Breeding for seed yield and seed quality in Oilseed Brassicas: main past successes and main challenges for the future?

M Renard

UMR IGEPP, Le Rheu, France

19th Crucifer Genetic Workshop, 2014
Wuhan

Area of the question

Brassica species: oilseed *B. napus*, *B. juncea* and *B carinata*

- Main successes since the 60s?

- Main challenges for the future?

Methodologies

A Survey

- A **worldwide survey** on main successes and challenges including failures and visions on international collaborations
- Recipients: scientists from worldwide Institutes and Universities, GCIRC members, European breeders
- Questionnaire was NOT CONFIDENTIAL

Friendly acknowledge

- **Australia**: M. Barbetti, W. Cowling, G King
- **Canada**: K Downey, W Keller, I Parkin, H Rahman
- **China**: D Li, Y Zhou
- **France**: MH Balesdent, AM Chèvre, R. Delourme, JP Despeghel, JE Dheu, T Foubert, F Labalette, G Larbaneix & AS Grenier
- **Germany**: M. Frauen, W Friedt
- **India**: A. Agnihotri, S Banga, PD Meena, D Pental, AK Pradhan,
- **Poland**: I Bartkowiak-Broda
- **Spain**: L. Velasco

A bibliometric study

by Anne-Sophie Grenier

- 2003-2014 period (2014, February 7th)
- **Database**: **Web of Science** ™ Core Collection (Thomson Reuters)

TOPIC: *("brassica napus" or "b. napus" or "b. juncea" or "brassica juncea" or "oilseed rape" or "canola" or rapeseed or "brown mustard" or "indian mustard" or "brassica carinata" or "b. carinata") AND* **TOPIC:** *(gene$ or genet* or genom* or genot* or "plant breeding" or transgen*)*

Refined by: DOCUMENT TYPES=(ARTICLE OR REVIEW)

→ 4833 references

- **Sphinx software** for quantitative and qualitative studies and analysis of textual data

Removing references irrelevant selected by Keywords Plus → 2890 references

- **Wordle** ™ software for generating "word clouds" from text. The clouds give greater prominence to words that appear more frequently in the source text.

Past successes

Main past success stories

- **Seed quality**
  - Increased oil content
  - massive increase in canola (double low *B. napus,B rapa, B. juncea*) production, esp. China, Canada, USA, N. Europe & Australia ; improved economical value of rapeseed oil and meal
  - HOLLi (*B. napus*) in Canada

  Consumer acceptance of rapeseed oil as a highly valuable vegetable food oil (for the 'cold kitchen') ; accepted value of stable HOLLi oil for the 'hot kitchen'

Main past success stories

- **Disease resistance**: introgression of disease resistance
  - Blackleg (*B. napus*): monogenic & polygenic resistance; demonstration of numerous gene for gene interactions
  - White rust (*B. juncea*)

Main past success stories

- **Herbicide tolerance**:
  - Triazine, Glyphosate, Glufosinate, Imidazolinone (*B. napus*) in Canada & Australia
- **Yield potential through Hybrids**
  - Hybridisation systems: seedlink®, GMS (MSL), ..), ogu-INRA CMS, Polima CMS and its derivatives, … (*B. napus, B. juncea*)
  - High performance hybrids in spring *B napus*
- **Replacement of *B rapa*** through adaptation of *B napus* and *B juncea* (higher yielding, shattering resistant, early maturing and bold seeded OP varieties like Varuna, Pusa bold) in Canada and India

Main success stories during the last 10 years

- Spread of hybrid cultivars
- Deployment of herbicide tolerant canola
- Clubroot resistant cultivars based on resynthesis
- Release of low erucic acid mustard hybrids in India
- Beginning of the WOSR semi dwarf hybrids in cold areas
- Genome sequencing of A, C & AC genomes
- Integration of genetic maps and anchoring to karyotype
- Cloning of 6 avirulence genes of *L. maculans*
- …..

Main failures

- Decrease of genetic variability
- The level of heterosis needs to be enhanced in *B juncea* and winter *B napus*
- Many component yield traits are poorly resolved
- In Europe, no substantial yield increase (seed and oil) on the farm level, during the last decade!
- Few resources for resistance to main diseases: sclerotinia, broomrape, Alternaria blight, ...
- No consensus nomenclature for RLM genes, ..

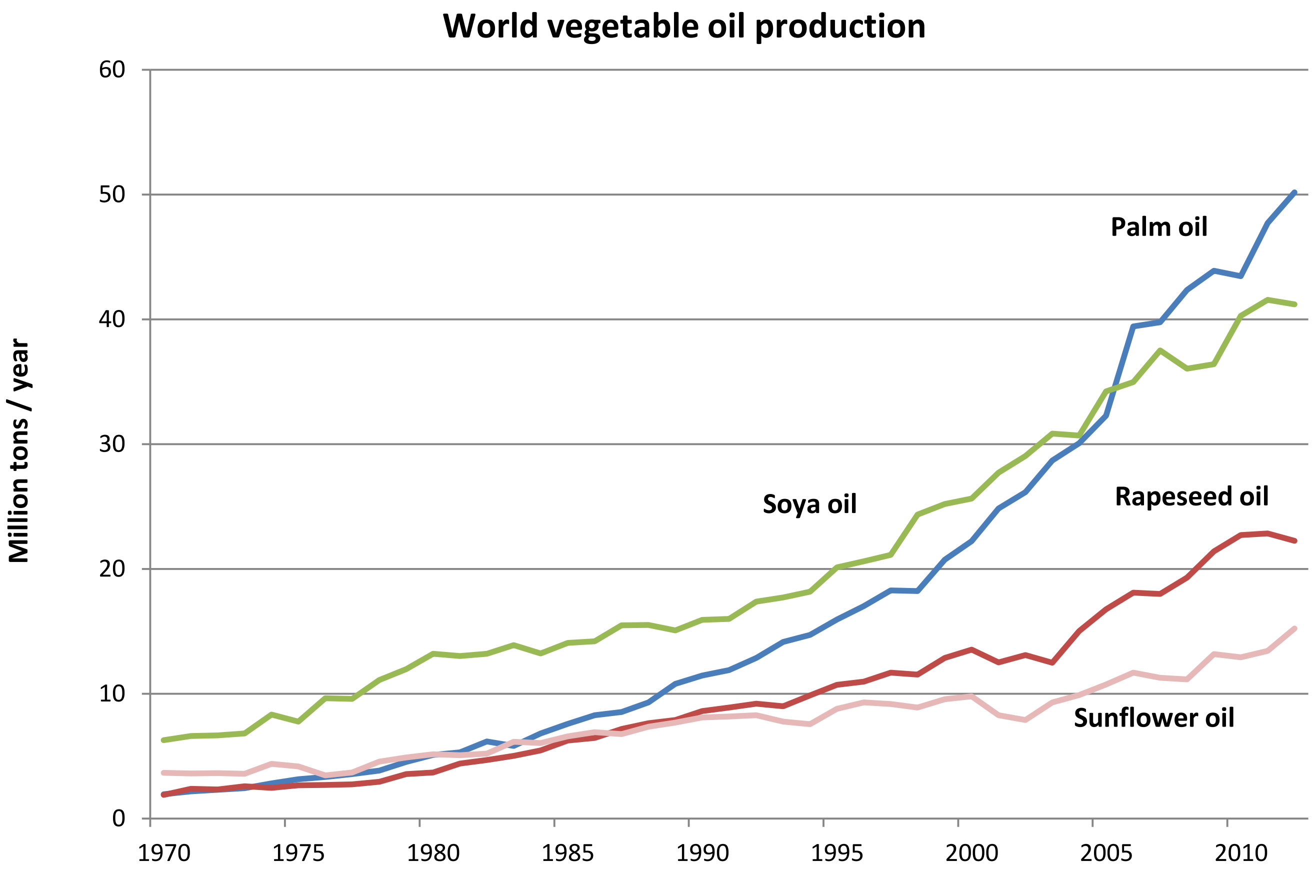
Main failures

- Very slow progress in abiotic stress-resistant breeding (drought, N, P, ..)
- No clearly identified resources for insect resistance (mustard aphid, ..)
- No major improvement of meal/cake quality (low fibre/lignin);
- Poor coordination of ‘reference’ sequencing projects. At one point (2010) 5 ‘reference’ genomes of *B. napus* being generated, two in one city. Crazy.
- Poor data sharing
- Limited progress in genetic engineering/modification
- GMOs banned in Europe

Future challenges

In a World swimming in oil but starving for proteins

with the need to keep oilseed Brassicas more competitive within upcoming economical & environmental constraints


World vegetable oil production
Million tons / year
60
50
40
30
20
10
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Palm oil
Soya oil
Rapeseed oil
Sunflower oil

Plant traits

- Continuous and steady enhancement of seed yield potential
- Improved harvest index
- Seed size for establishment and yield
- shattering-resistance for mechanic harvesting
- To introgress seed size and photo-insensitive traits from Indian *B juncea* gene pool to European one

Plant traits

To reduce input/energy costs

Abiotic stresses

- Increased phosphate use efficiency
- Improved nitrogen use efficiency
- Increased boron use efficiency
- Improved temperature-related stresses tolerance
- Improved drought tolerance

Plant traits

Biotic stresses

- Sclerotinia, clubroot (monogenic & polygenic) resistance
- Broomrape resistance in Europe and India
- Towards a durable disease resistance
- From multiple disease resistances in single Brassica genotypes to multiple stress resistance
- Improved 'tolerance' to insects (architecture, metabolites)

Plant traits

Seed quality

- Increased oil content
- Very low saturated fatty acids
- Greatly increased tocopherol content
- Phytosterols
- Superior meal for feed …. and food
- Better availability and composition of protein
- Yellow seeded varieties
- To introgress double quality, yellow seed color and white rust resistance in *B juncea* from European lines to Indian cultivars without compromising on the yield potential

Genetic & Genomic Resources

- Finished and being-finished genomic sequences for major cultivated species and their progenitor species (A-, B-, and C-genome);
- Genome for $100
- subgenomic substituted *B. napus* materials with novel variations
- High resolution micro-introgression populations
- Hypomethylated populations for reverse epi-genetics
- Methylation maps alongside transcriptome/proteome/metabolome : per tissue/environment
- Physical (BAC) libraries, fine mapping, large SNP arrays, sequence information of specific varieties (extreme or special phenotypes)

Technologies

- HTP sampling
- *In campo* DNA prep
- Large scale NGS applications
- Enhanced high-throughput phenotyping tools for any kind of traits, i.e. stress response (abiotic and biotic), yield components as well as biomass, seed and oil yield; fast, non-destructive screening techniques such as NMR and NIR;
- GWAS bandwagon

Technologies

- Genomic Selection still under development;
- Locus-specific genome editing in methylation deserts
- New cytological methods to visualize structural rearrangements & identify methylation rate and DNA compaction, to localize crossovers
- Use of RNAi's to inhibit or reduce expression of target genes and their enzymes.

New strategies

- To integrate G x E interactions
- To enlarge the genetic diversity
- More ideotype defined traits (modelling, ..): towards predictive biology
- Better hybrid systems & heterotic gene pools ; towards apomictic hybrids?
- Intergeneric hybrids, or even new crops
- New strategies to exploit efficiently the genetic variability of diploid progenitors (synthetic, triploid bridges with a control of crossover location)
- Understanding the structural evolution & functional regulations

New strategies

- Genome editing, epi-editing
- Impact of epigenetic regulations
- Greater understanding of methylome with respect to gene activation
- Reverse epigenetic screening of hypomethylated populations
- Efficient application of highly specific induced mutation techniques
- Tilling associated with HTP methods (large scale candidate genes screening)
- To combine sequencing, mapping, chromosome behaviour and phenotyping
- …….
- But still a demand for field-based plant breeders

Data management

- Coordinated integrated management of expensive trait/population data
- High density genotyping of GxE interaction with a dense and accurate environmental assessment requiring large data storage and data management facilities
- Big data from imaging tools
- Extensive data collections for specific/extreme phenotypes and extended bioinformatical tools
- Agreed standards for gene annotation and naming
- Comparative navigation:

Trait → QTL → genome → functional gene ← genome ← QTL ←Trait

- Alignment of RNA-seq etc with genomes.
- Collation of EMS mutant data related to function

The worldwide scientific production during the last decade

Main items

- Cell biology 1,10%
- Database 2,10%
- Seed yield 7,70%
- Biomass 4,30%
- Plant development 8,10%
- Dwarf 0,90%
- Meal quality 9,40%
- Oil quality 20,80%
- Feed 7,10%
- Disease resistance 18,60%
- Abiotic stress 18,70%
- Herbicides 6,50%
- Pest resistance 5,40%

Diversity 14,10%
Epigenetic 0,70%
Double haploid 6,60%
Phenotype 9,20%
Transgenic 31,70%
Hybrid 19,10%
Cytoplasm 4,90%
GWA 9,70%
Genome sequence 18,50%
Genome organization 0,90%
Breeding methodology 12,20%

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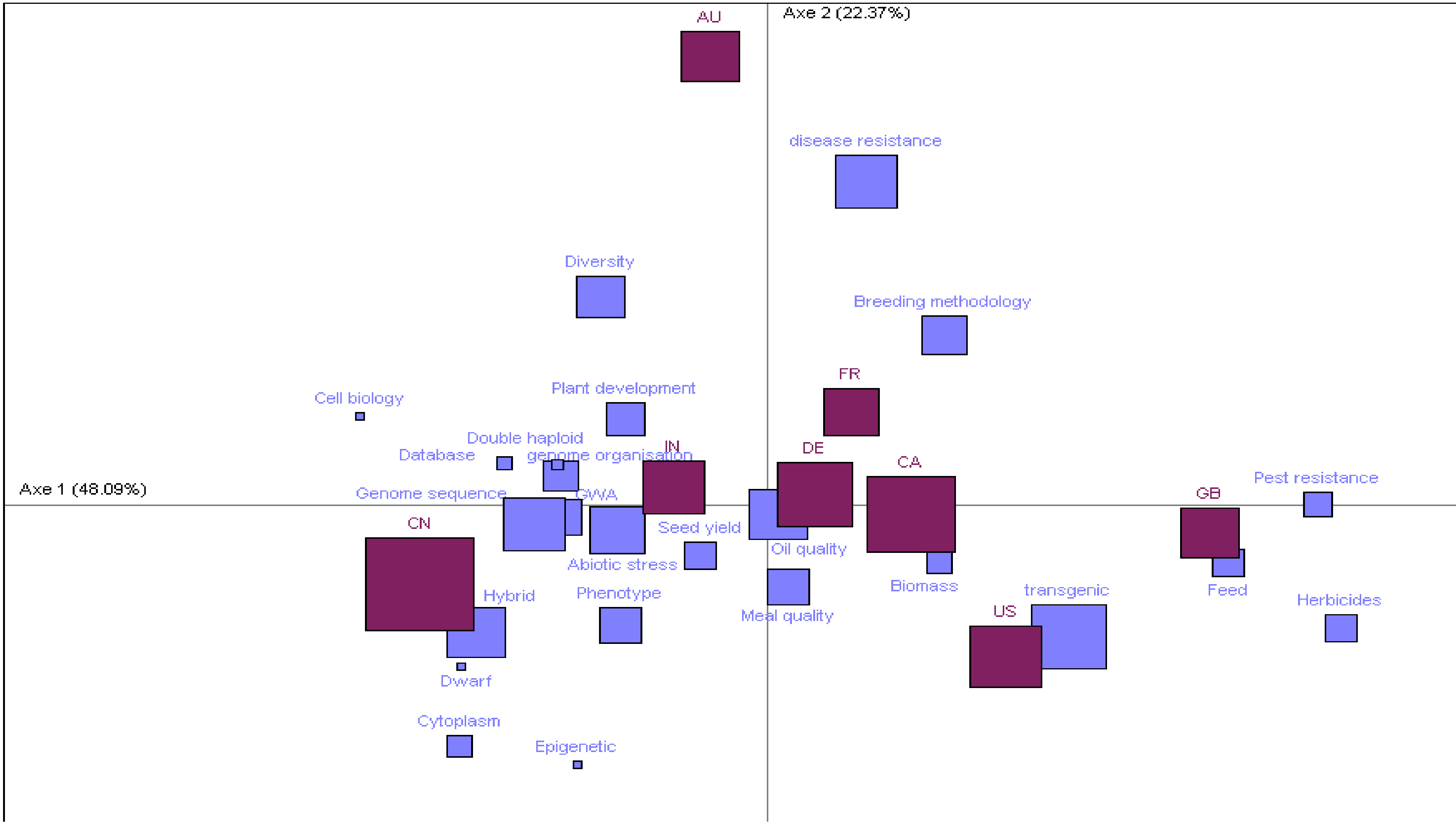
Axe 2 (22.37%)
Axe 1 (48.09%)
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disease resistance
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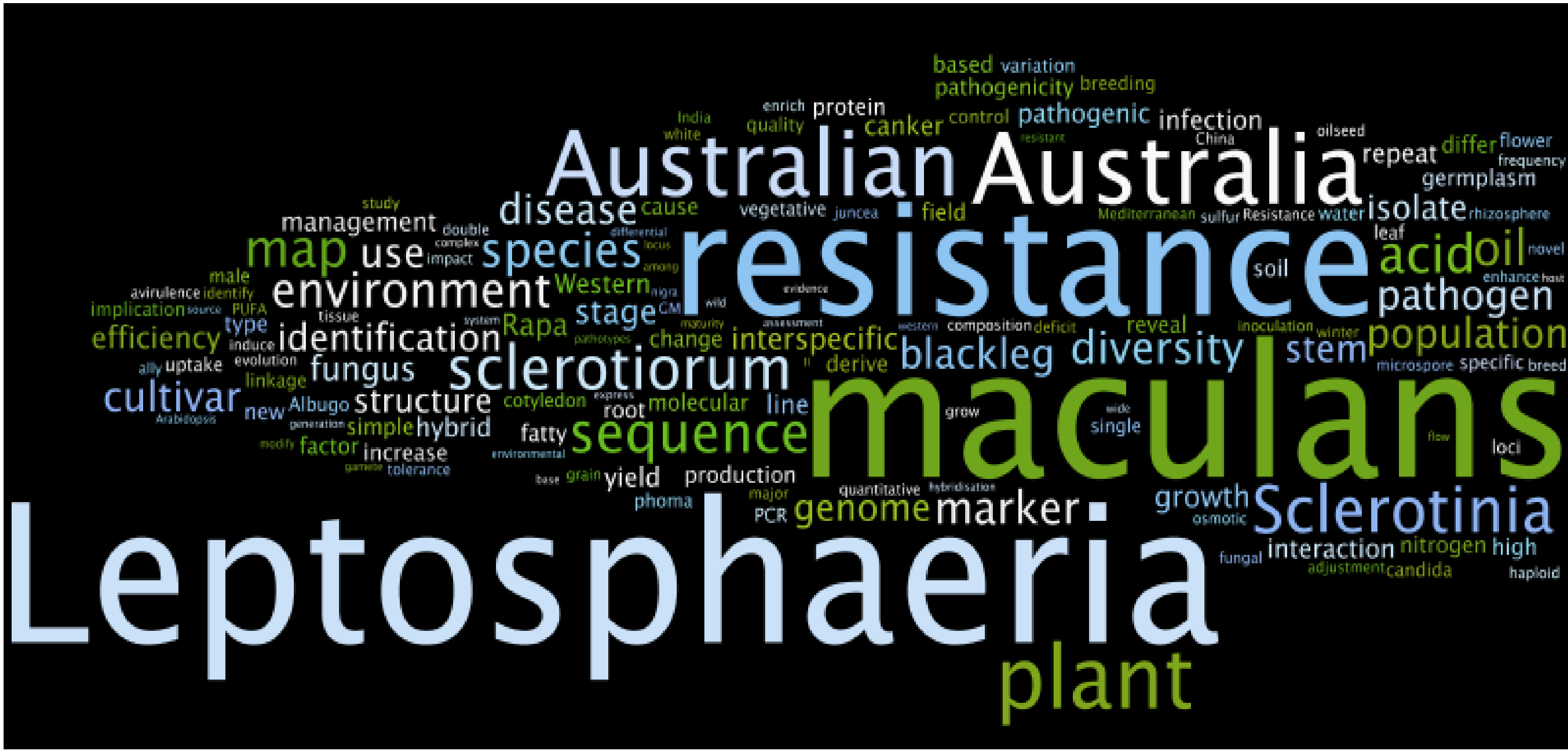
In Australia



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Main lacks

- Vision from partners
- International organization for sharing open resources
- Germplasms with desired traits, such as sclerotinia resistance, high efficient nutrition utilization
- Research and development in the field of protein content and composition
- Limited activities on factors affecting roots functioning
- Lack of visibility on non food use of oilseed Brassica oil other than biofuel
- Access to genomic resources for B-Genome
- **Funding**

Main constraints

- Amphiploidy of *B napus*, *B juncea* and *B carinata*
- Unstable crop productivity
- High cost of phenotyping compared to main other field crops
- Limited support for research and development in oil and protein crops including oilseed rape
- Limited exchange of research materials among the researchers
- Small farming size would slow down the rapid adoption of new technologies such as mechanic harvesting
- **Time**

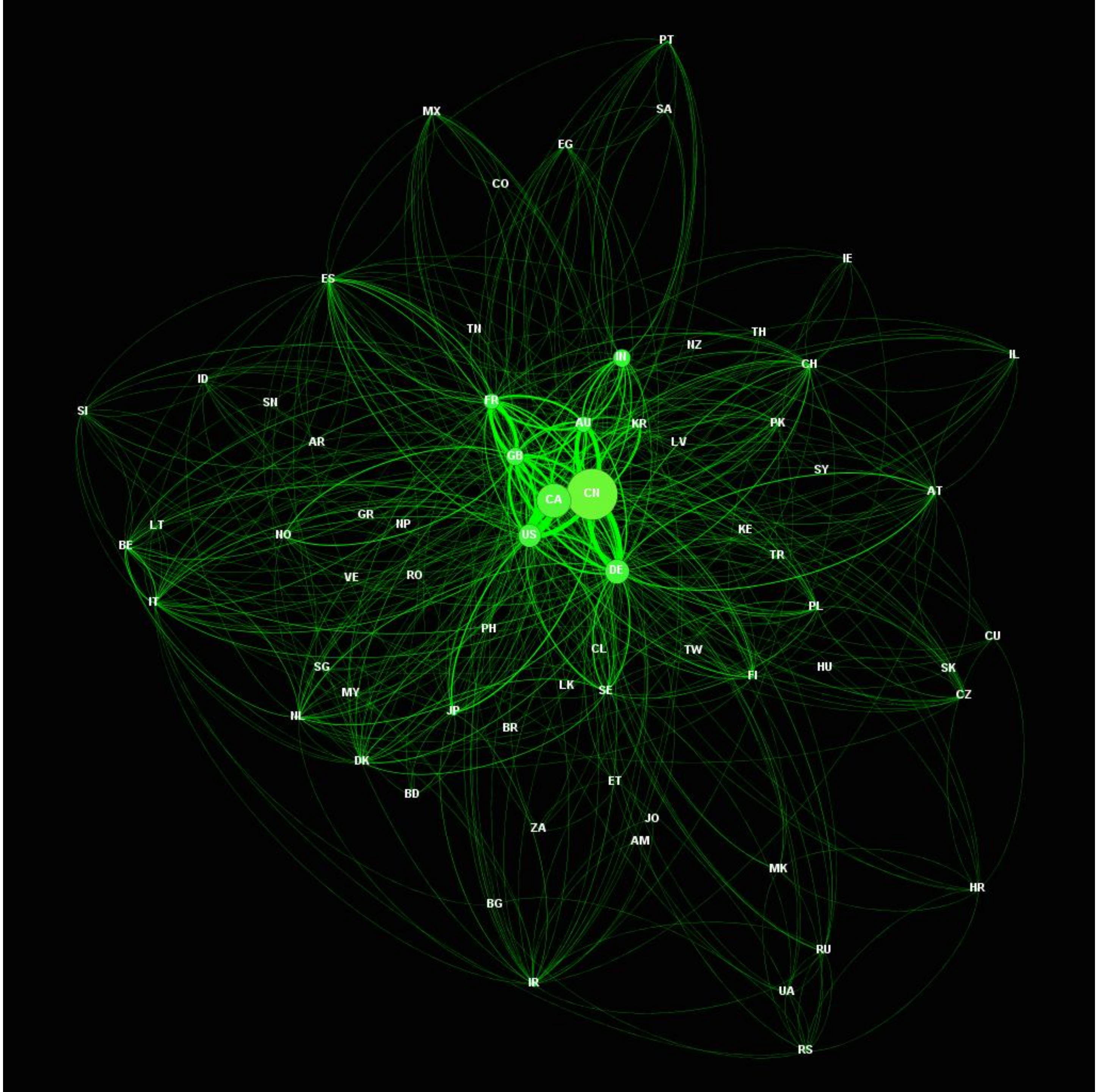
Main uncertainties

- Funding
- Effect of climate change on territories
- The future of oilseed rape production in Europe is uncertain, because of opposition by environmentalists, bad reputation in the context of climate change (greenhouse gas emissions, indirect land use change - iLUC)
- Duration of biofuel versus other sources of energy
- Future impact of other non food uses of oilseed Brassica oil remains unclear
- Threat in the chemical use against pests
- Competitiveness of oilseed rape versus other crops where the crop exist
- International prices

Towards more fruitful international collaborations?

Do we need to stimulate international collaborations?

- Challenges are tremendously ambitious
- Breeding targets are too diverse to be addressed by only one country
- Difficulties are encountered in funding academic research
- Breeding companies are now shopping around research groups at the international scale to meet their needs
- There is a common need to improve competitiveness of oilseed Brassicas in all the countries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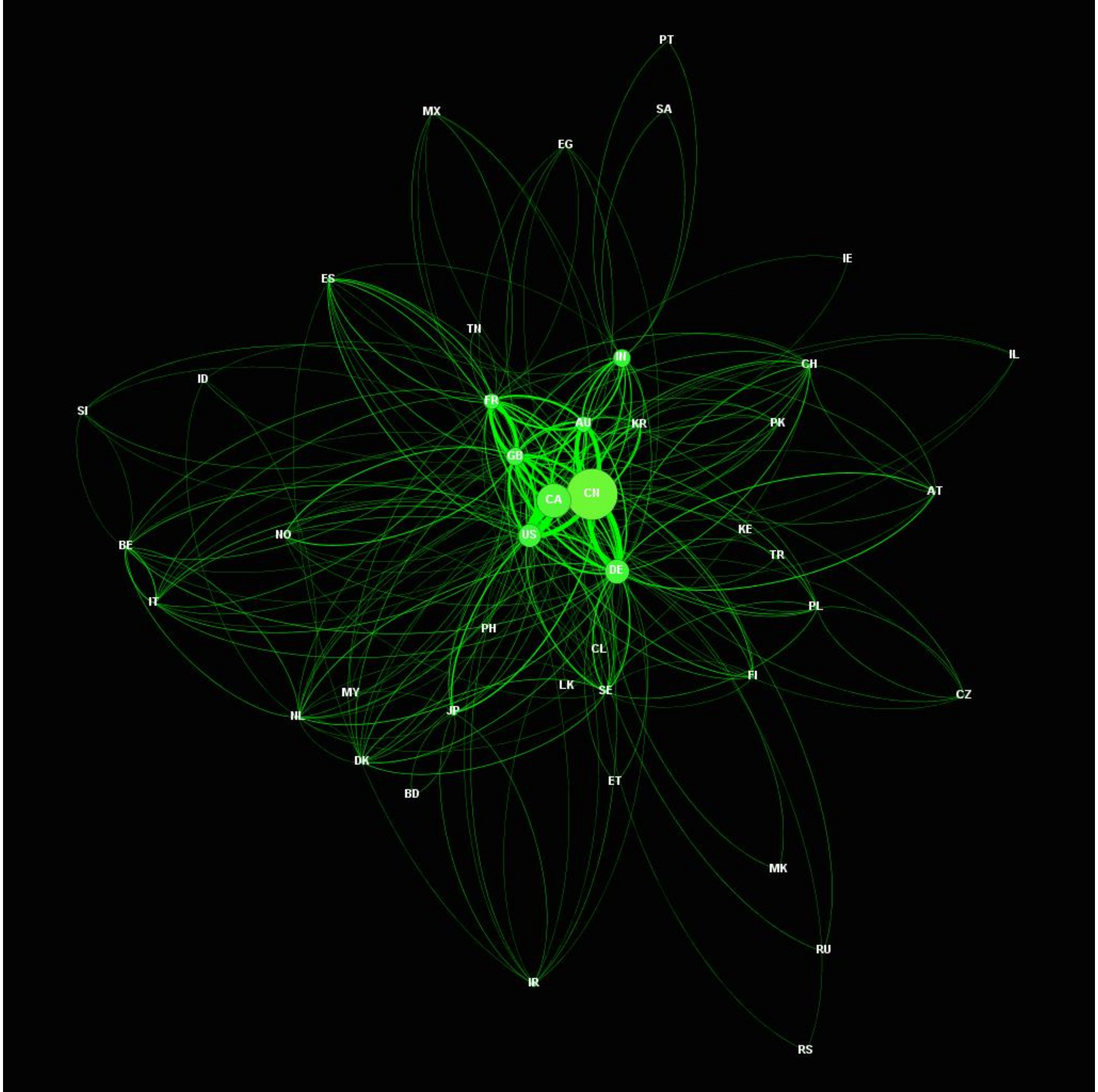
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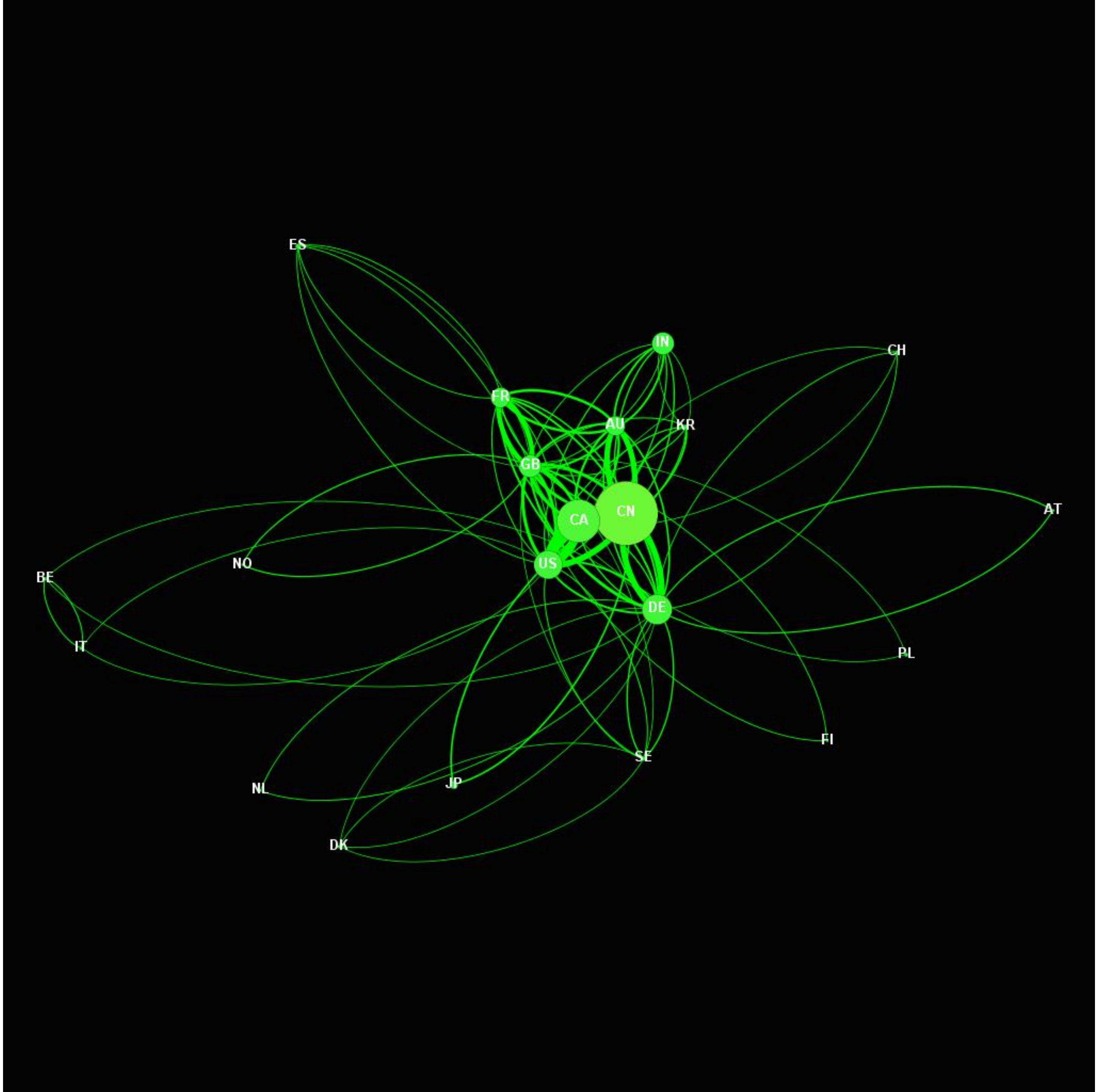
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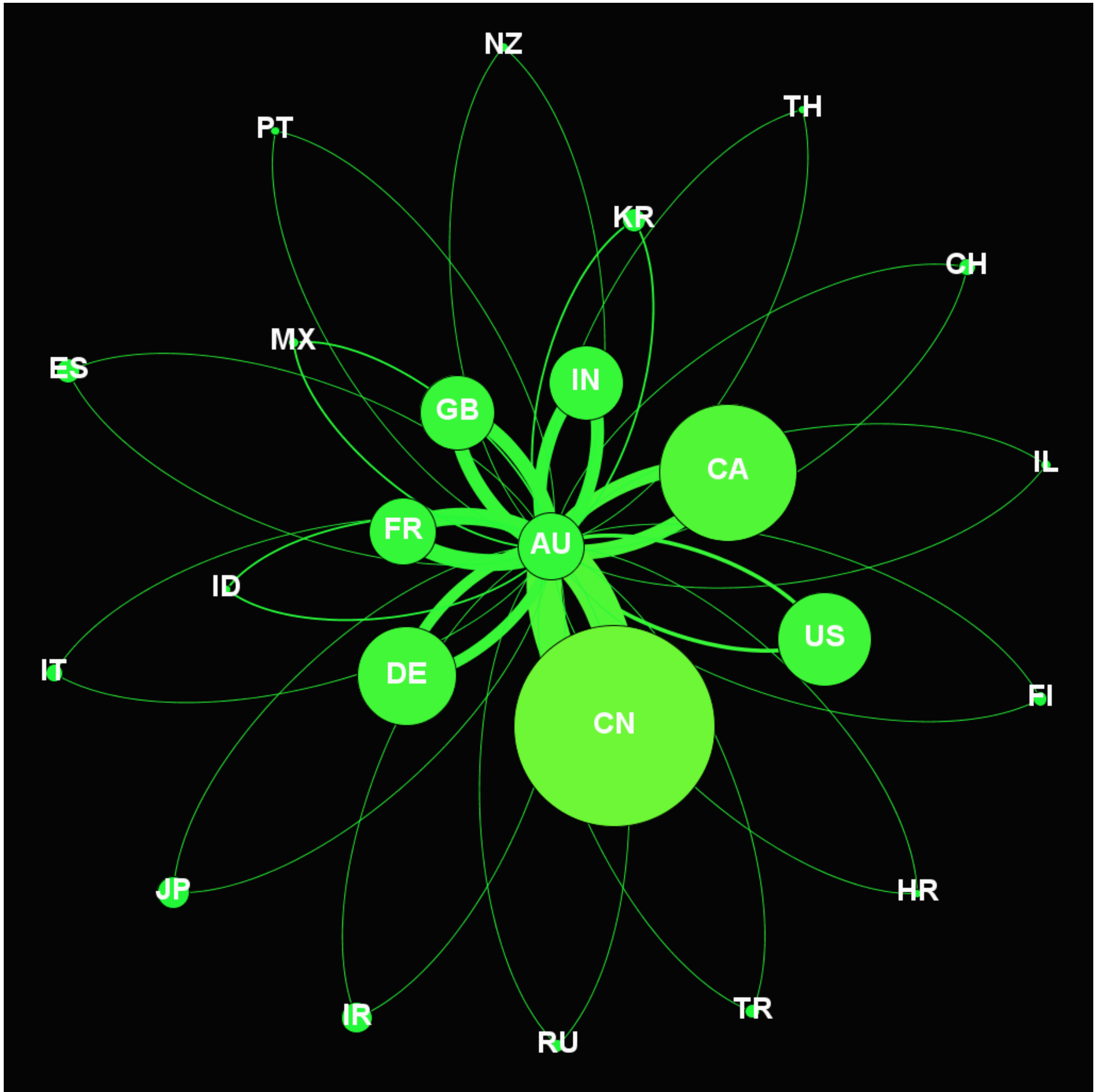

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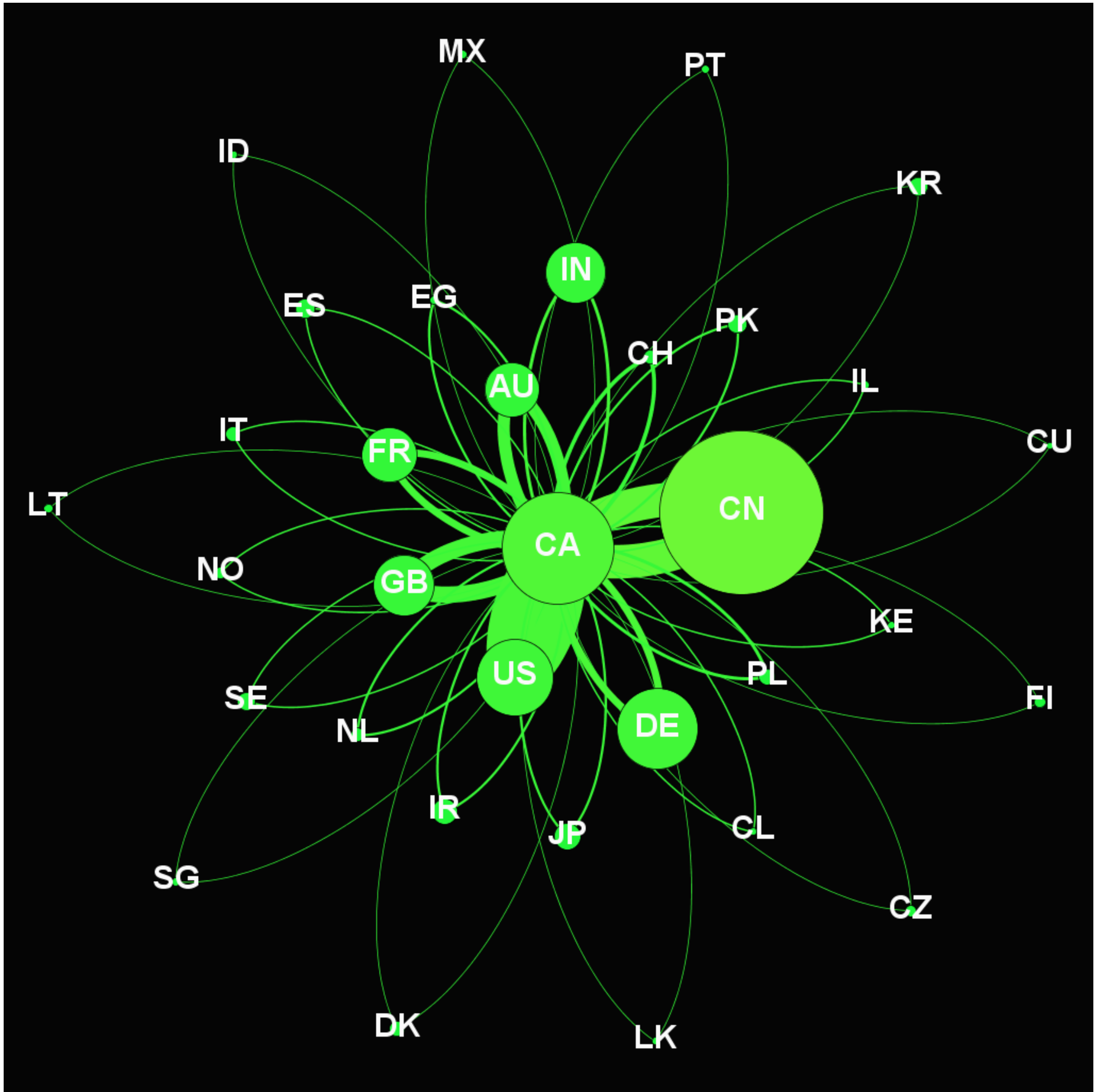

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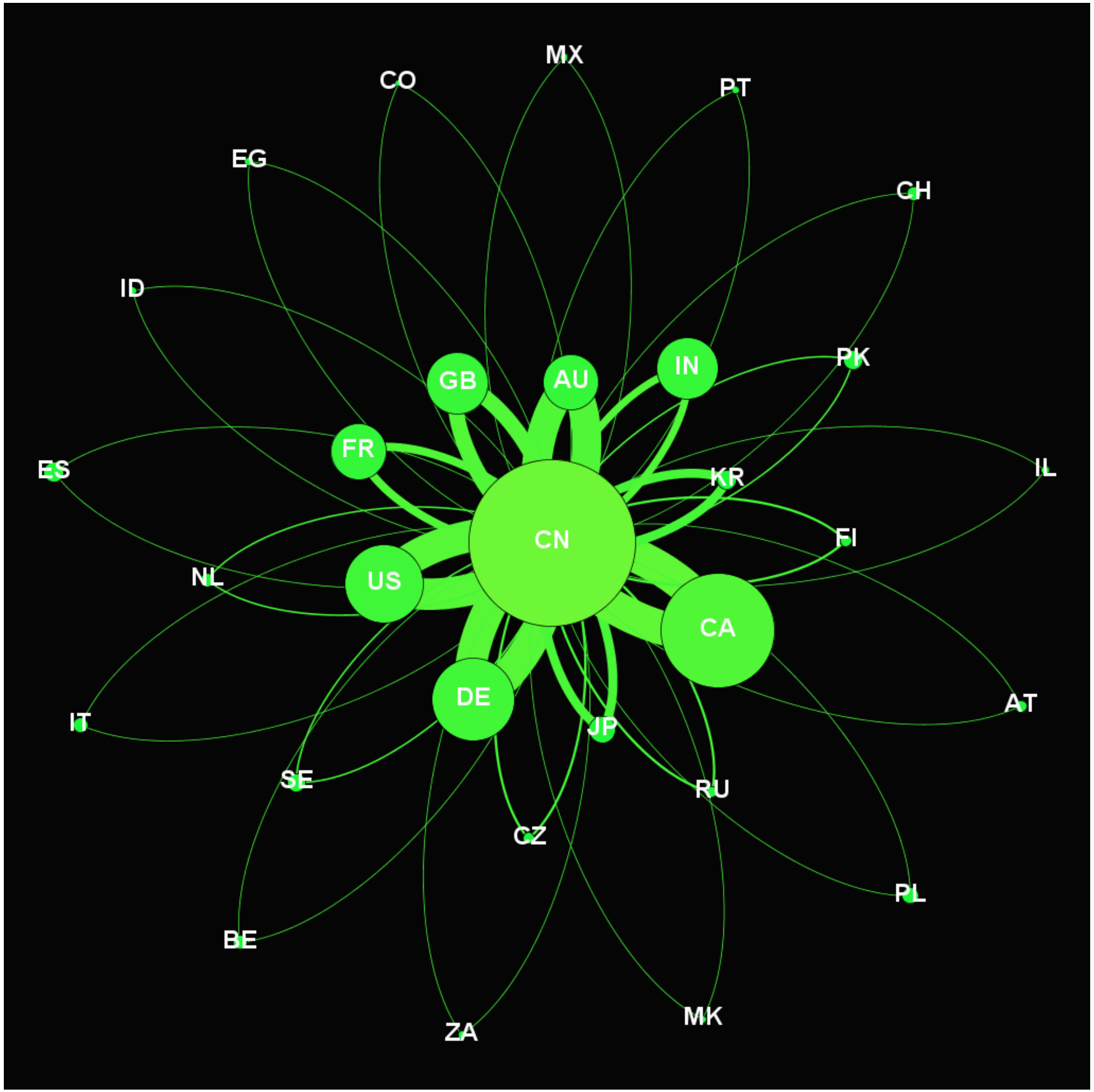
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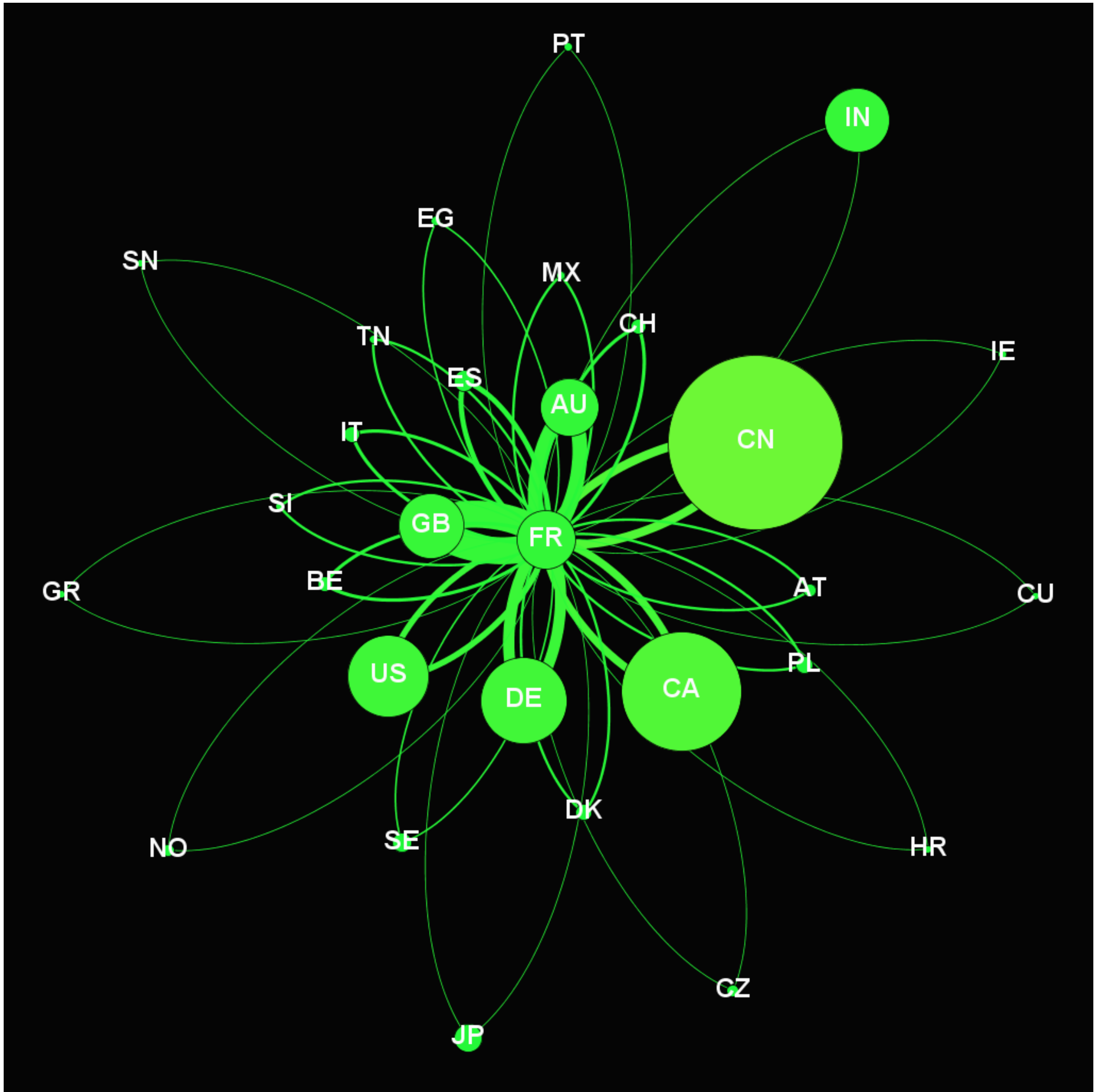

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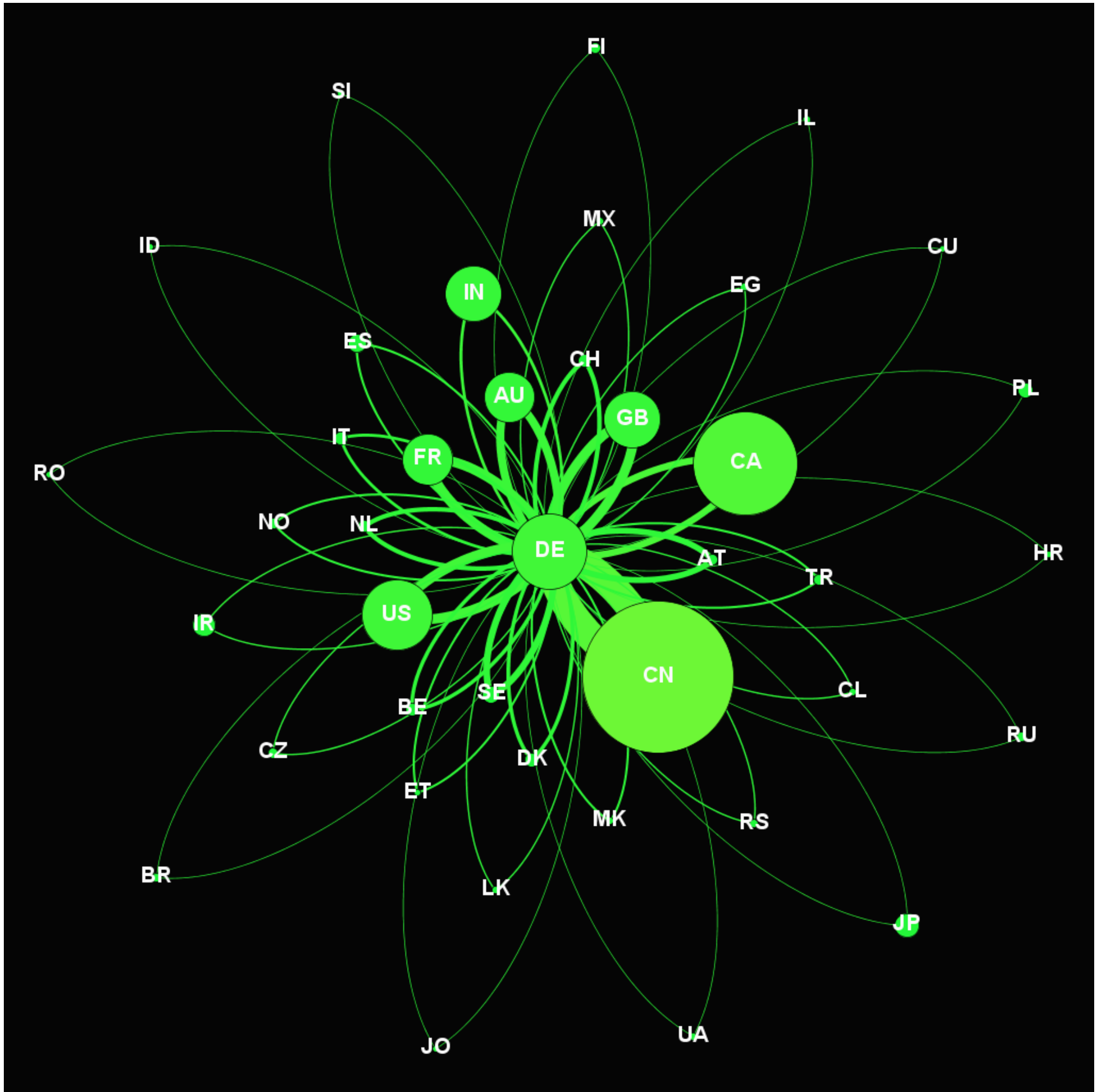
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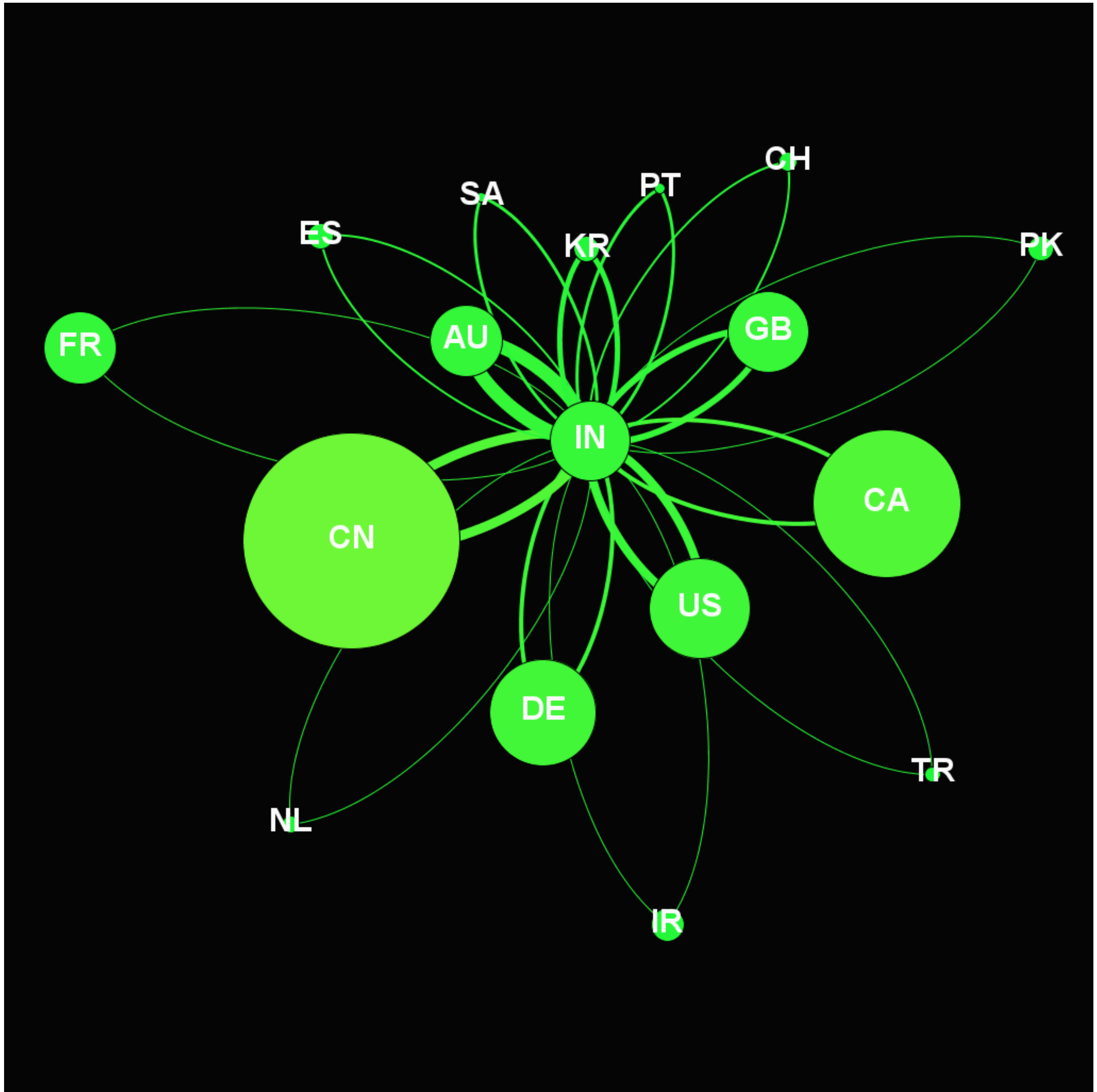

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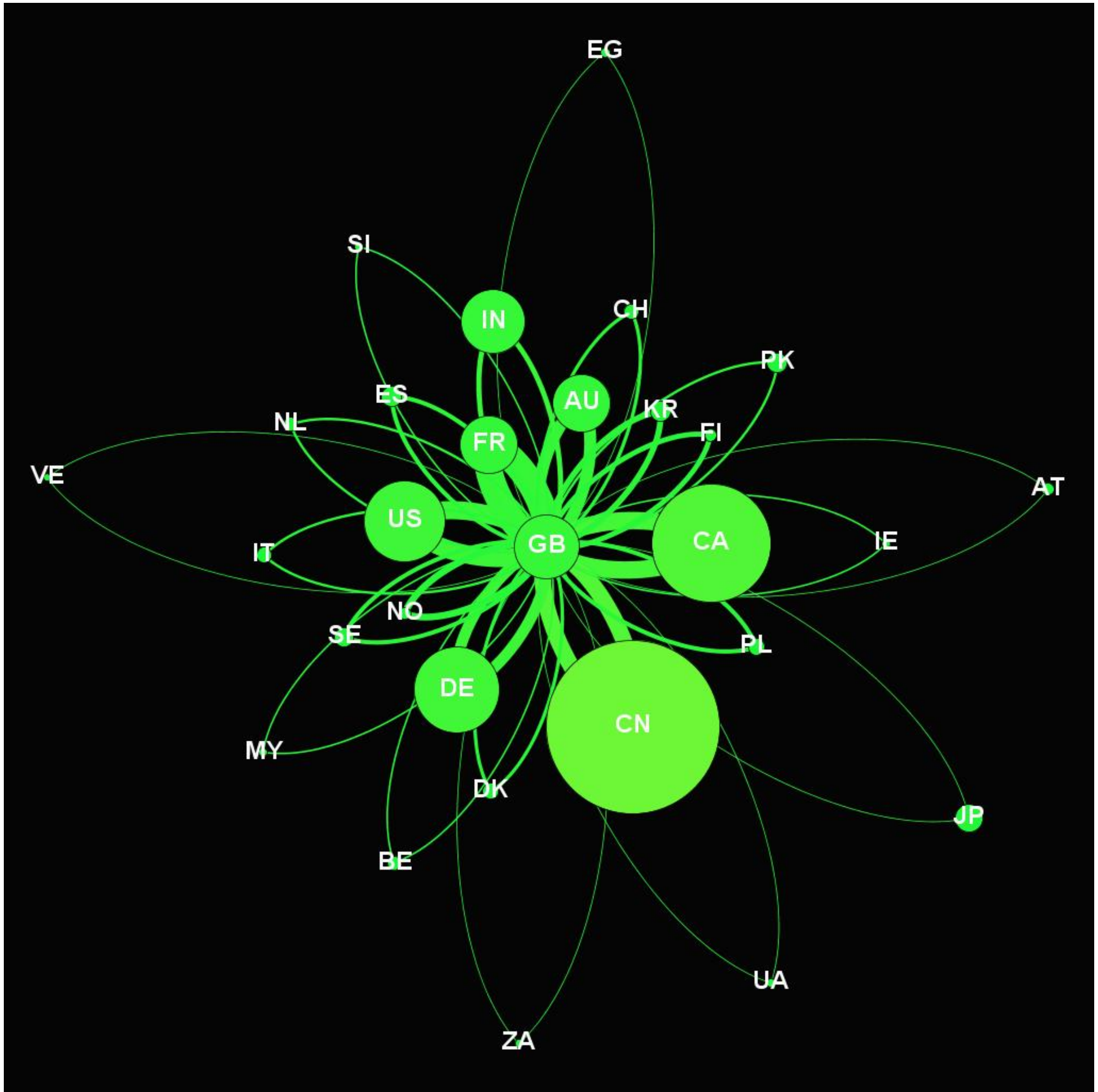
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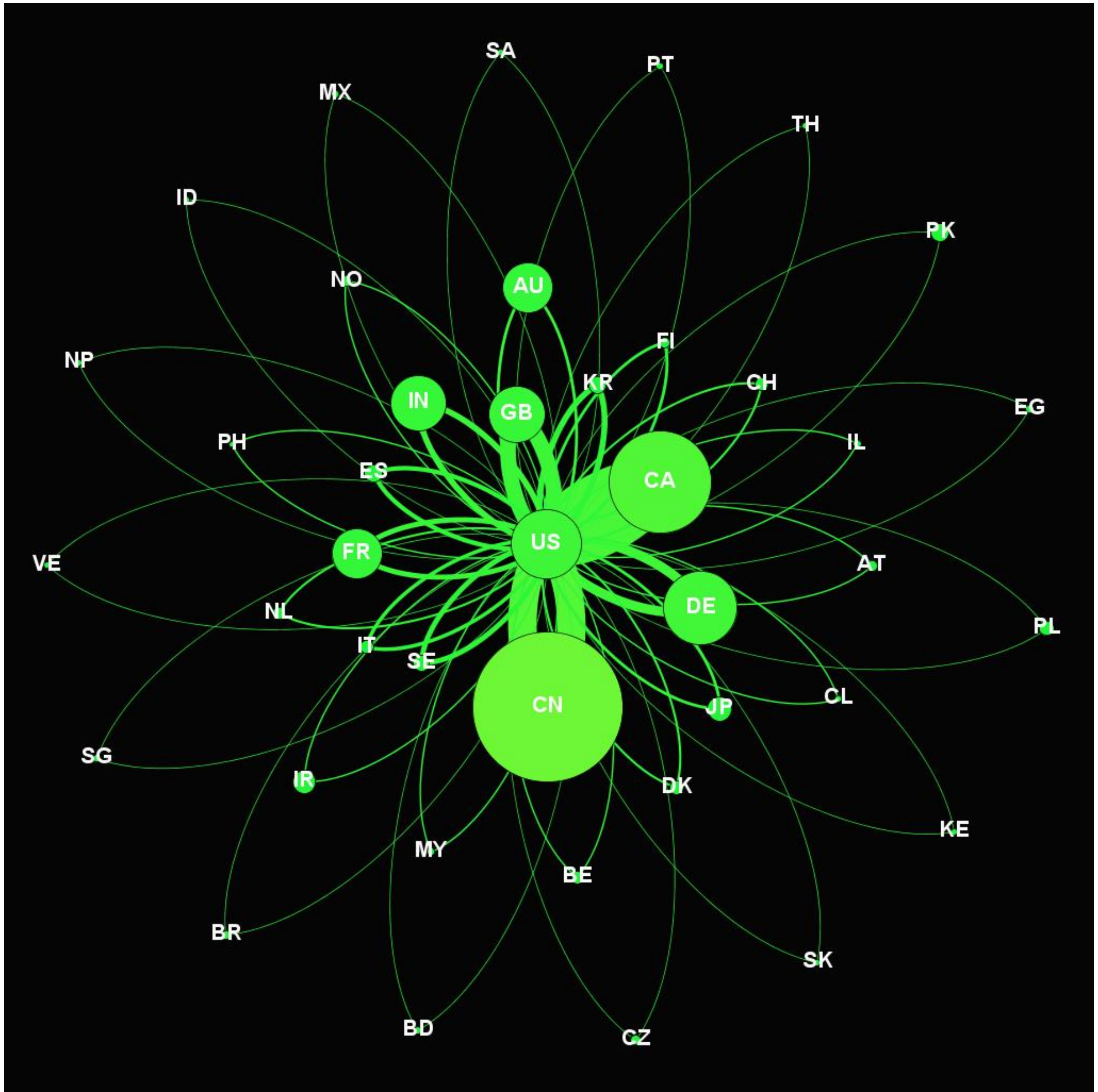
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Main international collaborations during the last 10 years

- So academic exchange programs with international institutions are available in many major research institutions
- **But** tend to be lab to lab for eg RNA-seq of diversity, use of populations …. Individual collaborations between Chinese breeding institutes/universities and western seed companies and/or research institutions.

Main international initiatives to propose to set-up

- A Consortium for genetic and genomic resources
- Establishment and assessment of core germplasm pools in major growth regions/species
- Functional genomics tools for polyploid species
- Pest resistance
- Root system

Main international initiatives to propose to set-up

- Molecular breeding strategies for Brassica genetic improvement
- International initiative and joint research to further promote and develop oilseed rape as one of the most promising and prospective oil and Protein crops and essential leaf crop in European agriculture is seriously needed
- A single Brassica Information System for Integration of phenotyping, genotyping, sequencing, transcriptomic, metabolomic, … public data
- *Low level industry sponsorship of brassica.info would help for data curation*

Brakes & Levers

- **Brakes**
  - A too much national vision
  - Partial freedom to operate at an international level?
  - Competition between groups and countries
  - Time from scientists
  - Difficulties in finding financial supports for international projects

"My filling is that international collaborations are too weak between the big producing countries like Canada, France, Germany, China especially on genetic mapping and gene expression, on genetic diversity evaluation and creation etc..due to competitions between teams and countries"

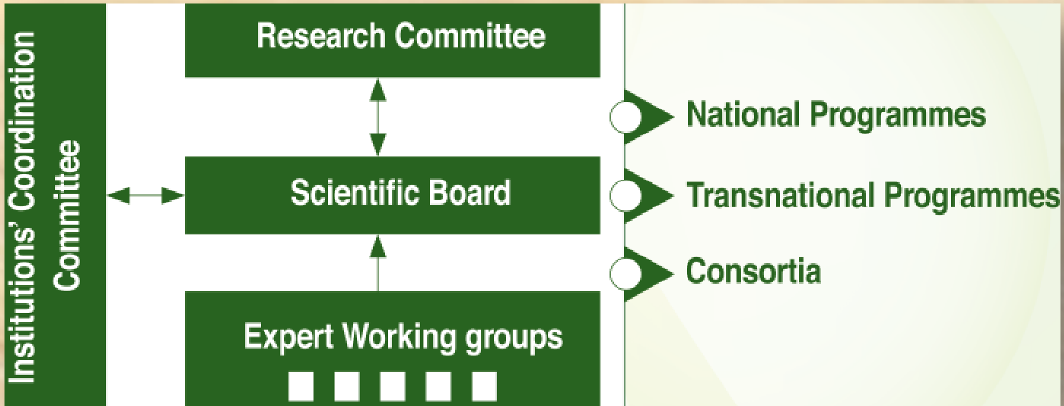
Brakes & Levers

- **Levers/dangers**
  - Quality of individual human relationships
  - Any kind of international consortium or collaboration strengthening would be good *because giant private group are in the way of extending their domination on genetic tools and sources and agronomic advises in order to integrate all the agriculture chain.* Strong public research is necessary to allow new actors to play a role in the brassica world, to make possible some collective or public choices in different alternative ways and to avoid the confiscation of the biological resources and tools.
  - In addition, do not forget that brassicas are not major crops compared to majors like soybean, maize, wheat, rice and palm. Stronger collaborations are needed to keep existing, progressing and attracting investments and researchers.

How to stimulate international collaborations?

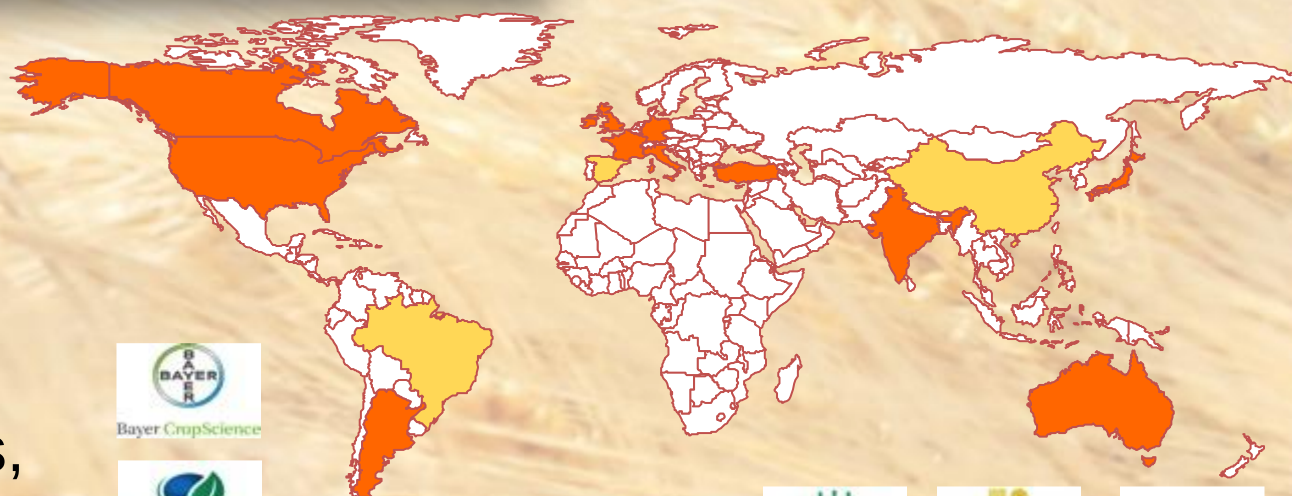
Towards an International Initiative on Oilseed Brassica Improvement?

Governance



Members

15 countries,
9 private companies,
2 international organisations



Towards an International Initiative on Oilseed Brassica Improvement?

- A necessity to increase international coordination and investments
  - First step: « To elaborate a common document on our international vision for oilseed Brassica improvement »
  - Second step: “to establish an integrated information system providing access to information”: *ontologies, … (www.cropontology.org)*

Towards an International Initiative on oilseed Brassica Improvement?

- **Current levers**
  - GCIRC: International Consultative Group of Research on Rapeseed (www.gcirc.org) and mustard
  - MBGP: Multinational Brassica Genome Project (www.brassica.info)
  - ???

All the data from the survey and the bibliometric study will be publically available through a link with the www.Brassica.info web site

The CGW was in Rennes, France in 1998

French application

to organise the 21th CGW

in July 2018

in France, Brittany, St Malo


http://www.pgl-congres.com
BRASSICA 2018
Le Grand Large, Saint-Malo’s Convention Cent

Thank You for a very fruitful time within the Brassica community

Towards an e-science World for more creativity & imagination and more opportunities

DESTINATION SAINT-MALO

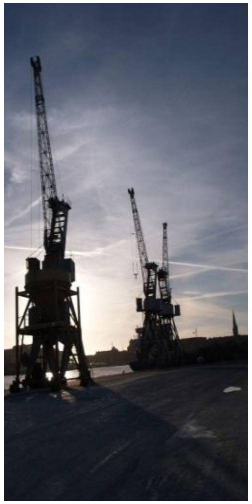
Brittany: a region renowned for the beauty of its amazing landscapes, the wealth of its Historical heritage and the strong temperament of its inhabitants.

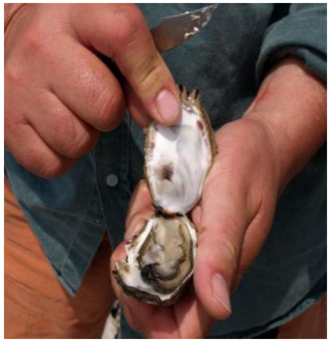
The Côte d’Emeraude: an authentic and well preserved sea-side, so called because of the indescribable emerald blue of the sea.

Saint Malo: a proud and independent Corsair City which name is forever associated with the literature and romance of the sea.

SAINT-MALO BRIEFLY:

- 50,000 inhabitants all year round and up to 200,000 in summer time !
- A technically advanced research-and-development centre with ties to marine biotechnologies
- A healthy economy with 5,300 businesses, including 2,400 shops, 900 industrial enterprises, and 2,000 services businesses.
- A commercial port among France's largest ports (1,85 M tons' flow/year)
- A harbour where more than a million annual passengers arrive or depart each year





FACING THE SEA, LE GRAND LARGE CONVENTION CENTER

- Right in the heart of the town and of the hotel area
- 7 000 m2 on 3 levels
- a 25-year expertise
- 130 to 150 events per year
- 120 000 delegates or visitors per year
- 200 days of occupancy
- 45 M € in spin-off revenues

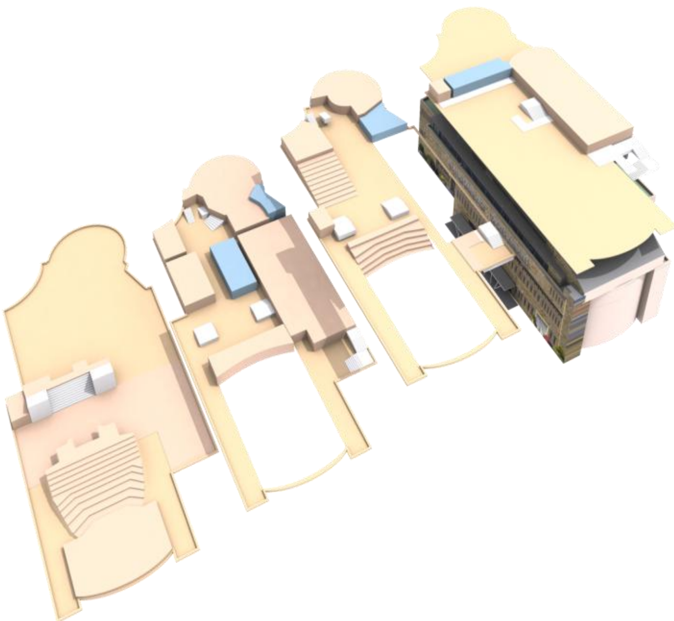
LOCATED AT THE HEART OF THE CITY

Next to the ramparts of the old city and facing the beach, 15 minutes walking from the train station

RIGHT IN THE MIDDLE OF THE HOTEL AREA

Saint Malo has a hotel infrastructure of 2,450 rooms, which are to be found mainly intra-muros and on the sea front,
900 of which are within walking distance of the Grand Large.

ROOMS WITH MODULAR DESIGN AND A SEA VIEW



- 2 auditoriums:

  - Chateaubriand auditorium, modular from 400 to 1,030 seats

  - Maupertuis amphitheatre, 200 seats

- 2 rotundas with views over the sea and the ramparts of the old town
- 2 panoramic multi-purpose spaces with sea view
- 14 committee rooms
- 2 independent reception areas
- 4,500 m2 of exhibition space.

FOR PLENARY SESSIONS

Chateaubriand Auditorium

400 seats at the orchestra up to 1,030 seats with the 3 balconies

FOR PARALLEL SESSIONS

committee rooms that can be adaptated to your needs

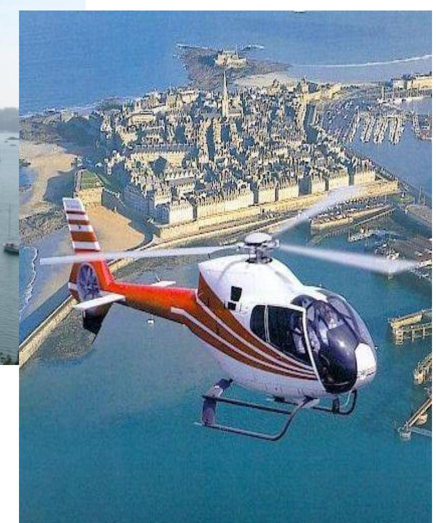
FOR POSTERS, SPONSORS' EXHIBITION, COFFEE BREAKS & LUNCH-BUFFETS

A 1,100 m2
exhibition area
with a sea view

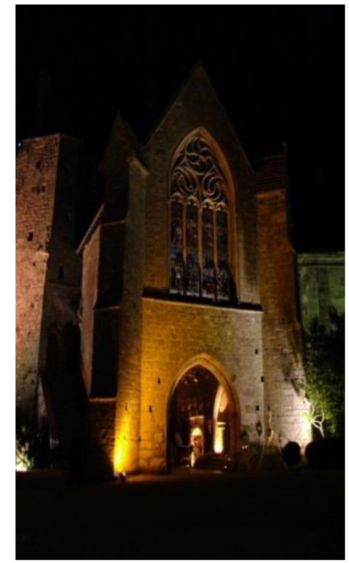
FOR THE GALA DINNER

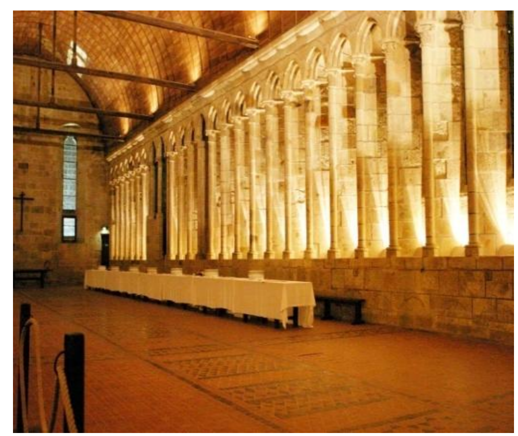
A Rotunda with a view onto the sea and the ramparts of the old city

A WELL-PRESERVED ENVIRONMENT FOR UNFORGETTABLE EXCURSIONS

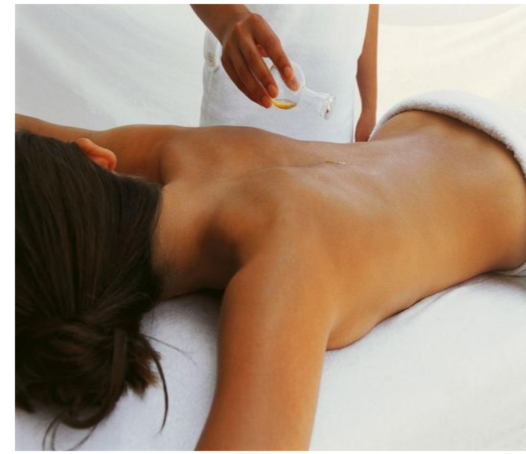


AMAZING AND AUTHENTIC VENUES FOR MEMORABLE EVENINGS





LEISURE AND SPORT ACTIVITIES FOR ACCOMPANYING PEOPLE



SPEEDY AND EFFICIENT TRANSPORT SYSTEMS

Arriving by plane

⇨**420 km from Paris CDG Airport:**

- 3.5 hours by motorways A11/A13 (through Rennes) or A13/A84 (through Caen)

⇨**200 km from Nantes Airport:**

- 50 destinations served with direct flights
- 1st airport of Western France, ISO 9001
- Nantes Airport elected best European airport (AWARD 2011/2012)
- All European capital Cities in less than 2 hours

⇨**70 km from Rennes Airport:**

- 80 regular connections with major French and European Cities
- 3 daily flights from Roissy CDG, 1 hour from Paris

⇨**13 km from Dinard / Pleurtuit Airport:**

- Low cost daily flights from and to London and Nottingham

Arriving by train

⇨ **From Paris town center** (Montparnasse railway station): Direct TGV train (high speed train) to Saint Malo in 2h56.

⇨ **From Roissy airport:** TGV train to Rennes (three-hour trip, 3 trains a day) and then connection to St Malo

⇨ **From Orly airport**: Air France bus shuttle to Montparnasse railway station (every30 min. from 06:00 am to 11 pm). and then TGV to Saint Malo or Rennes.

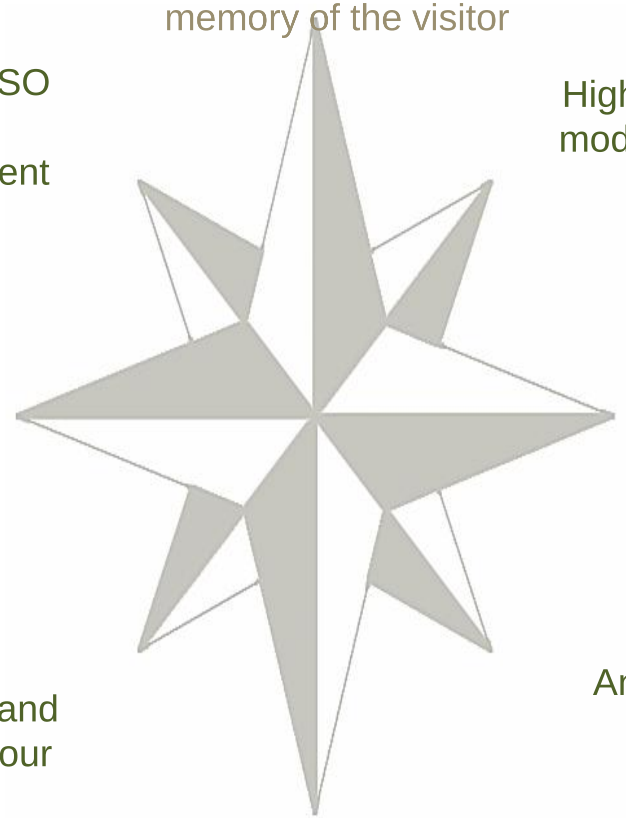
LA PLUS BELLE FAÇON DE RÉUSSIR VOS ÉVENEMENTS

8 REASONS FOR CHOOSING SAINT MALO AND « LE GRAND LARGE »

A great historical heritage and beautiful landscapes that will remain engraved on the imagination and the memory of the visitor

A double-certification ISO 9001 and Quality & sustainable Development

High-Tech equipments and modular rooms that can suit any specific needs



Hotels, restaurants, shops, beaches and train station close by the « Grand Large »

A great housing capacity with 2,450 rooms, 900 of which being at a walking distance of the Grand Large

A professionnal team combining motivation and enthusiasm to make your event a success

An twenty five-year experience in organising scientific conferences

Speedy and efficient transport systems to reach Saint-Malo

2h15 in 2017

We hope to see you soon in Saint Malo for the Crucifere Genetics Wokshop!....

Quality & sustainable development

LE GRAND LARGE - PALAIS DES CONGRES DE SAINT MALO

ai Duguay Trouin – BP 409 35407 SAINT MALO CEDEX - FRANC

Tel. : 33.(0)2.99.20.60.20 Website : www.legrandlarge-congres.com

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