The Montreal Neurological Institute in 1934

Towards a global brain imaging network

AC Evans, Ph.D.
Montreal Neurological Institute

Global Health Conference
April 26th, 2010

Mapping the Brain with Neuroimaging

Clinical Expertise

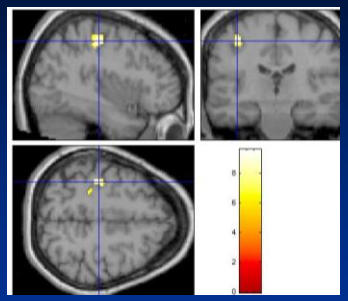
Physical Sciences

Basic Neuroscience

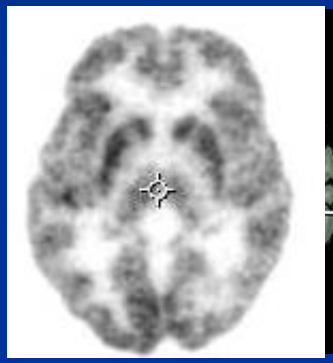
Imaging Technology

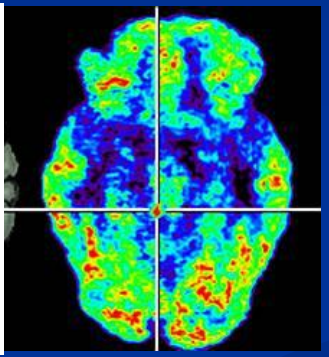
High-performance Computational Infrastructure

Scanner Infrastructure



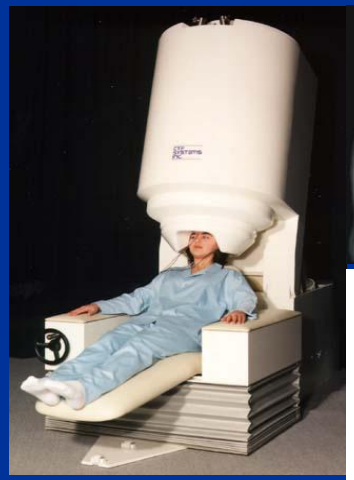
MRI

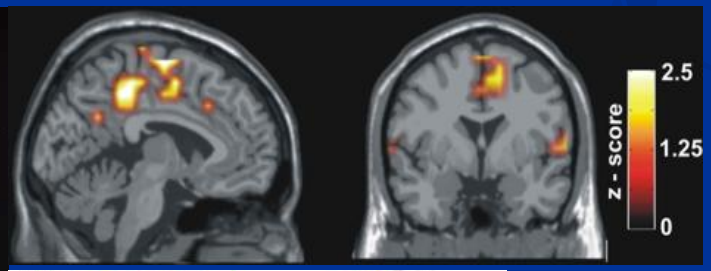


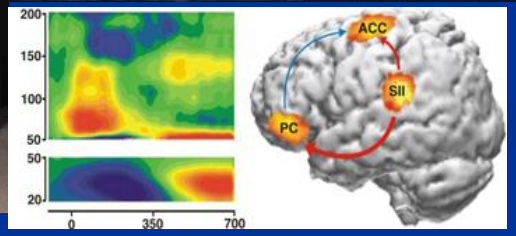


PET

Computing

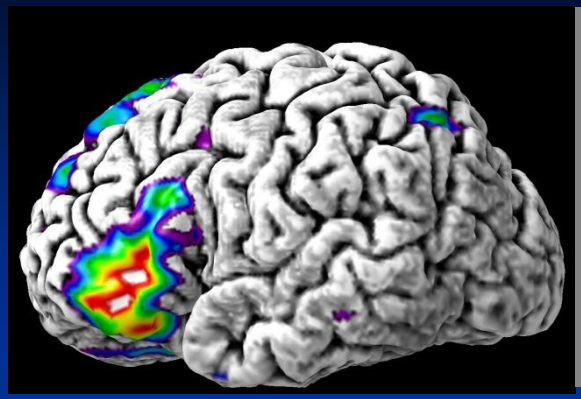




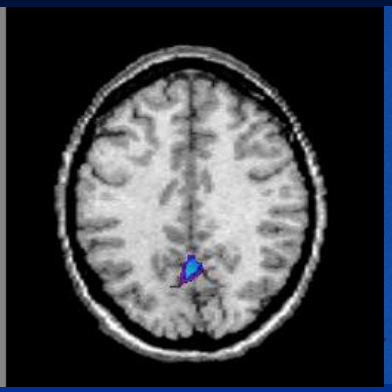


MEG

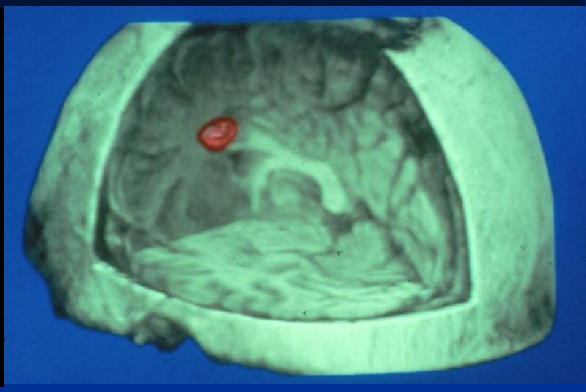
fMRI Activation Studies



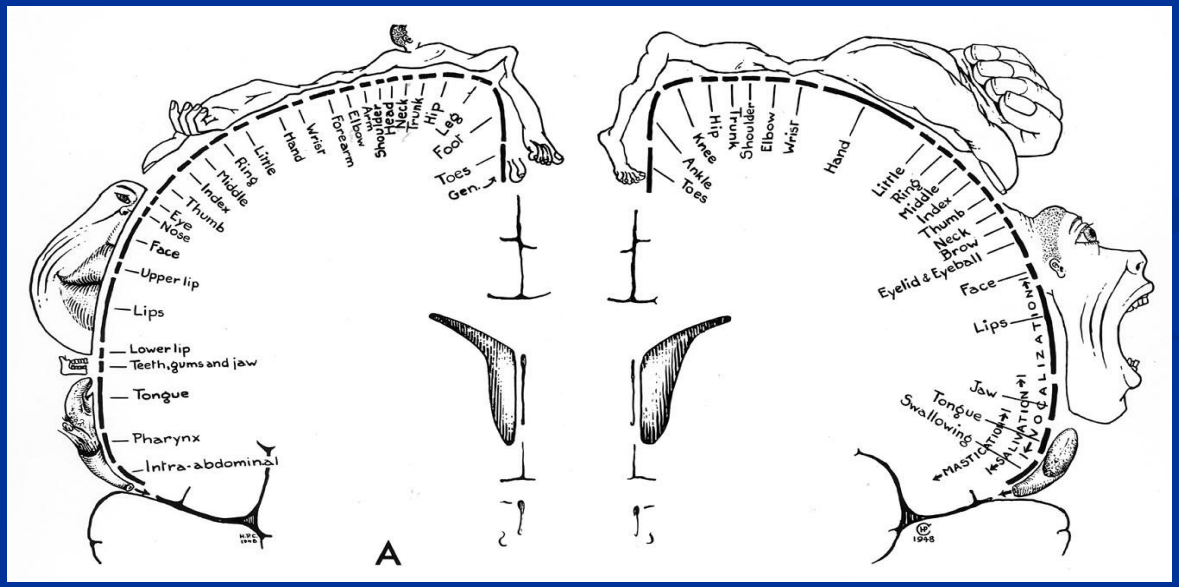
Language



Vision



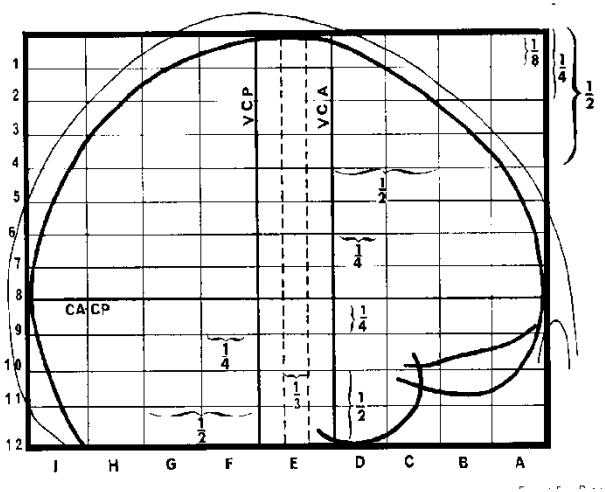
Pain

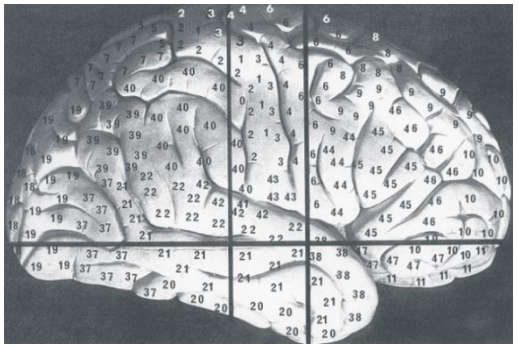


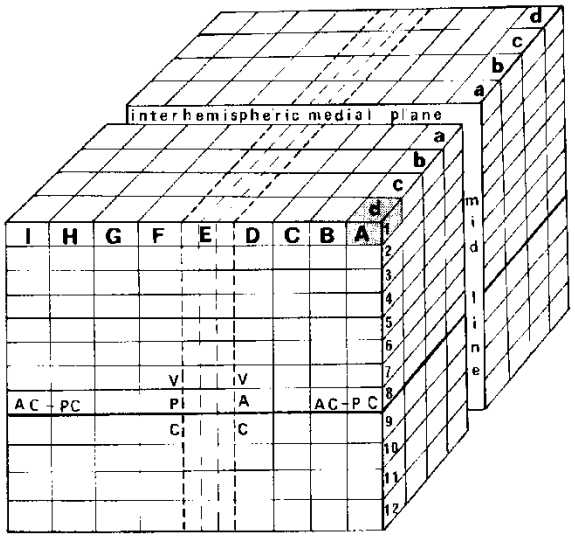
Sensory homunculus

Motor homunculus

Stereotaxic Space







J Talairach & P Tournoux
"Co-planar stereotaxic atlas
of the human brain"
ed: Georg Thieme, 1988

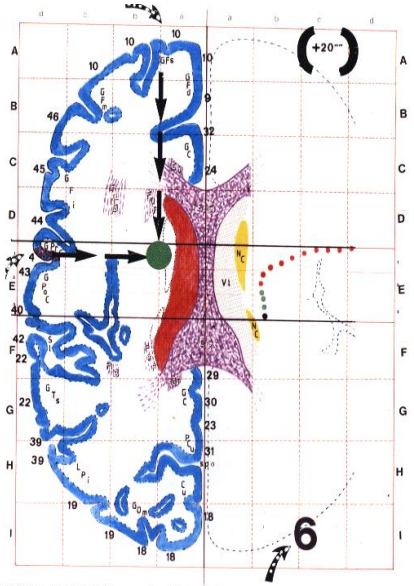
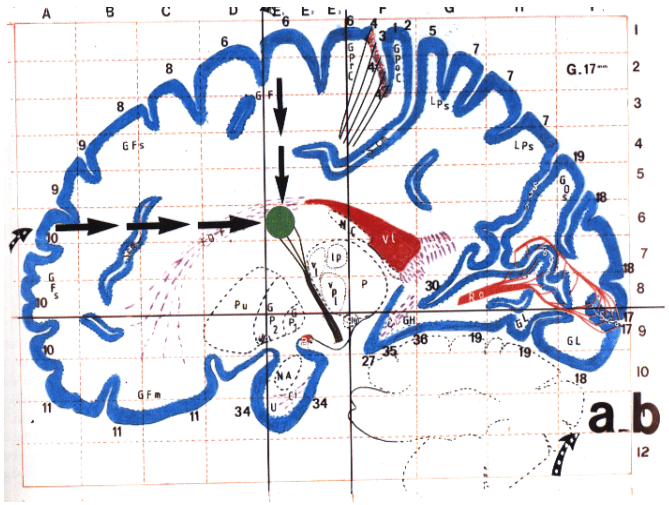


Figure 19 Horizontal Atlas section. Section of the Atlas 20 mm from the CA-CP line.



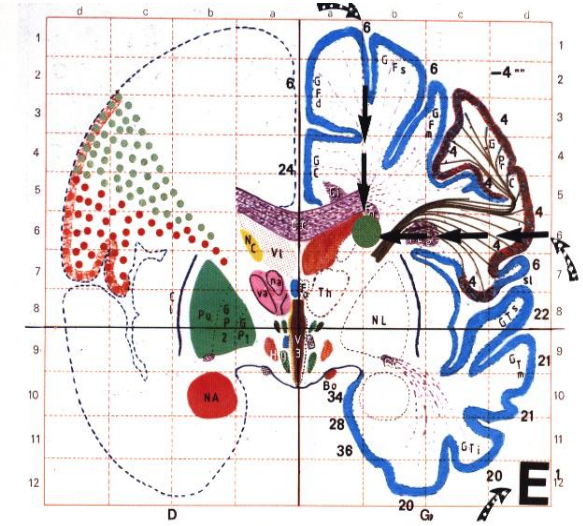
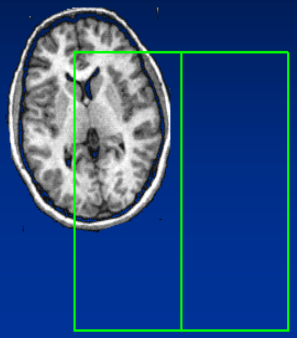


Figure 21 Verticofrontal section of the Atlas corresponding to Figures 19 and 20.

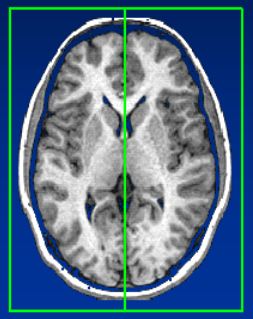
Brain mapping uses a universal coordinate space "MNI Space"

- Labs around the world repeat experiments, compare results directly
- Raw image data and processed maps readily shared among labs
- Results are reproducible
- Networks of laboratories sharing data and/or algorithms become feasible
- Data repositories for global scientific community can be placed on the Web
- New questions can be asked of mapped data, long after primary research completed
- New or improved algorithms can easily be applied to old questions
- **Adaptable to any species, imaging modality or organ – N.B.**

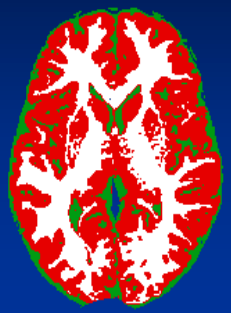
Pipeline Processing



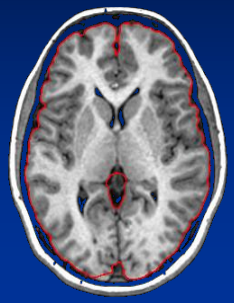
"Native" T1-weighted MRI



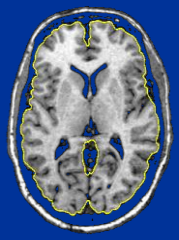
Registered MRI



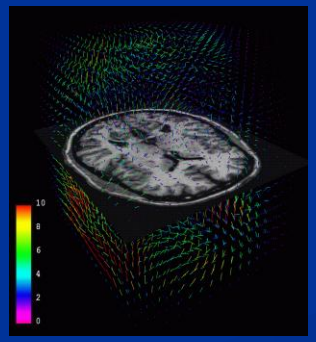
Classification



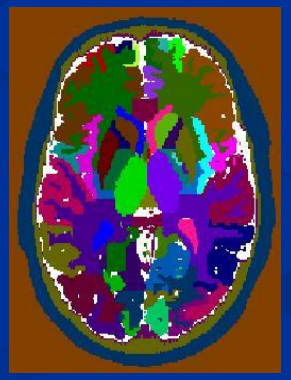
Subject brain with its cortical surface



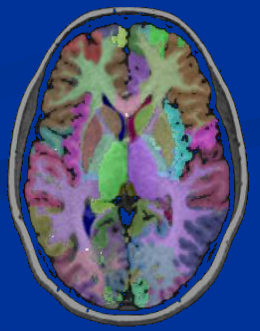
Template brain, in stereotaxic space



Deformation field



Atlas defined on template brain, in stereotaxic space

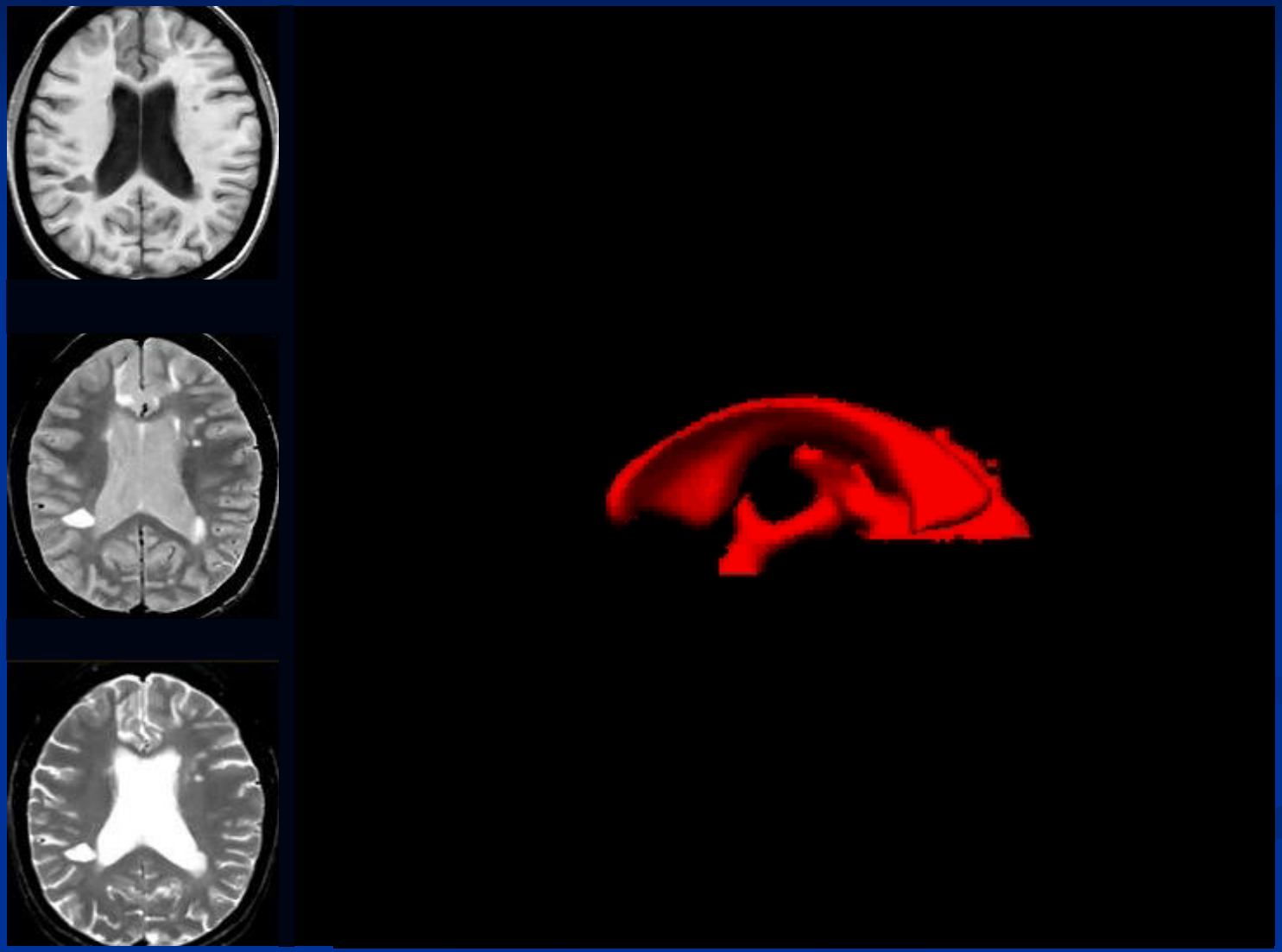


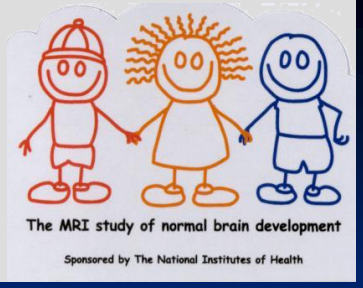
Automatic segmentation

Phase III MS Trial – Myloral

14 sites ; 508 patients (RR) ; 1800 studies
T1, T2, PD volumes at each study
T1: 3D GE, 60 x 3mm, TR=35,TE=min, flip = 45
T2/PD: 2D multi-slice, double SE, TR=3000,TE=30,80

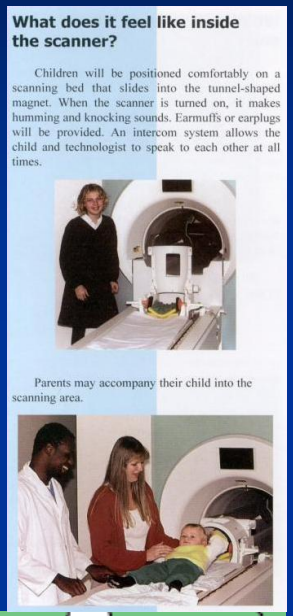
MS lesion map (425 patients)

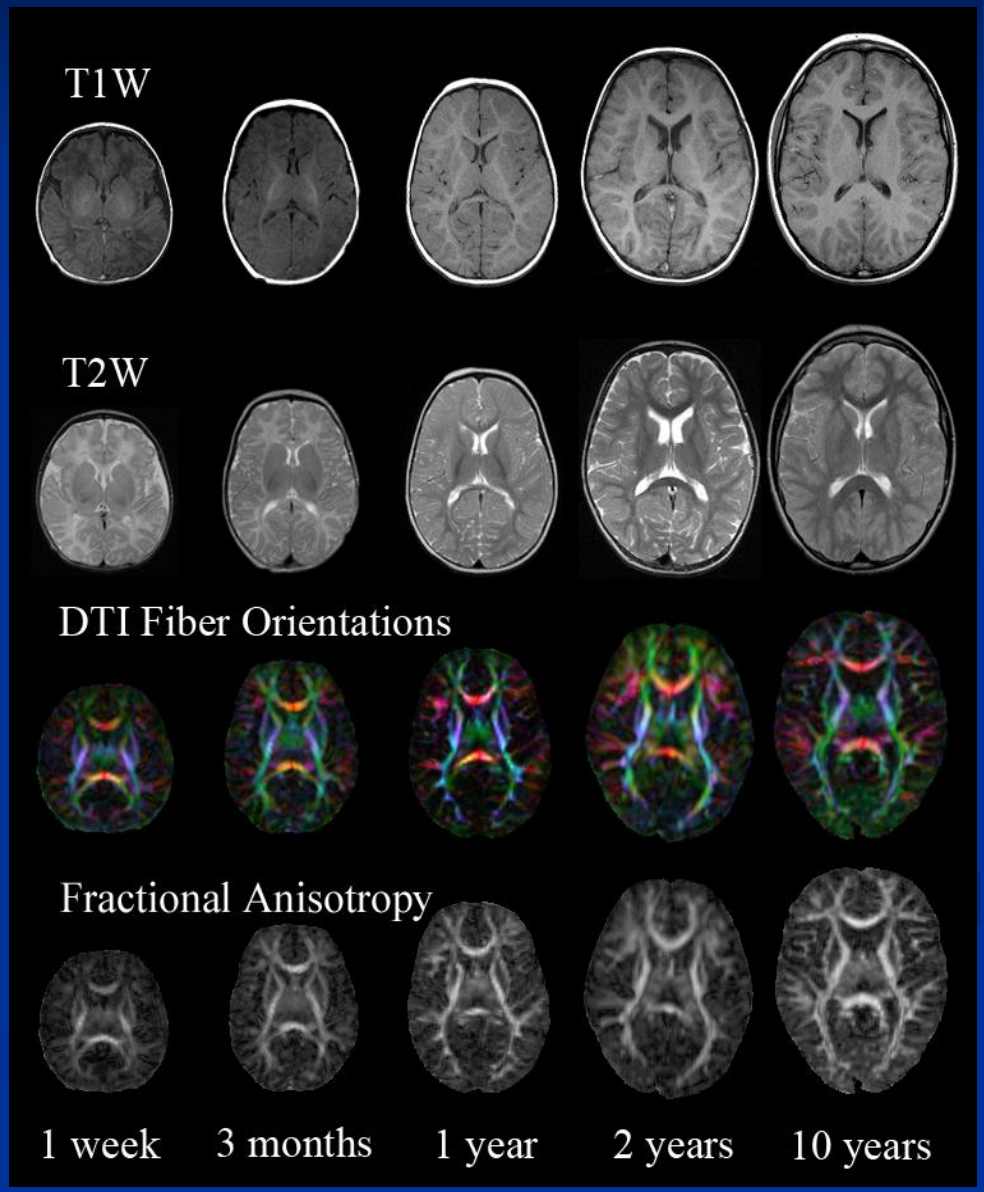




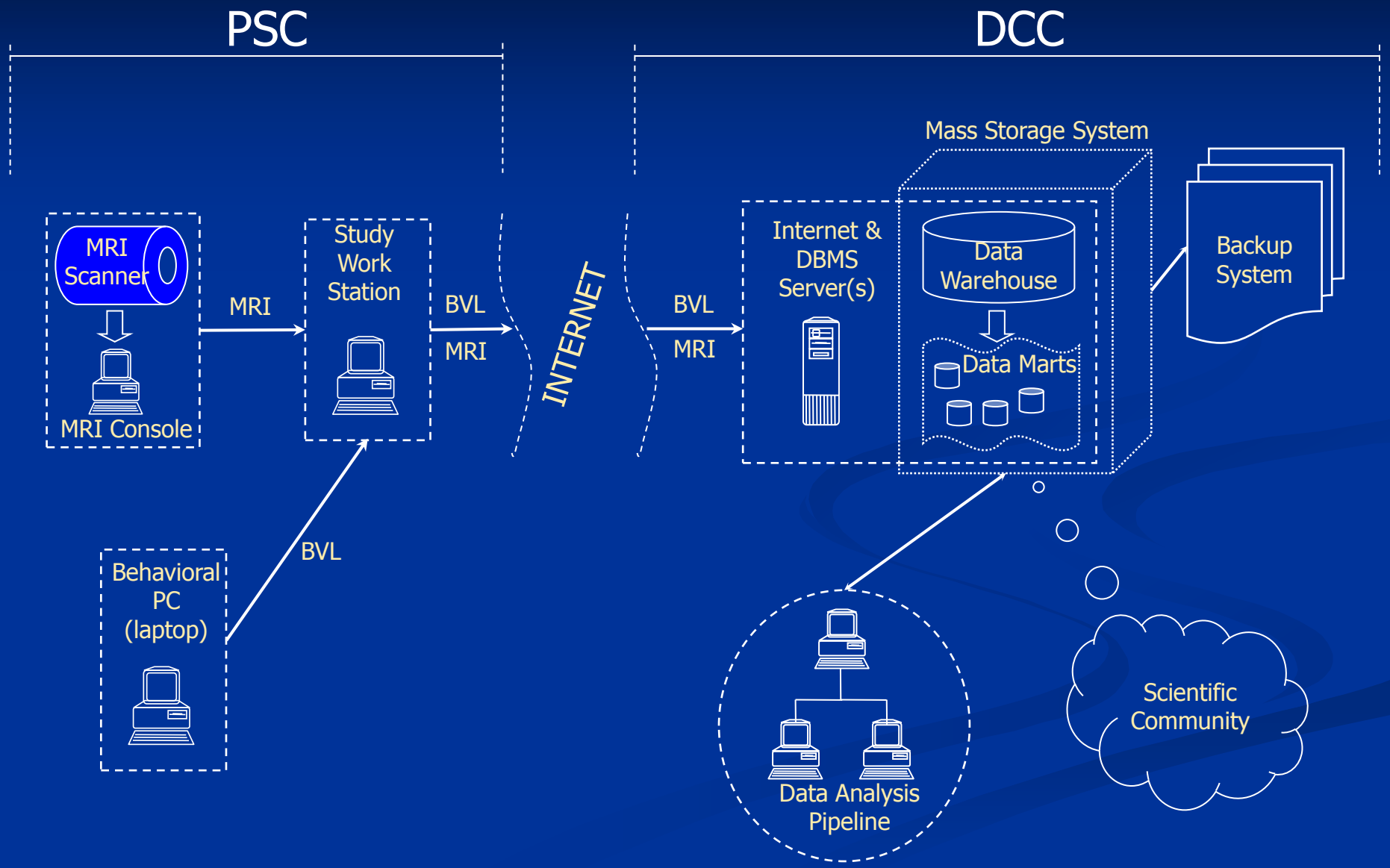
NIH MRI Study of Normal Brain Development (N=500)

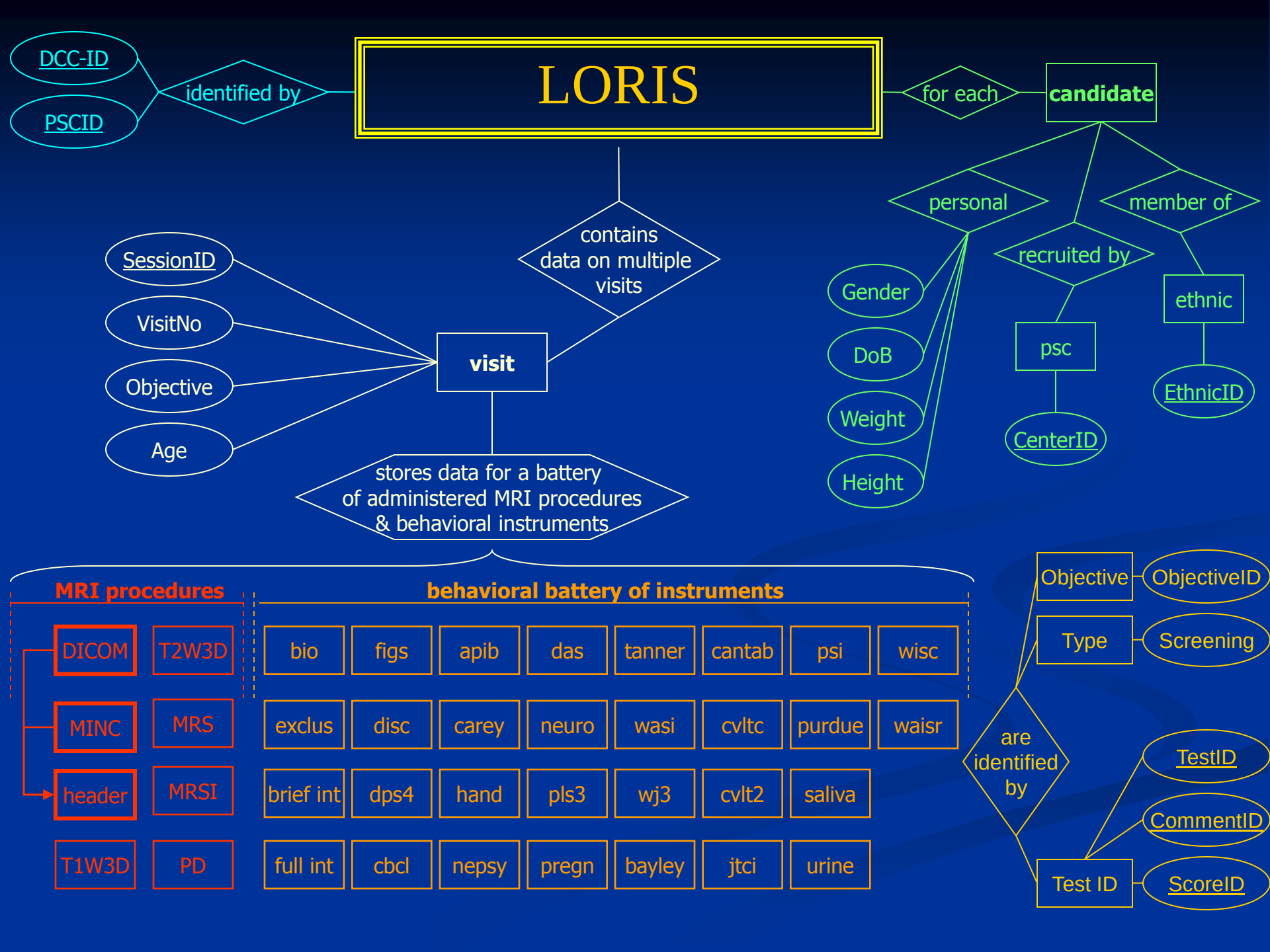
- Behavior/MRI for ages 0-18 yrs
- Structure-behavior relationships
- Disseminate results





NIHPD Network Architecture




LORIS
DCC-ID
PSCID
identified by
for each
candidate
personal
member of
recruited by
Gender
DoB
Weight
Height
psc
CenterID
ethnic
EthnicID
contains data on multiple visits
SessionID
VisitNo
Objective
Age
visit
stores data for a battery of administered MRI procedures & behavioral instruments
MRI procedures
behavioral battery of instruments
DICOM
T2W3D
MINC
MRS
header
MRSI
T1W3D
PD
bio
figs
apib
das
tanner
cantab
psi
wisc
exclus
disc
carey
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wasi
cvltc
purdue
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brief int
dps4
hand
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wj3
cvlt2
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are identified by
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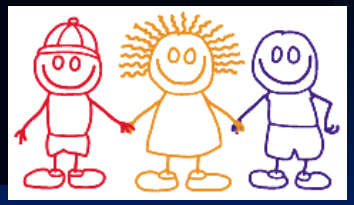

Clinical Neurobehavioral Battery Objective 1 (4.5-18.0 yrs)

1. Handedness: Performance Task
2. IQ - Age dependent
   - Differential Ability Scales (DAS)
   - Wechsler Abbreviated Scale of Intelligence (WASI)
3. Achievement: Woodcock –Johnson III (WJ-III)
4. Physical/Neurological Examination
5. Tanner Staging Questionnaire
6. Saliva & Urine sample Collection
7. Verbal Fluency (NEPSY) -Semantic & Phonemic
8. California Verbal Learning Test-Children's Version (CVLT-C) or CVLT-II
9. CANTAB: Motor Screening, Spatial Span, Spatial Working Memory
10. Purdue Pegboard
11. Junior Temperament and Character Inventory (JTCI)
12. Behavior Rating Inventory of Executive Function (BRIEF)
13. MRI Questionnaire – music, sports, leisure activities, medication exposure

MRI Study of normal brain development
Behavioral characterization (Objective 1)

Journal of the International Neuropsychological Society (2007), **13**, 1–18.

DOI: 10.1017/S1355617707070841

The NIH MRI study of normal brain development: Performance of a population based sample of healthy children aged 6 to 18 years on a neuropsychological battery

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[6]Brain and Body Centre, University of Nottingham, Nottingham, UK
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(RECEIVED May 8, 2006; FINAL REVISION February 2, 2007; ACCEPTED March 2, 2007)

Abstract

The National Institutes of Health (NIH) Magnetic Resonance Imaging (MRI) Study of Normal Brain Development is a landmark study in which structural and metabolic brain development and behavior are followed longitudinally from birth to young adulthood in a population-based sample of healthy children. The neuropsychological assessment protocol for children aged 6 to 18 years is described and normative data are presented for participants in that age

NIH MRI Study of Normal Brain Development

Behavioral characterization (Objective 1)

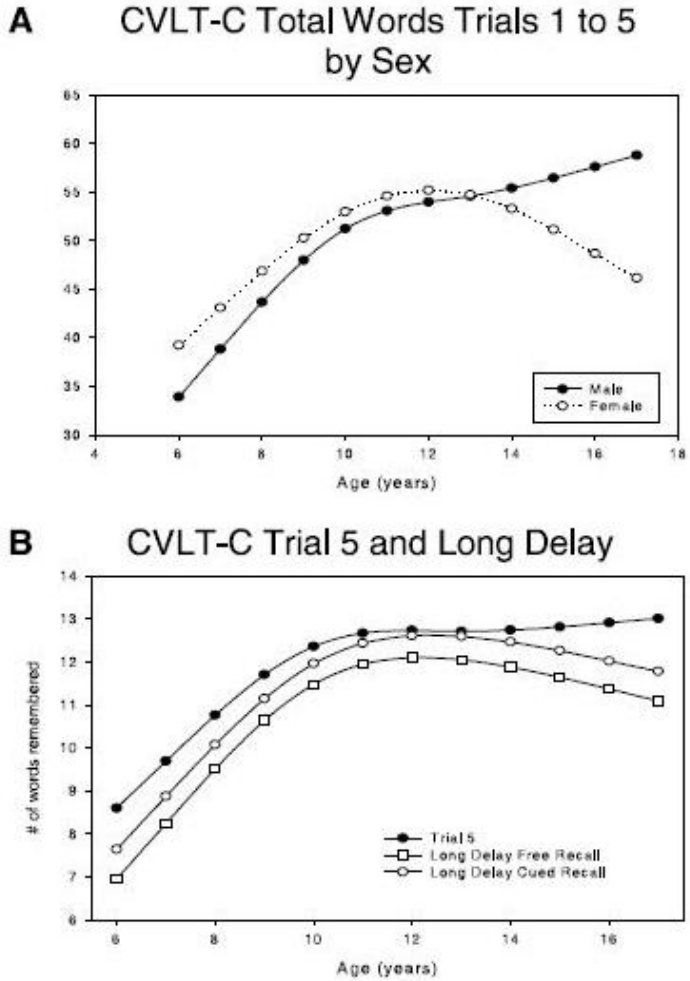


Fig. 3. Estimated relationship of age to raw scores for California Verbal Learning Test for Children (CVLT-C). In addition to linear effects of age, there were significant quadratic effects for all outcomes ($p < .01$). (A) Estimated relationship of age to raw scores for Total Words Trials 1–5 displayed separately for males and females (adjusted for income) and (B) Estimated relationship of age to raw scores for Trial 5, Long Delay Free and Long Delay Cued Recall. Although the Age × Sex interaction is not displayed the CVLT variables in Fig. 3B in the interest of simplicity, this interaction was in fact significant for each of them and the shape of the functions for males and females is very similar to that displayed in 3A for Total Words Trials 1 to 5.

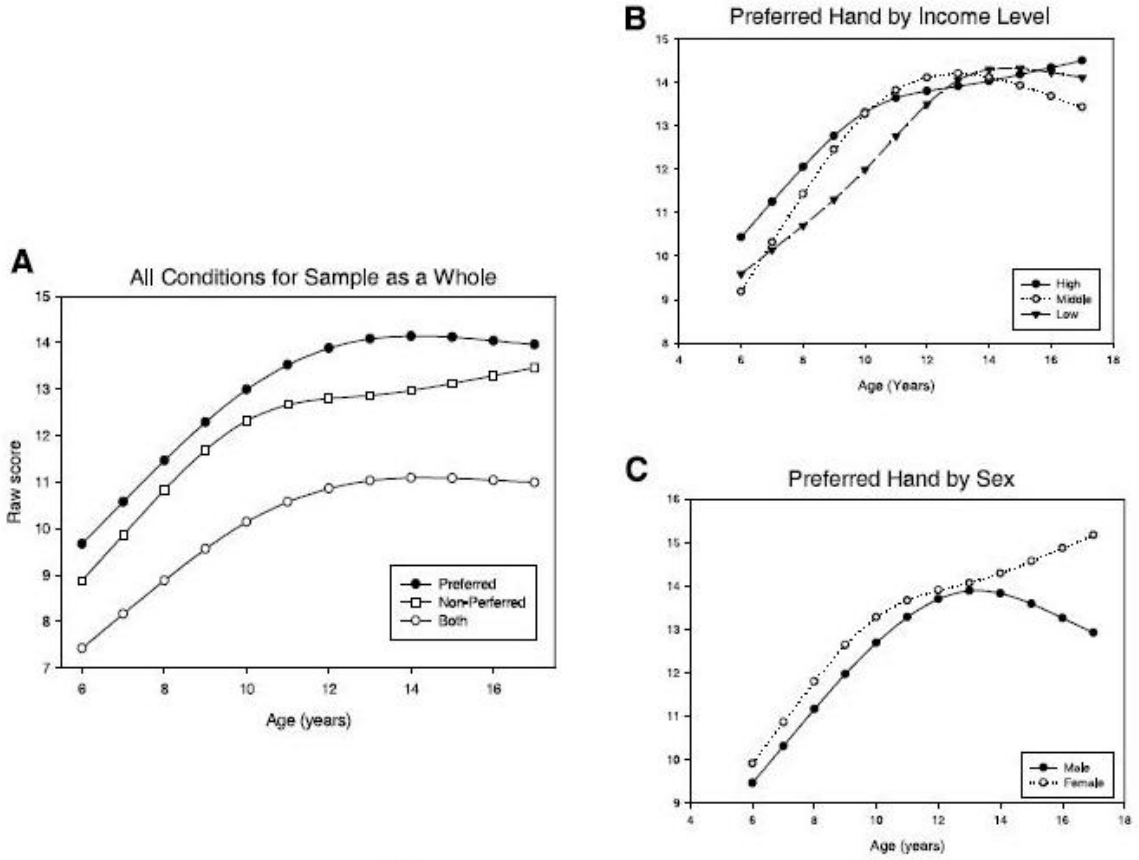


Fig. 4. Estimated relationship of age to number of pegs correctly placed on Purdue Pegboard. (A) Estimated relationship of age to number of pegs for preferred hand, non-preferred hand, and both hands adjusted for sex and income level. In addition to linear effects of age, there were significant quadratic effects for the preferred and both conditions ($p < .05$); a significant cubic effect was documented for the non-preferred condition ($p < .05$). Interactions of age with sex and income level were observed for the Preferred Hand condition only. (B) Estimated relationship of age to number of pegs correctly placed with preferred hand displayed separately for income level (adjusted for sex). (C) Estimated relationship of age to number of pegs correctly placed with preferred hand displayed separately for males and females (adjusted for income).

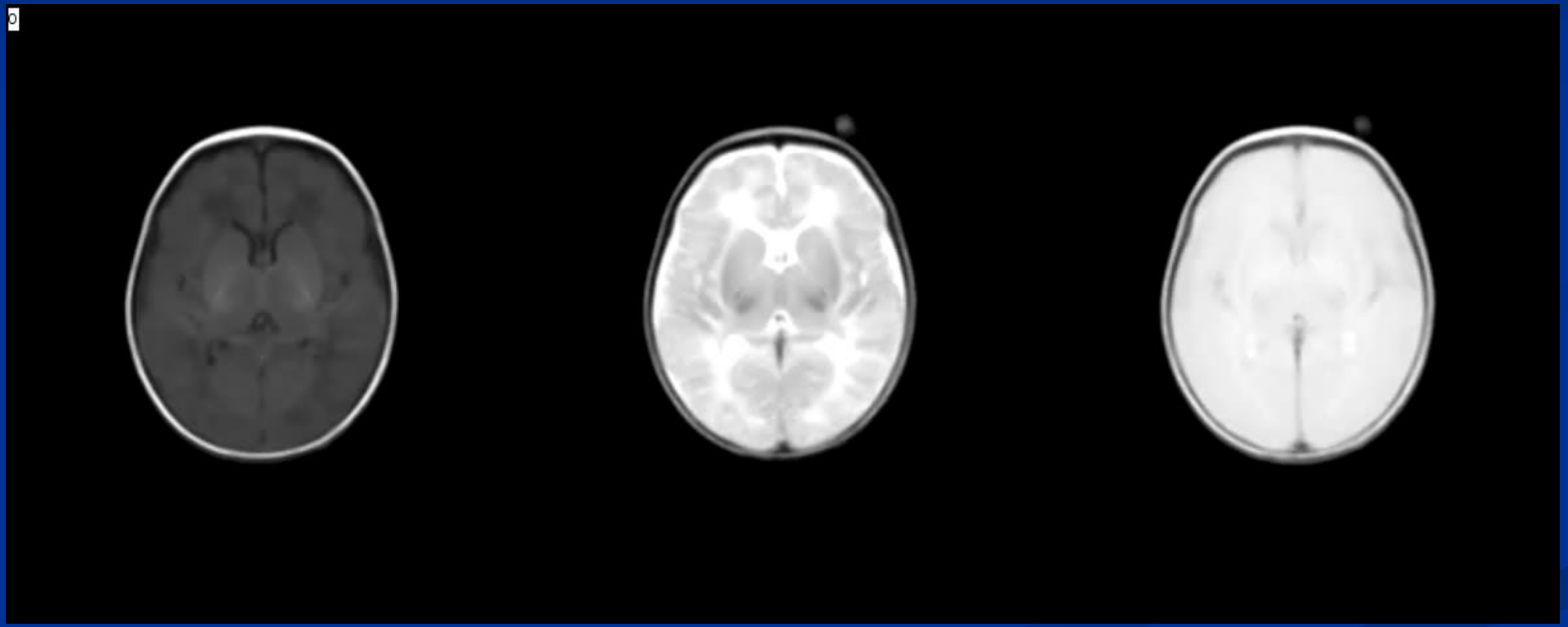
Objective 2 Battery (0.0-4.5 yrs)

Neurological Examination (NEURO)	0:0 to 4:5	neurological development
Bayley Scales of Infant Development-II (BSID-II)		
Mental Scale	0:3 to 2:6	mental development
Motor Scale	0:3 to 3:0	motor development
Behavior Rating Scale	0:3 to 2:6	behavioral development**
Preschool Language Scale-3 (PLS-3)		
Auditory Comprehension Subscale	0:3 to 4:5	receptive language
Expressive Communication Subscale	0:3 to 4:5	expressive language
Total Language	0:3 to 4:5	total language
Differential Abilities Scale (DAS)		
Block Building	3:0 to 3:5	fine motor, visual perceptual
Verbal Comprehension	3:0 to 4:5	receptive language
Picture Similarities	3:0 to 4:5	reasoning, recognition
Naming Vocabulary	3:0 to 4:5	expressive language
Pattern Construction	3:6 to 4:5	visual-spatial orientation
Early Number Concepts	3:6 to 4:5	math concepts/skills
Copying	3:6 to 4:5	fine motor, visual perceptual
General Conceptual Ability	3:0 to 4:5	intelligence
Handedness-1:0 (HAND-1)	1:0 to 2:11	hand preference
Handedness-3:0 (HAND-3)	3:0 to 4:5	hand preference
Verbal Fluency (NEPSY)	3:0 to 4:5	semantic fluency
Purdue Pegboard (PEG)***	3:0 to 4:5	fine motor coordination
Cambridge Neuropsychological Test Automated Battery (CANTAB)		
Motor Screening	4:0 to 4:5	reaction time/accuracy
Spatial Span	4:0 to 4:5	figure/sequence memory
Spatial Working Memory	4:0 to 4:5	memory/plan/monitor
Big Circle-Little Circle	4:0 to 4:5	category rule/reversal
Intra/Extra Dimensional Set-Shift	4:0 to 4:5	rule shifting/interference

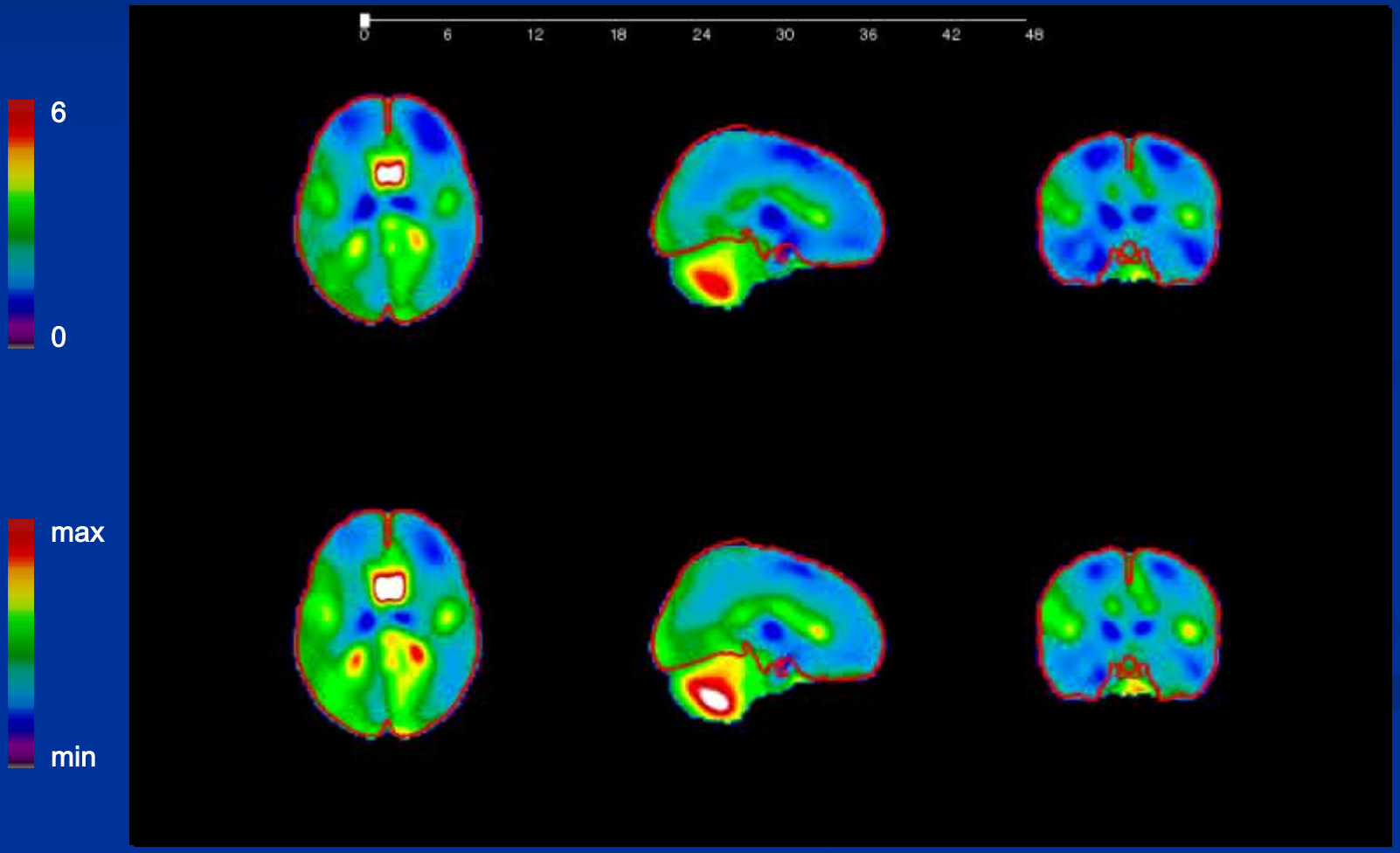
*Administration Ages—years:months (e.g., 2:6 = 2-years, 6-months)
**Behavioral Development includes: attention, engagement, emotional regulation, motor quality, etc.
***Half-Board Version

Normal brain growth from 0-48 months (N=50)

T1 T2 PD

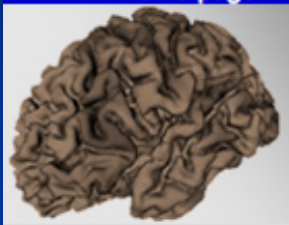


MRI Study of Normal Brain Development
Objective 2 - annual tissue growth rate



NIH MRI Study of Normal Brain Development

www.bic.mni.mcgill.ca/nihpd/info



The NIH MRI Study of Normal Brain Development

A project sponsored by the National Institutes of Health

Welcome to the Pediatric MRI Data Repository Website. This site provides information about the NIH MRI Study of Normal Brain Development (Pediatric MRI Study) and resulting Pediatric MRI Data Repository. This website serves as the portal through which data can be obtained by qualified researchers. The overarching goal of the Pediatric MRI Study is to foster a better understanding of normal brain maturation as a basis for understanding atypical brain development associated with a variety of disorders and diseases.

Project overview:

This multi-site longitudinal study uses technologies (anatomical MRI, diffusion tensor imaging (DTI), and MR spectroscopy (MRS)) to map pediatric brain development and is organized around two Objectives. Data collection began in November 2001 and will continue through August 2007. Data will be released in stages... read more →

Protocols:

A collaborative effort among the participating centers and NIH resulted in age-appropriate MRI protocols and clinical/behavioral batteries of instruments... read more →

Publications:

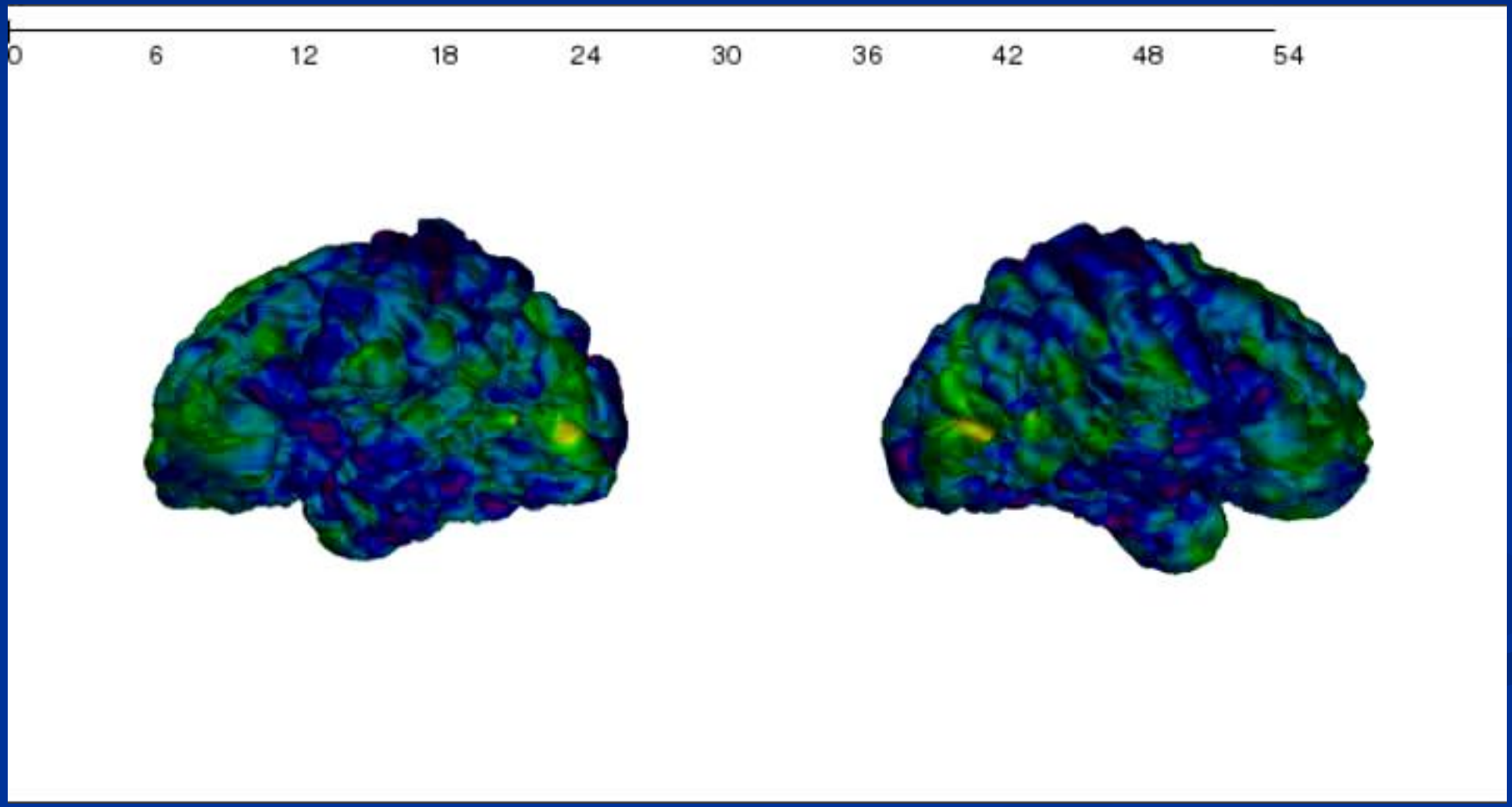
Published papers from the project are available... read more →

Data access:

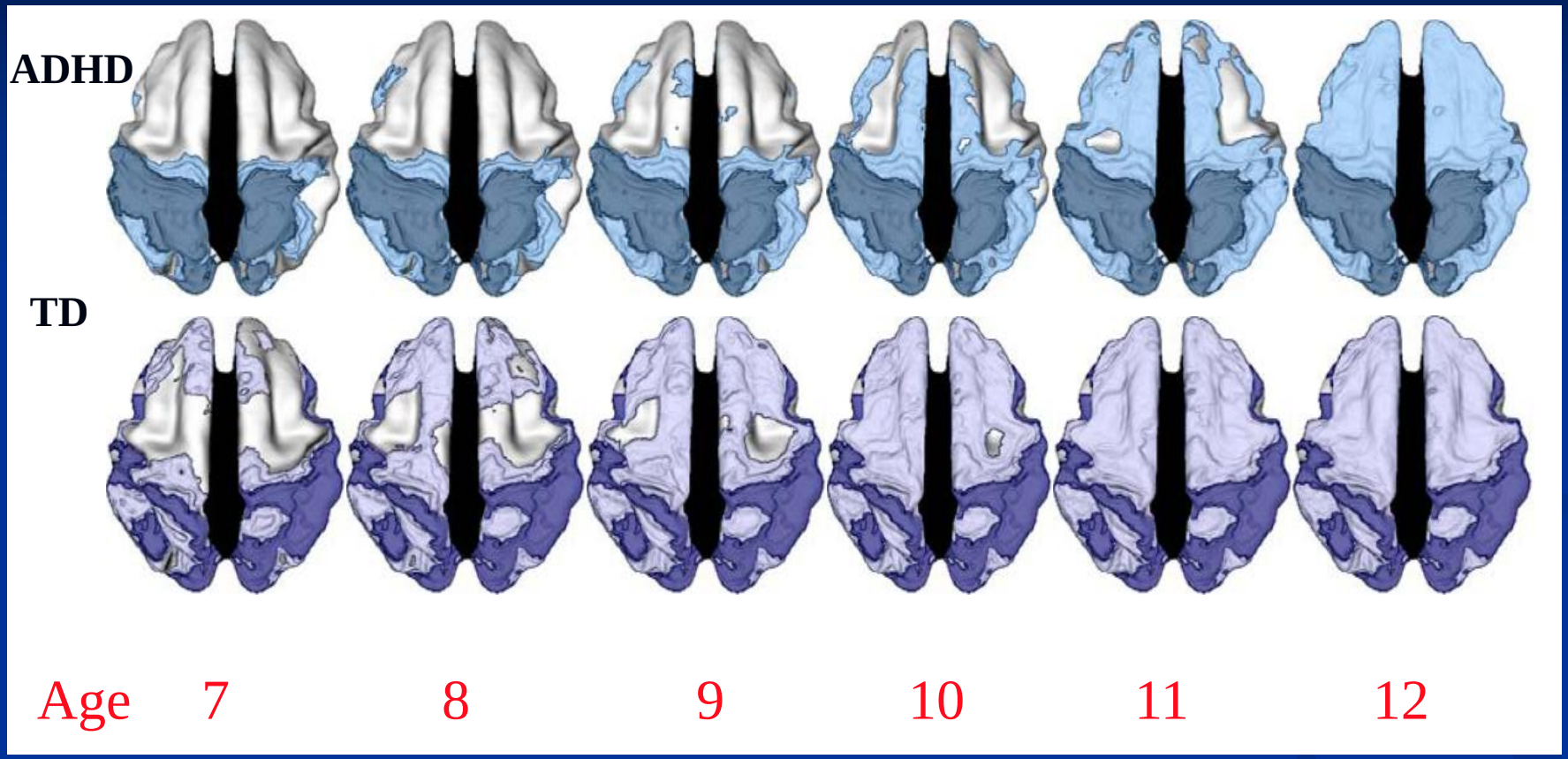
Qualified researchers may apply by completing the Data Use Certification, available through this website. Full and partial data sets of clinical/behavioral and image data are available for download... read more →

MRI Study of normal brain development
Evolution of hemispheric asymmetry from 0-54 months
(N=90)

Colours show hemispheric difference in surface position (L > R)



Delay in attaining peak cortical thickness in ADHD



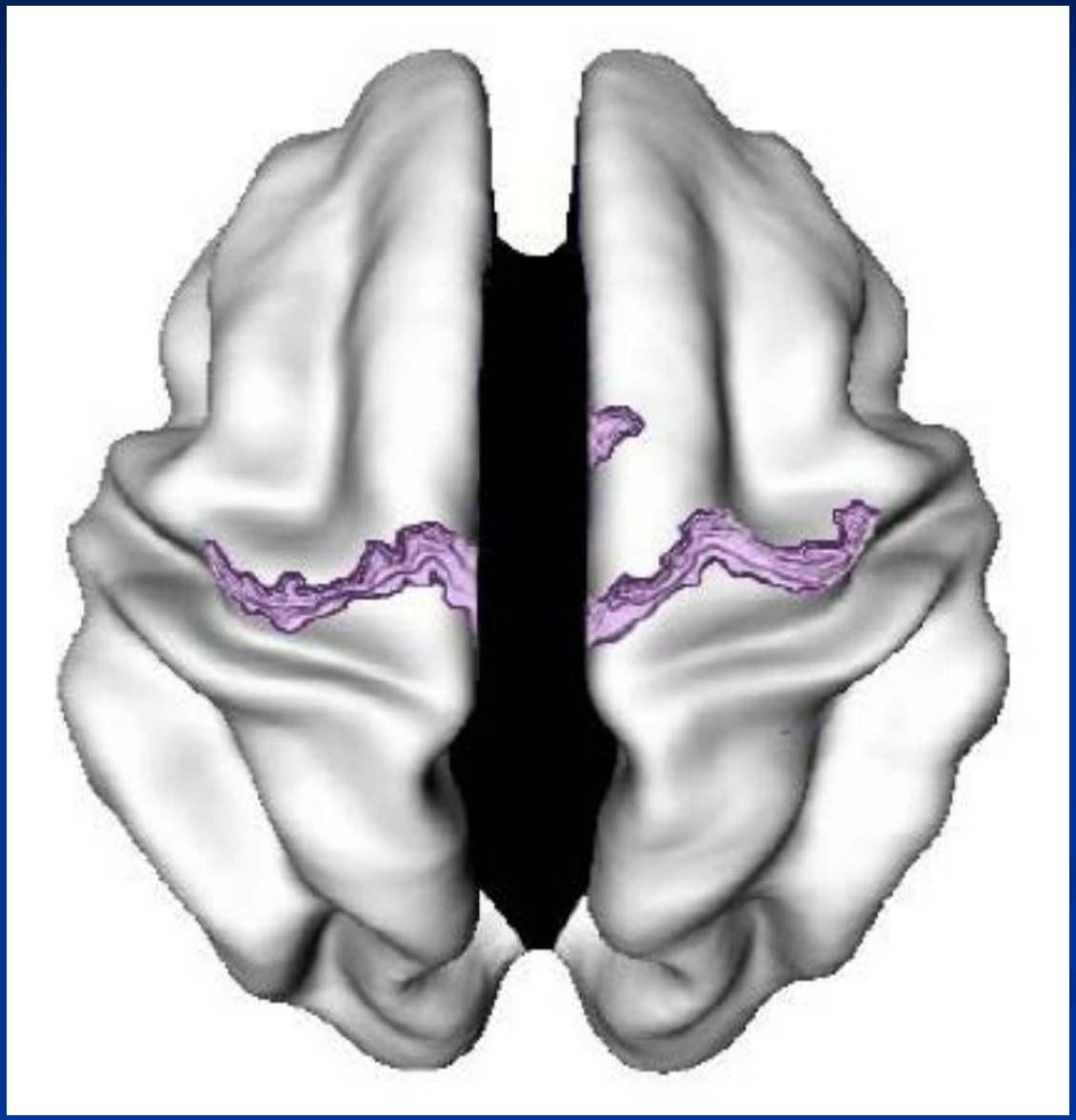
Dark colors → inappropriate quadratic model (peak age not calculable or outside age range).

Groups show similar sequence of regions attaining peak thickness, but ADHD is delayed.

Shaw P et al., PNAS, 2008

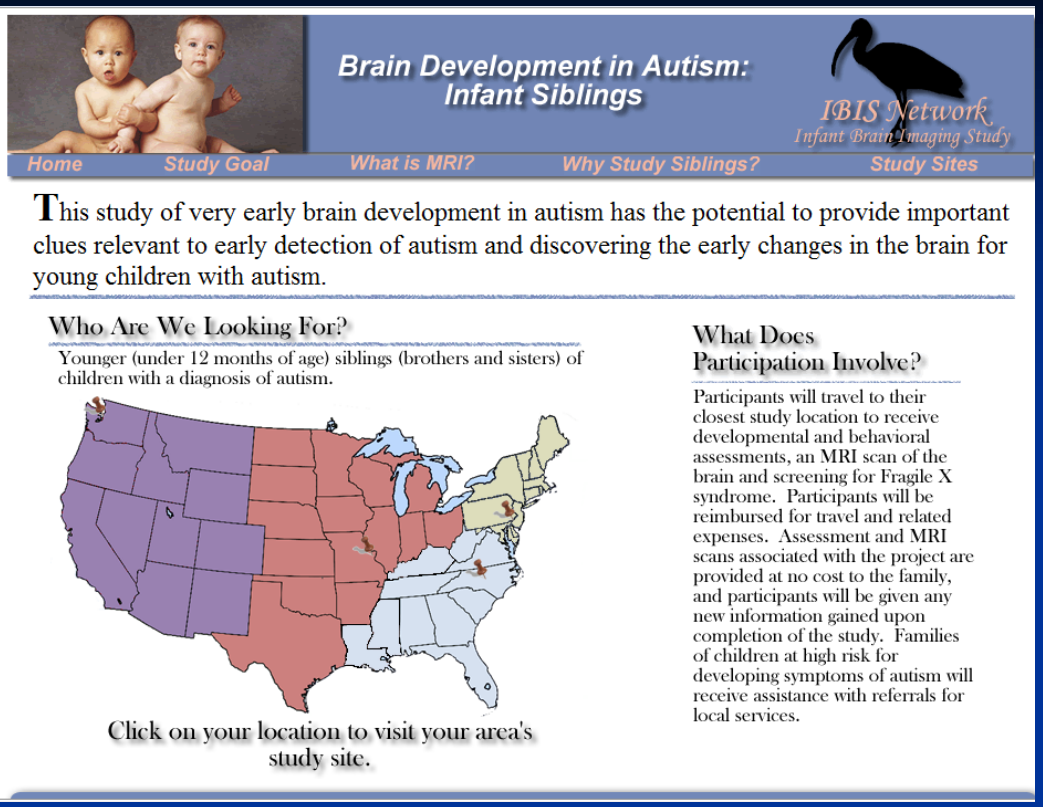
Early cortical maturation in ADHD

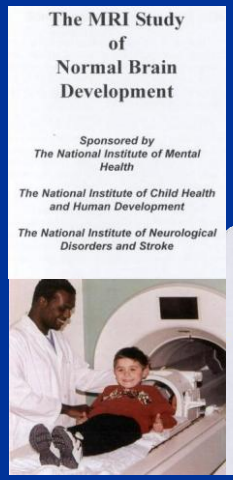
indicated by younger age of attaining peak cortical thickness

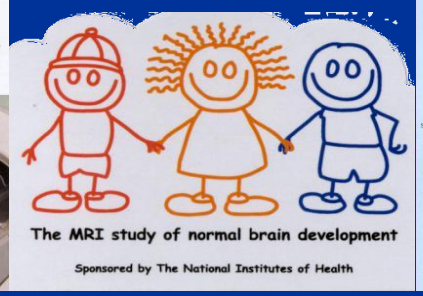


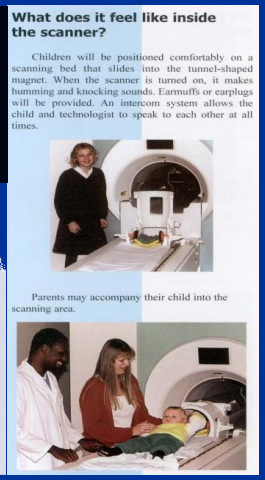
Shaw P et al., PNAS, 2008

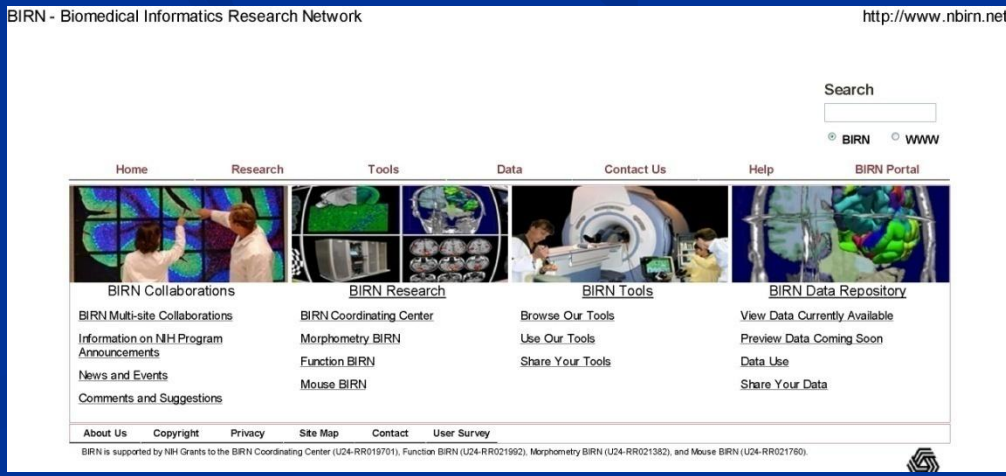
Brain Networks





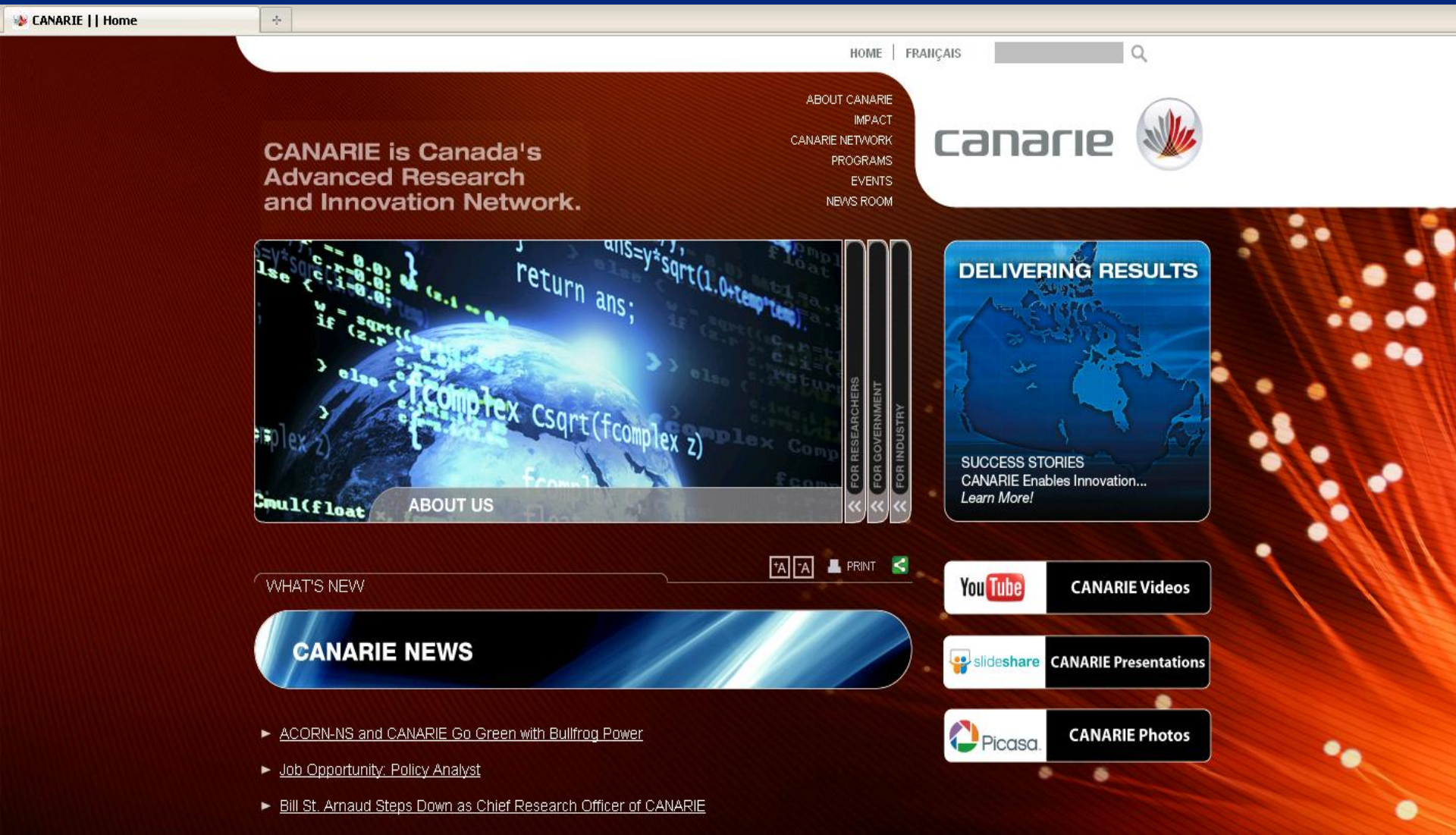




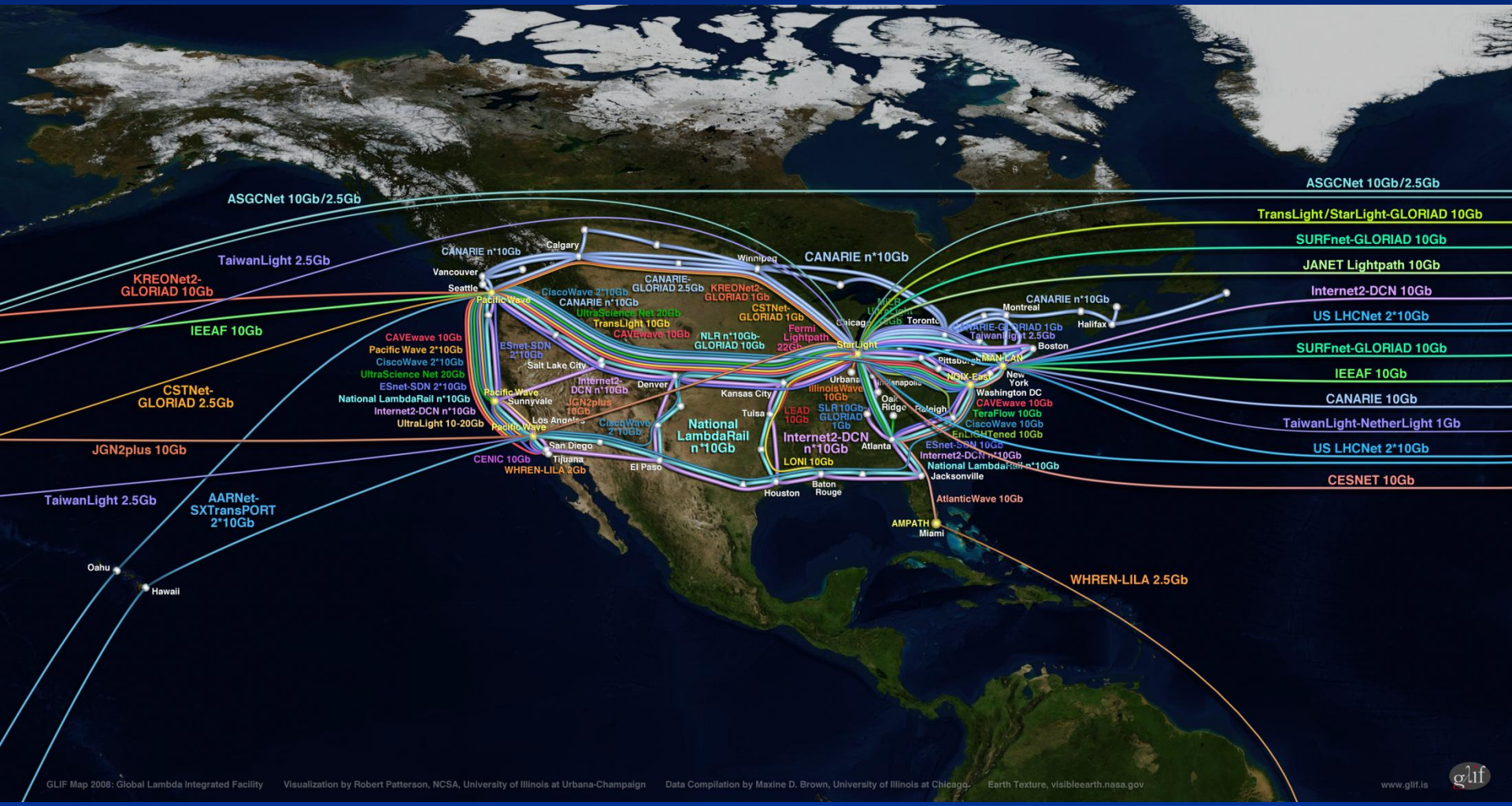


CANARIE

CANADA'S ADVANCED RESEARCH AND INNOVATION NETWORK

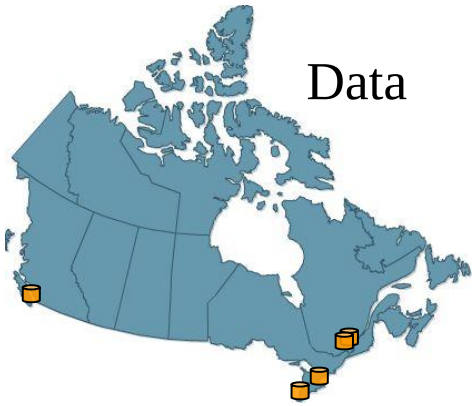


Research and Education Networks
North America



CBRAIN

- Canadian Distributed Neuroimaging Platform (5 Canadian Centers)
- Prototype Collaborative 3D Visualization of a High Resolution Brain



Data

Computing

Distributed Architecture

Users

canarie

McGill

UNIVERSITY OF TORONTO

ARC·CNRC

Université de Montréal

UBC

UNIVERSITY OF CALIFORNIA · SAN DIEGO

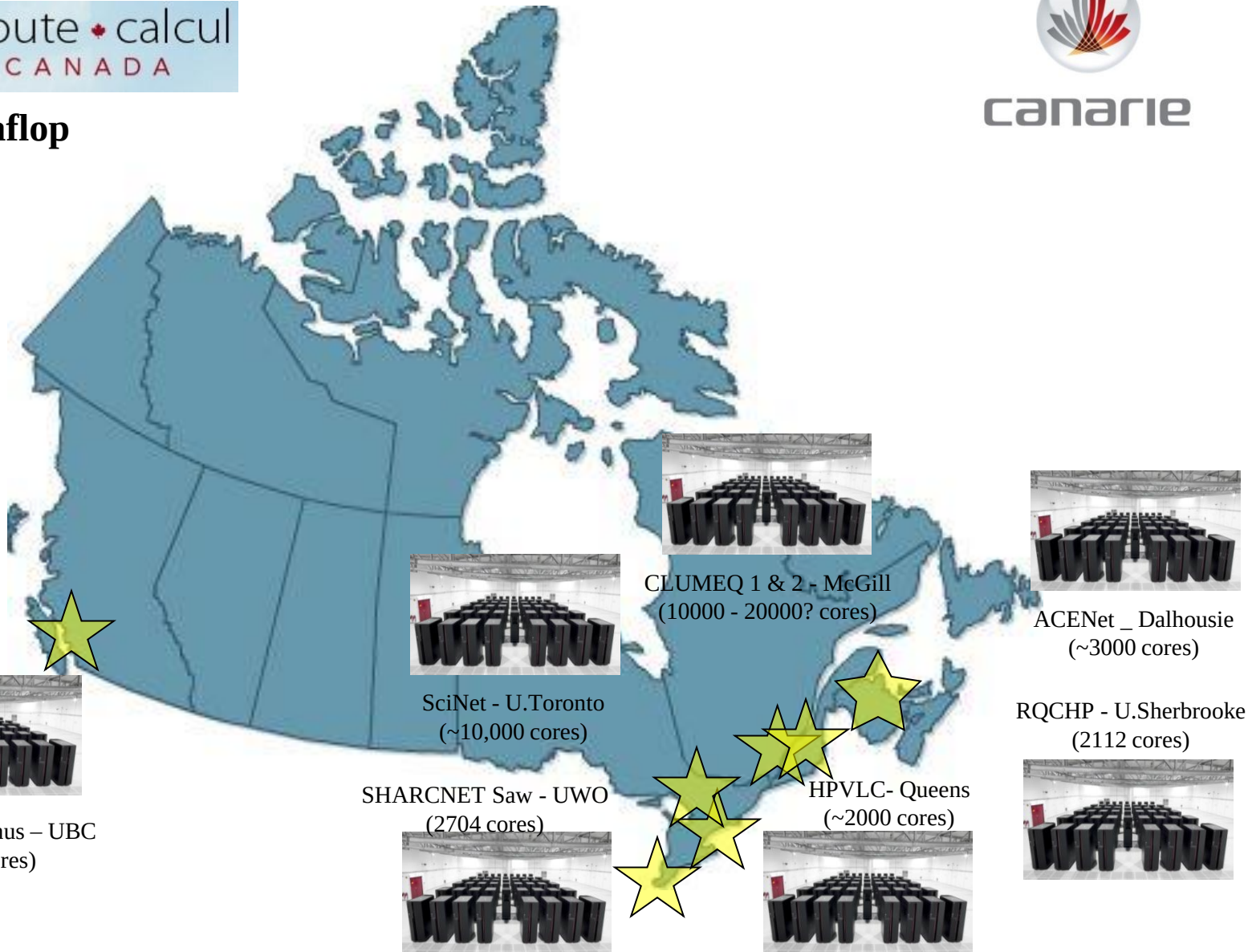
CBRAIN HPC Roadmap

(20,000 – 30,000 CPUs)

compute • calcul CANADA

canarie

~ 1 Petaflop



CLUMEQ 1 & 2 - McGill
(10000 - 20000? cores)

ACENet _ Dalhousie
(~3000 cores)

SciNet - U.Toronto
(~10,000 cores)

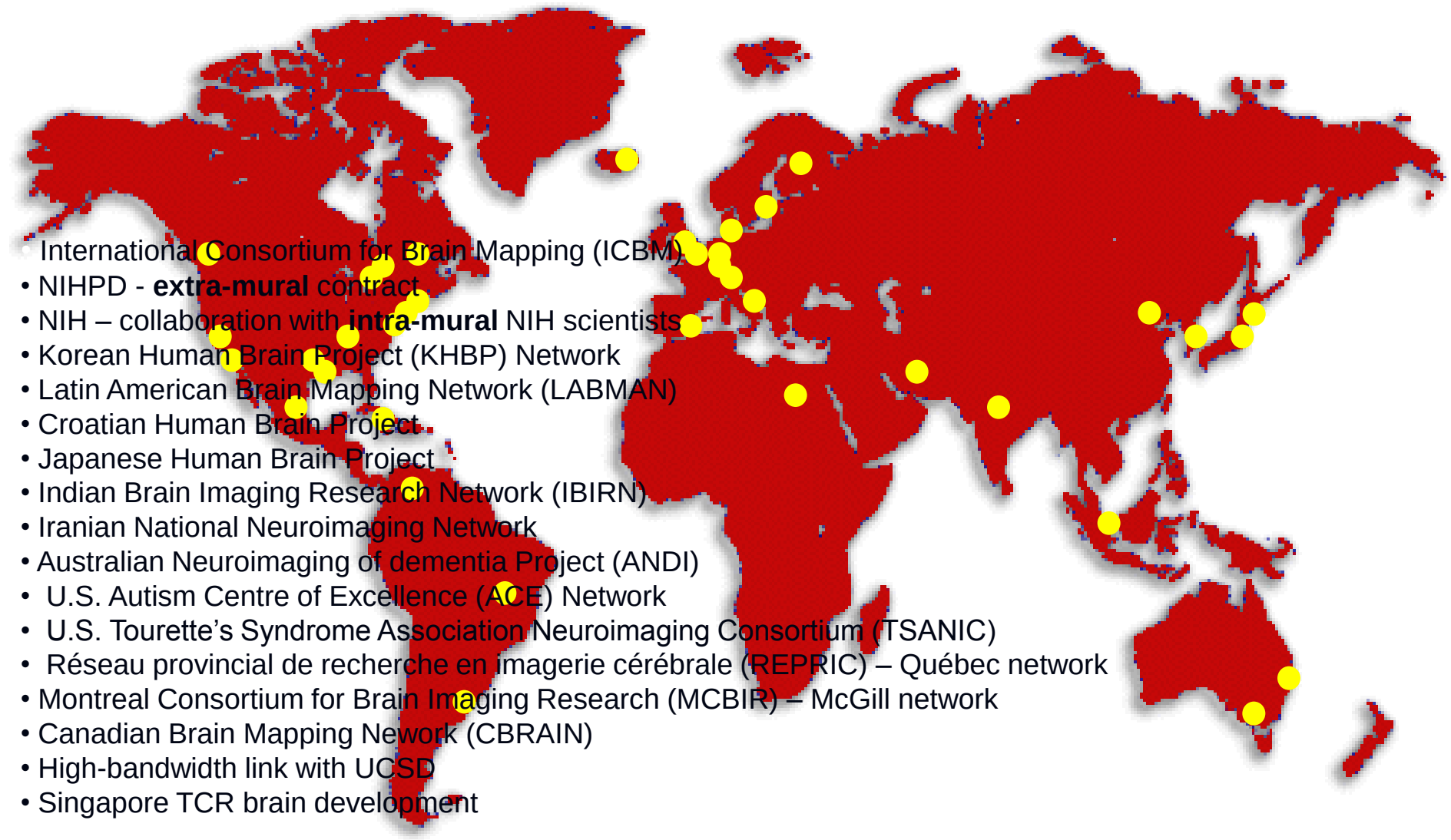
RQCHP - U.Sherbrooke
(2112 cores)

Westgrid Orcinus – UBC
(3072 cores)

SHARCNET Saw - UWO
(2704 cores)

HPVLC- Queens
(~2000 cores)

International Links



- International Consortium for Brain Mapping (ICBM)
- NIHPD - **extra-mural** contract
- NIH – collaboration with **intra-mural** NIH scientists
- Korean Human Brain Project (KHBP) Network
- Latin American Brain Mapping Network (LABMAN)
- Croatian Human Brain Project
- Japanese Human Brain Project
- Indian Brain Imaging Research Network (IBIRN)
- Iranian National Neuroimaging Network
- Australian Neuroimaging of dementia Project (ANDI)
- U.S. Autism Centre of Excellence (ACE) Network
- U.S. Tourette's Syndrome Association Neuroimaging Consortium (TSANIC)
- Réseau provincial de recherche en imagerie cérébrale (REPRIC) – Québec network
- Montreal Consortium for Brain Imaging Research (MCBIR) – McGill network
- Canadian Brain Mapping Nework (CBRAIN)
- High-bandwidth link with UCSD
- Singapore TCR brain development

Singapore Birth Cohort Study

H1: Epigenetic changes in conceptual tissues obtained at birth reflect fetal environment.

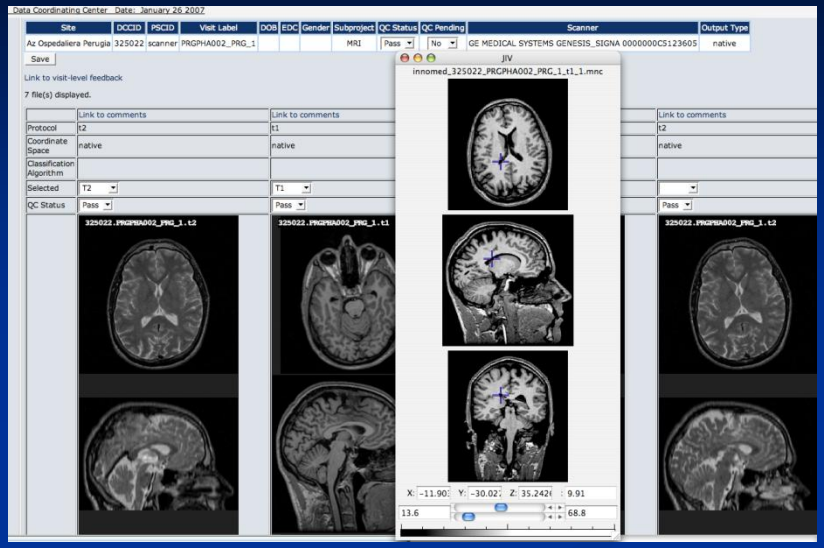
H2: Pattern of epigenetic marks in gene promotors in DNA of birth tissues, along with genotype, phenotype, and early environmental exposures predict risk of obesity and metabolic disease.

1200 mothers (200 Indian, 200 Malay, 800 Chinese) through regnancy until the child 3yr of age.

Vanguard group of 100 mothers (60 Chinese, 20 Malay and 20 Indian) recruited from June 2009

Measure fetal/child growth and influences on *epigenetic* factors

Canada-Europe Brain Network Links

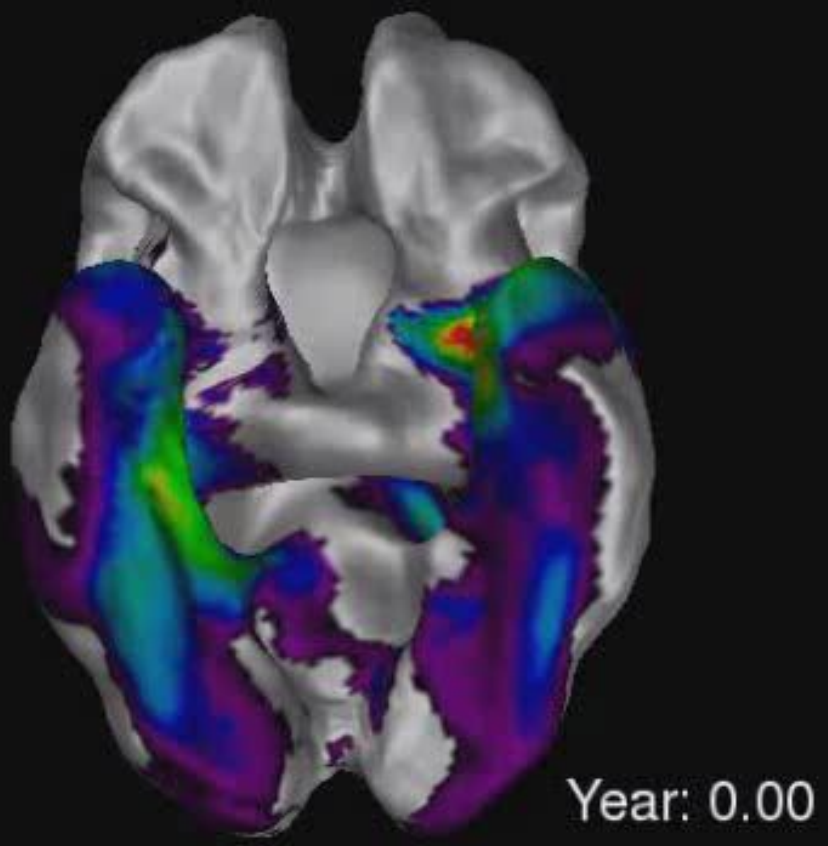


Innomed / AddNeuroMed
Alzheimer's Disease

NeuGrid – Grid Computing
Distributed processing
Distributed databasing

Cortical atrophy in Alzheimer's Disease

(Lerch J et al., Cerebral Cortex 2005)



Latin American Brain Mapping Network (LABMAN)

NeuroImage 47 (2009) 312–313

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Comments and Controversies

Latin American Brain Mapping Network (LABMAN)

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[f] Instituto do Cérebro – IIEP – Albert Einstein, Brazil
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ABSTRACT

On March 8, 2008 in Havana, the Latin American Network for Brain Mapping (LABMAN) was created with participants from Argentina, Brazil, Colombia, Cuba and Mexico. The focus of LABMAN is to promote neuroimaging and systems neuroscience in the region through the implementation of training and exchange programs, and to increase public awareness of the Latin American potential to contribute both to basic and applied research in human brain mapping.

Cuban Brain Mapping Project

Random sampling from general population N=20,209

Age Range: 0-90

Both Genders

Screening for general pathologies

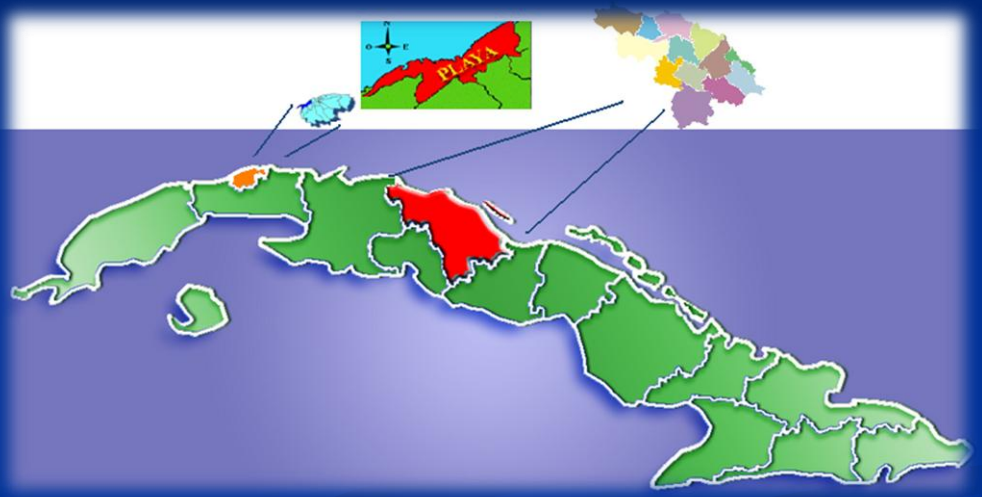
Age Range: 18-81 N = 1574

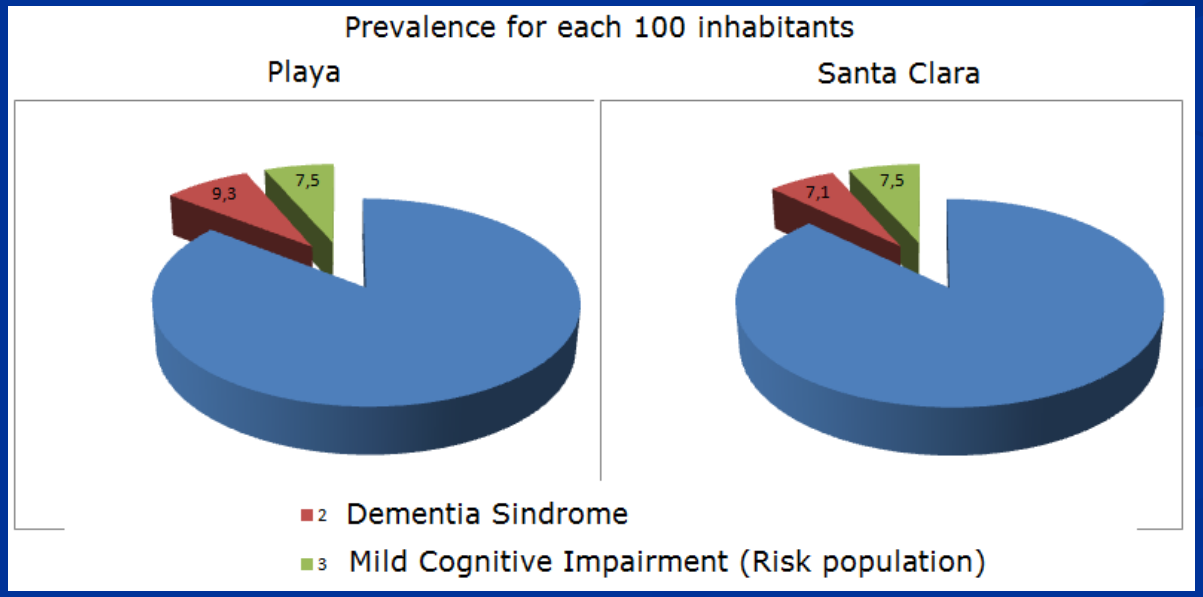
Causes of Exclusion	Quantity.	% respecting to the screened sample
Pathologies	**705**	**44.79**
Arterial Hypertension	224	14.23
Neurological Diseases	209	13.28
Athma	69	4.39
Psychiatric disorders	64	4.07
Other systemic diseases	59	3.75
Diabetes Mellitus	37	2.35
Cardiovascular diseases	29	1.84
Malignant neoplasia	8	0.5
AIDS	6	0.38
Others	277	17.6

Cuban Dementia and Alzheimer Study

Playa Municipality, Havana & Santa Clara, Villa Clara

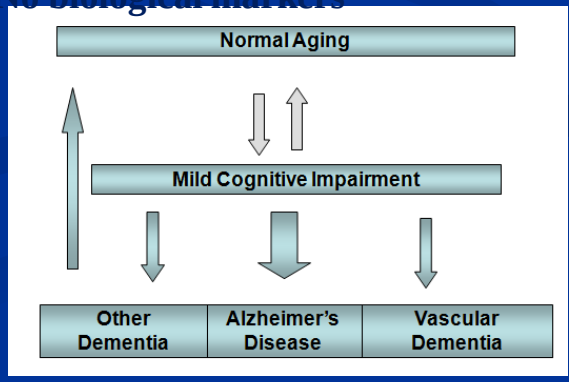
Total Municipalities Population Studied Over 65 years old approximately 40 000 inhabitants





Diagnostic Problems of Alzheimer Disease (AD)

Depends on diagnosis
No biological markers

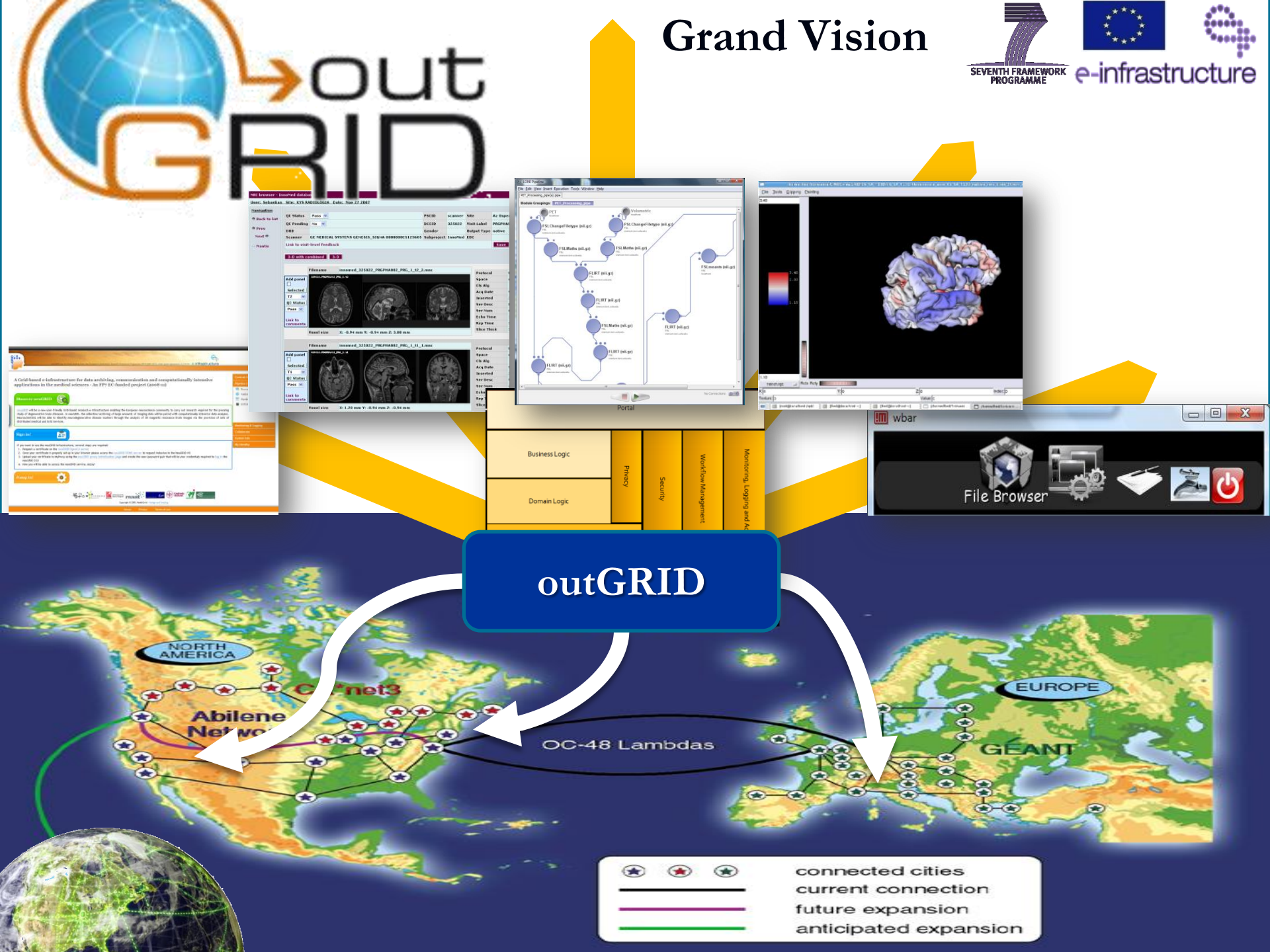


Indian National Brain Research Centre
Manesar, Haryana

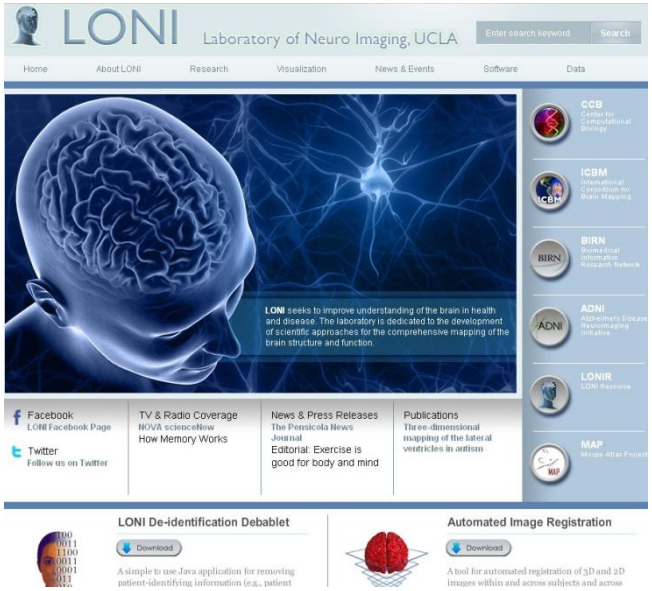
Drs. Vijayalakshmi Ravindranath, Prasun Roy, Shobini Rao

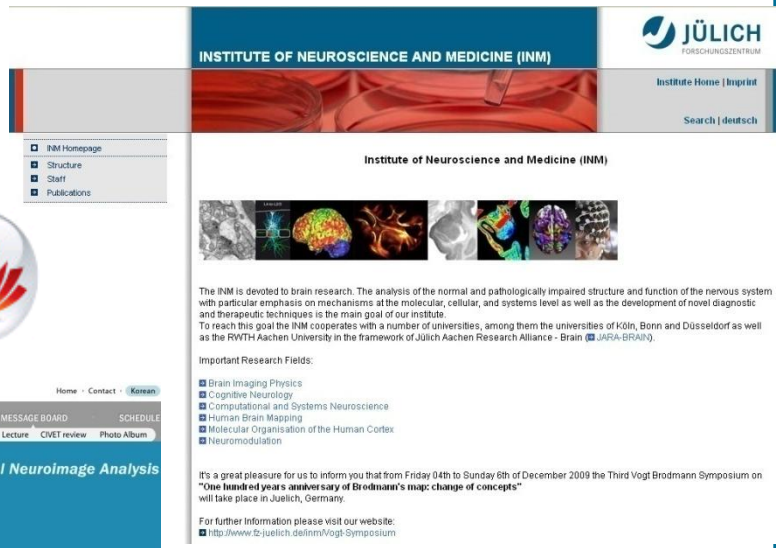
Dr. Sumitra Purkayastha (Indian Statistical Institute)

Grand Vision

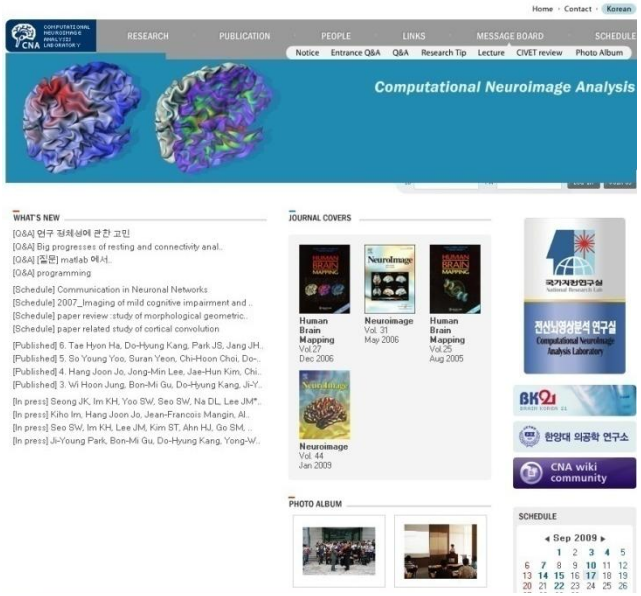


GBRAIN





canarie



Toga
USA

Lee
S. Korea

Zilles
Germany

McGill Centre for Neuroinformatics and Genomics (MCNG)

Existing Strengths

- Well-defined global target community
- Spatial framework for combining results from brain mapping experiments
- Computational emphasis of the brain mapping field
- High profile neuroscience community
- Software infrastructure from for databasing and pipeline analysis
- High-bandwidth transfer capabilities from CANARIE
- CLUMEQ Supercomputing Facility
- Supercomputing resources across Canada (LRP)
- CBRAIN/GBRAIN
- High-bandwidth partners in US, Europe, Asia
- Commercial links already in place - Biospective

McGill Centre for Neuroinformatics and Genomics (MCNG)
Functions

- Database storage of brain mapping/genomic data (private or public)
- Creation/dissemination of gold-standard datasets for normal and disordered brain
- Processing of brain mapping data using BIC image-processing pipelines
- Statistical analysis of processed images, clinical/behavioural data
- Genomic analysis at every 3D voxel
- Training with brain image analysis methods for visiting scientists/students/HQP

Immense computation - Grid-computing, e.g. NeuGrid www.infoalzheimer.it/neugrid
Use CANARIE backbone and the HPC National Platforms www.c3.ca
Staff: 2 database managers, 2 IP specialists, 1 facilities manager, 1 financial manager

N.B. not restricted to human brain MRI
Species: human, primate, rodent
Organs: brain, heart, liver
Modalities: (PET, fMRI, histology, IHC, DNA/RNA)