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## Enriching the human connectome: BigBrain & The Virtual Brain to feature the newly digitized Economo & Koskinas human cytoarchitectonic atlas

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### Background

- Fundamental relations between architecture, connectivity and function of the cerebral cortex still remain elusive. This is partly due to a **lack of detailed, quantitative cytoarchitectonic data** for the human brain
- Currently, the only comprehensive source of such information is the classic work of **von Economo and Koskinas** [1,2] – which, however, is only available in a **paper-based 2D atlas in non-standard space**
- Our project aims to construct a virtual 3D model of the von Economo and Koskinas atlas in stereotactic space

### From plaster model to virtual 3D model

- Starting point:** Plaster models from the von Economo era
- Recent studies [3-5] manually mapped the von Economo and Koskinas parcellation onto the FreeSurfer Desikan-Killiany atlas [6] based on the textual description and 2D drawings in [1,2,7]
- To circumvent previous limitations, we aim to explicitly define a virtual 3D von Economo and Koskinas model independent of existing reference geometries – this is made possible with the use of two individual, well-preserved copies of the 3D plaster model of the cortical parcellation [1,2] manufactured in the 1920s for illustrative use in medical training - ordered, authenticated and praised for their accuracy by von Economo himself

Constantin von Economo  
 Professor of Neurology and Psychiatry at the University of Vienna, Austria

## Cellular Structure of the Human Cerebral Cortex

Translated and edited by

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Fig. 42. A patented plaster model of the human brain, with the various cytoarchitectonic areas marked according to the original Economo and Koskinas (1925, 2008) lettering system, and indicated by Economo with various colors on the convexity and median faces of the cerebral hemispheres, was manufactured in 1920s by Fabrikation Chirurgischer Instrumente Carl Reiner, Mariahilfengasse 17, Wien IX (still operating today in the same locality after four generations). Economo made a demonstration using such a model in his December 3, 1929 lecture at the Section on Neurology of the New York Academy of Medicine (Economo, 1930). One additional model is on display at the Institut für Geschichte der Medizin (Institute for the History of Medicine) of the University of Vienna, next to Economo's death mask. The numbers in the upper left frame (post-sagittal hemispheric view) denote the five structural types of isocortex (cf. Fig. 8 and 9 in the introductory chapter). Photos courtesy of Nikolaus Reiner, Manufaktur Chirurgischer Instrumente Carl Reiner GmbH, Vienna, Austria.

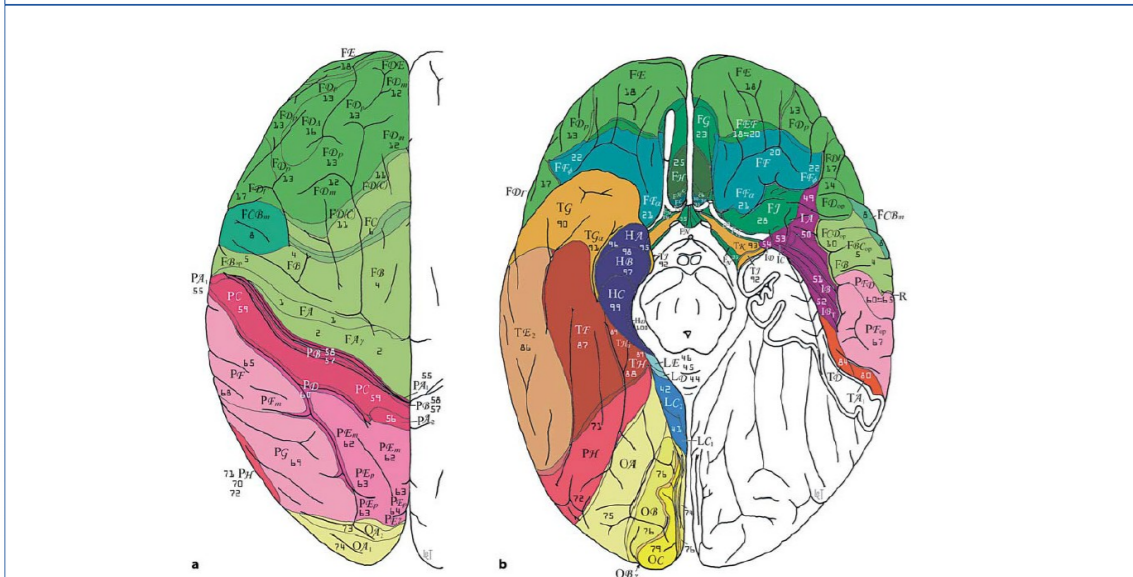


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### A virtual model in standard space

For improved usability, the model will be aligned to standard space i.e. MNI-152

- Comprehensive cytoarchitectonic information [1,2,7] – see figure above –
- will be assigned to the corresponding labels in 3D space
- The resulting digital atlas will be a result of manual verification using two copies of the plaster model, allowing for a more reliable reconstruction and error estimation both in geometry and texture

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Table 6. Summative table of quantitative data in sixteen fundamental areas of the frontal lobe. Overall layer thickness based on the present work. Separate data for the wall data and some additional values supplemented from Tables I, III, V and VI in Economo and Koskinas (1925, pp. 794-801).

Area symbol	Cortical layer	Layer thickness at dome (mm)	Layer thickness at wall (mm)	Layer thickness overall (mm)	Cell content (cells/mm <sup>2</sup> )	Cell size (µm <sup>2</sup> )
F.A. precentral area	I	0.18	0.20	0.18	7,000	5/6
	IIb				55,000	8/7
	IIIb	1.47	1.40	1.43	30,000	12/10
	IV				20,000	20/15
	V	0.70	0.40	0.55	15,000	30-40/20
F.a. agranular frontal area	I	0.22	0.27	0.22	7,000	4/8
	IIa				65,000	7/8
	IIIa	1.40	1.20	1.50	30,000	17/12
	IV				25,000	30/15
	V	0.50	0.47	0.50	25,000	30-40/20-25
F.c. intermediate frontal area	I	0.26	0.38	0.25	5,000	4/8
	II	0.32	0.17	0.35	17,000	7/5
	IIIa	1.00	0.90	1.00	24,000	15-20/8-12
	IIIc				28,000	30-50/10-20
	IV	0.30	0.25	0.15	45,000	15-15/8
F.c.a. macrocellular agranular intermediate frontal (Broca's) area	I	0.21	0.27	0.24	5,000	4/8
	II	0.38	0.18	0.38	55,000	15-15/4-6
	IIIa	1.00	1.00	1.00	28,000	15-20/8-12
	IIIc				28,000	30-50/10-20
	IV	0.15	0.18	0.17	60,000	15-15/8
F.o. granular frontal area	I	0.21	0.23	0.20	9,000	4-6/8-10
	II	0.38	0.20	0.39	75,000	10-15/4-6
	IIIa	0.78	0.89	0.80	32,000	15-20/7-10
	IIIb				16,000	15-20/10-20
	IV	0.31	0.36	0.34	85,000	6-10/5-8
F.o.a. middle granular frontal area	I	0.25	0.27	0.26	9,000	4-6/8-10
	II	0.38	0.20	0.20	65,000	10-15/4-6
	IIIa	0.82	0.80	0.81	32,000	15-20/7-10
	IIIb				16,000	20-30/10-15
	IV	0.40	0.30	0.35	30,000	6-8/4-8
F.o.p. triangular granular frontal area	I	0.18	0.25	0.21	8,000	4-6/8-10
	II	0.12	0.16	0.14	65,000	6-7/4-6
	IIIa	0.78	1.05	0.91	25,000	20-40/15-40
	IIIb				70,000	6-8/4-8
	IV	0.38	0.40	0.39	30,000	15-30/15-25
V				12,000	20/10	
	VI	0.50	0.36	0.70	37,500	20/8-10
	VII				18,000	10-16, 18

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