2) Are disease emergences linked to evolutionary changes, either after introduction, or prior to introduction? What types of evolutionary changes underlie disease emergence and how do we can detect these?
- 3) Are disease emergences facilitated by environmental changes, such as changing climates or habitat destruction? What will patterns of fungal disease look like in the future and is this predictable?

Insights and answers to these questions were sought by 30 innovative and world-leading international conference faculty. The invited scientists and participants to the Jacques Monod conference were asked to identify methodologies, parameters and approaches that are important for our understanding on how emergent fungal diseases have appeared in the past. The conference was successful in ascertaining whether it is possible to predict patterns of emergence in the future, using new and interdisciplinary approaches, and incorporating knowledge on the coming environmental changes. Additionally, the conference identified important new policy objectives to leverage mitigation against emerging fungal pathogens of animals and plants.

## SUMMARY OF SPEAKERS AND DISCUSSIONS

### DAY 1 MORNING:

Chair: Prof. John Taylor & Prof. Ingrid Parker

- Fisher provided a general overview of fungal emerging infectious diseases (EIDs) in animals, and focused on *B. dendrobatidis* emergence in amphibian populations in Europe, the risk that this poses to biodiversity and the use of genomics to identify invasive lineages.
- Hood focused on hybrid speciation in pathogens with a focus on the anther smut/*Silene* system. The data shows that hybridisation rates are higher in sympatric systems, and that these are associated with higher F2 inviability. This provides evidence of ecological speciation in sympatry within this system.
- Giraud next explored the mechanisms allowing speciation of fungal pathogens via host shifts. Importantly, some life history traits of fungal pathogens, such as the sexual reproduction occurring within host plants, may greatly facilitate host shift speciation and therefore disease emergence.
- Balloux contributed an important talk showing that an important component of popgen neutral theory, that the probability of fixation is independent of population size, may not hold for populations with fluctuating sizes and overlapping generations. This has important implications for the dating of pathogens where populations experience substantial bottlenecks.
- Delmotte gave an excellent talk identifying North American populations of downy mildew as the progenitors of lineages that have invaded and cause disease in European grapevine populations. This poses questions as to when, and where, these disease introductions occurred. This talk was followed on day 2 by Milgroom, where it was shown that powdery mildews that this class of pathogens appear to have followed the same route of introduction.
- Linde spoke authoritatively about the Scandinavian origin of Barley scald (*Rhynchosporium*). This contradicts earlier hypotheses that the disease originated in the middle eastern fertile crescent and suggests host-jumps from wild grasses into agricultural species. Molecular evidence points to a host-jump occurring 1,200 ybp followed by a rapid increase 250 ybp likely driven by increases in agricultural productivity.

### DAY 1 AFTERNOON:

Chair: Prof Sergey Gavrillets & Dr. Eva Stukenbrock

- Le Cam detailed the evolutionary history of apple-scab molecular epidemiology, showing the origin of the emergence to be China. This parallels work on the rice blast *Magnaporthe* which also appears to have a southeast Asian origin, again on the original host population and was a common theme throughout the meeting (see Linde above and Fournier on Day 3).
- Brasier and Stenlid provided important input into rapidly-evolving plant pathogens that threaten Elm and Ash. Both hybridisation (a common theme throughout) and climate change triggering aspects of the fungal life cycle were discussed as mechanisms underpinning emergence.
- Halkett illustrated an important theme: that clonal epidemic waves can propagate from sexual populations, using examples of *Melampsora* on Poplar in the Durance valley, France

## DAY 2 MORNING:

Chair: Dr. Matthew Fisher & Prof. Anne Pringle

- Gurr initiated a theme that underpinned much of the conference: that there is a systematic underappreciation of the health and economic consequences of the impact of fungal EIDs. Gurr used examples from the host/pathogen 'disease triangle' to illustrate drivers of emergence, and promoted the concept of raising public awareness against novel pathogens.
- Marcais subsequently presented work on the emergence of *Dothiostoma* blight in French forests that illustrated the occurrence of strong environmental forcings of infection and the likelihood of increases of disease under current models of climate change.
- Boddy presented data from a longterm dataset of British fungi showing that fungal fruiting times are now earlier, and later, than they were in the 1950's. This work provides clear evidence of the effect of climate change on fungal phenology.
- Van den Bosch presented theoretical work alongside longterm agricultural datasets to show that bi-stable evolutionary stable strategies (ESS's) exist for fungi and that there is evidence for the evolution of virulence as the relative contribution of horizontal versus vertical transmission changes. Both Boddy & van den Bosch's presentations illustrated the key importance of longterm datasets to track changing patterns of fungal life-histories and their environment.

## DAY 3 MORNING:

Dr. Celeste Linde and Prof. Michael Hood

- This session focused on the ecology and genetics of fungi and their hosts. Pedersen provided a multidisciplinary perspective on the relationship between biodiversity and disease emergence by showing that transmission between hosts is strongly dependent on phylogenetic relatedness. Garner provided a viewpoint from the host, by showing that hosts with complex life histories show different responses to infection that likely translate into significantly different disease trajectories depending on infection history. Deprez-Loustau presented a study that identified the most important traits in controlling the probability of disease emergence in fungal forest pathogens; this model likely has widespread applicability for predicting invasion of forest pathogens.
- This session also had strong talks on the genomics of virulence in phytopathogens, with a focus on plant cell wall degrading enzyme (CWDE's) in wheat pathogens (Brunner) and *Phytophthora* (Kamoun). Specific attention was drawn to the role of effectors in causing virulence: these are numerous (over 700 in *Phytophthora*), rapidly evolving and occur in gene-poor & repeat-rich regions of the genome. This '2-speed genome' concept is likely to provide key evidence as to why fungal pathogens are able to evolve so much faster than their hosts, and why crop cultivar resistance breaks down so rapidly. Farrer provided direct genomics evidence of this occurring owing to the recent (1960) hybridisation event in *Batrachochytrium* and how this was translated into biodiversity loss via the global trade in amphibians.

## DAY 3 AFTERNOON:

Prof. Sarah Gurr and Prof. Bruce McDonald

- The afternoon session focused on the ecology of fungi, with a taxonomic perspective on emerging powdery mildews from Kiss. Parker showed extensive

ecological experiments testing invasion ecology in *Trifolium* & endophytic fungi. The hypothesis that introduced hosts 'escape' their native parasites to become 'superweeds' was not supported by the data and instead climate appeared to be the dominant influence.

- Rigaud presented on an emerging animal fungal pathogen, the microsporidian *Cucumispora* on the invasive 'killer shrimp' *Dikerogammarus villosus*. This study exemplified many characteristics of other animal fungal pathogens including pathogen spill-over, and may present a threat to native European *Gammarus*.
- Fournier presented data supporting the 'clonal wave' hypothesis by showing that SE Asia acts a sexually-reproducing 'pump' for novel clones of the rice blast *Magnaporthe* however the sexual stage has yet to be discovered.
- Weinert provided an overview of the importance of molecular dating of pathogen emergence, and illustrated some of the common advantages and pitfalls that currently exist.
- This session was followed by a group discussion on 'How do we leverage our scientific knowledge to achieve action?' Key points identified were:
  - Where there is the political will, disease can be controlled. An example here is HIV
  - To action this for fungal pathogens, full economic costing of the impact of fungi to forests, biodiversity and ecosystem services, is required, and rapidly as outbreaks are occurring annually, and are increasing in incidence.
  - The practice of vectoring pathogenic fungi in the plant and animal trade is virtually unrestricted
  - We scientists need to speak with one voice if we are to action policy makers. The onus is on us to provide clear guidance exemplifying the state-of-the-art and to set down achievable and politically tenable guidelines.

#### **DAY 4 MORNING:**

Prof. Tatiana Giraud

Taylor showed comparative population genomic data of genome-wide association studies to identify the genes involved in speciation events using a model fungal species *Neurospora*. This approach is likely to find widespread use to not only discover 'speciation genes' but also 'virulence genes' in pathogens. Stuckenbrock presented data on hybrid speciation that illustrated many of Taylor's points, showing the amount of linkage equilibrium that is likely to be achieved after ~250 generations following a hybridisation event.

#### **CONCLUSIONS**

Via the discussion that followed talks, the Conference came to the following conclusions:

1. Similarities exist between 'red' and 'green' pathogenic fungi (i.e; plant and animal fungal pathogens). Principally, international travel and trade is key to introducing novel pathogens into new naïve environments. Life-history characteristics identified included high virulence, environmental persistence, host-generality and recombination. These traits are allowing these organisms to emerge as

terminal pathogens in animal populations as well as causing severe population declines across diverse plant communities. Anthropogenic activity was shown to be forcing current spatial and temporal increases in infection rates by increasing long-distance dispersal, creating novel selection arenas, and by modifying natural environments to the detriment of host immunity

2. Differences exist between 'red' and 'green' pathogenic fungi. Principally, it is currently unclear the molecular effector repertoire in animal pathogenic fungi is as extensive as that seen in plant pathogens. This leads to fundamental differences in the probability of host-switching and ecological speciation.
3. Interdisciplinary approaches are fundamental to furthering the science of fungal disease emergence, including merging theoretical approaches with genomics and new informatic technologies. Public engagement is also key to success.
4. There is a strong need for action aimed at influencing policy makers. To this end, the conference faculty have **committed to drafting a paper containing the key policy objectives identified by the meeting.**

## RECOMMENDATIONS

The high level of debate that followed presentations, the excellence of the presentations themselves and the strong attendance of the meeting showed that this was a popular and timely meeting, many of the participants claiming this was one of the best meetings they even attended to. **There was a unanimous vote from all attendees present to attempt to hold the meeting in ca. 3 years time to reassess the state of the art.** To this end, Tatiana Giraud was elected President, and Bruce MacDonald, ETH Zurich, the VicePresident. There were no abstainers or dissenters.

Through general conversation, feedback showed that the attendees thought that the organisation of the meeting was excellent, and that Roscoff provided an excellent location to hold a meeting. While travel to Roscoff is relatively long, it was apparent that the benefits of travelling to such a beautiful location with excellent facilities outweighed the costs. At all times, the attendees felt that the CNRS staff were excellent in hosting participants, and the quality of the food and location was better than most had ever met at an international meeting. We feel that the CNRS and people of Roscoff deserve special thanks for allowing such a successful meeting to occur.