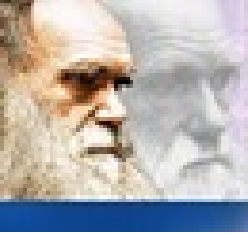
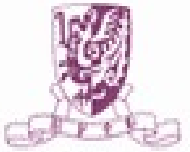


語言工程實驗室
Language Engineering Laboratory



SOUND PATTERNS IN LANGUAGE

InterSpeech, Singapore
September 14-18, 2014

William S-Y. Wang
Center for Language & Human Complexity
Chinese University of Hong Kong

Sound Patterns in Language

- **How is speech possible?**
- African origins, diversity in genes & words.
- Three case studies of sound patterns in motion.

  Consonants & Grimm's Law.

  Vowels & the Great Vowel Shift in English.

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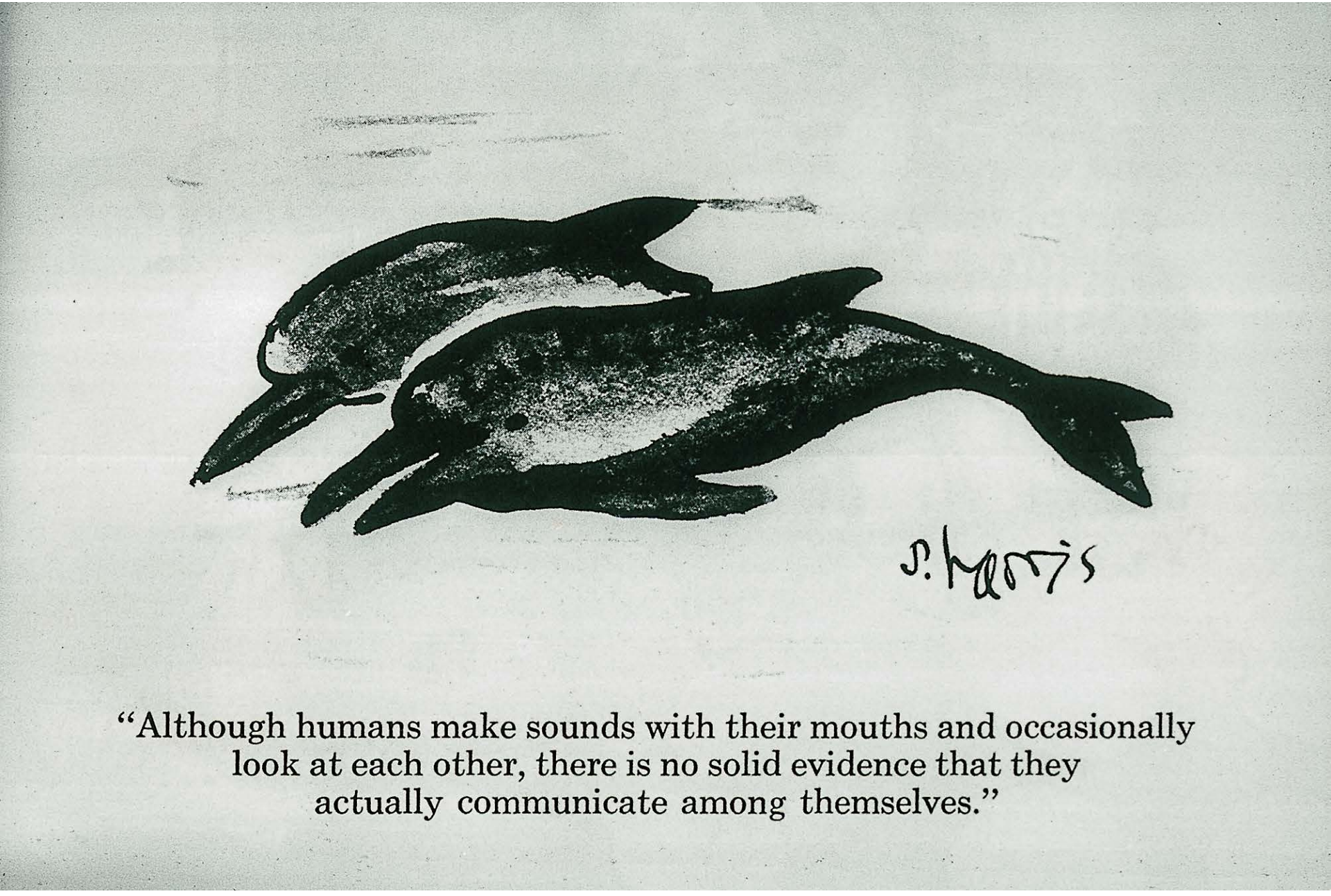
- Speech & music, two cultural universals.
- Summary.

Diverse languages, diverse cultures.

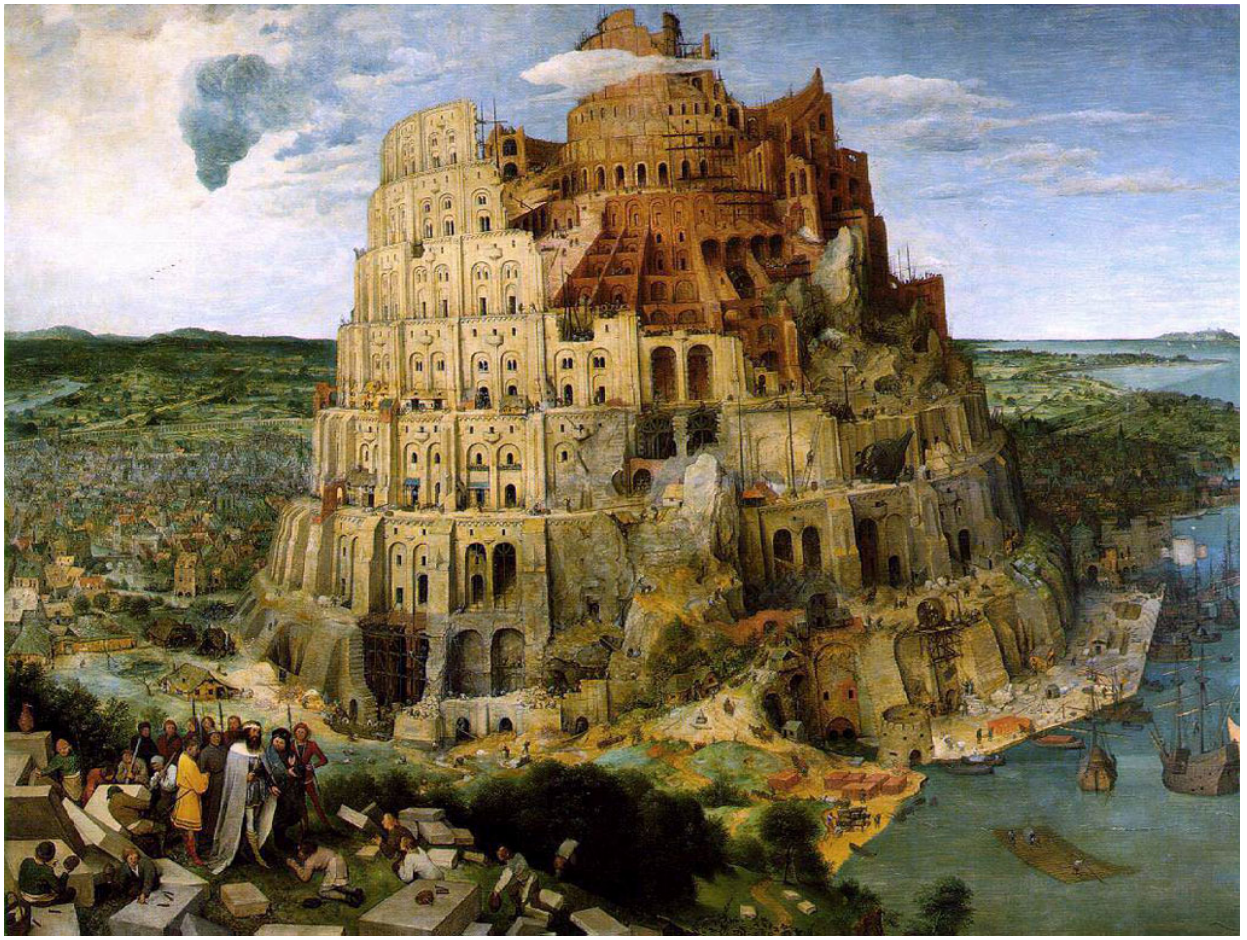


"Although humans make sounds with their mouths and occasionally look at each other, there is no solid evidence that they actually communicate among themselves."

Language Diversity:
an early account

Tower of Babel
圣经故事：
古人建筑巴贝儿塔

Painting by
Pieter Bruegel
1525-69



Genesis *11:7* “Go to, let us go down, and there confound their language, that they may not understand one another's speech.”

Henry Higgins in My Fair Lady:

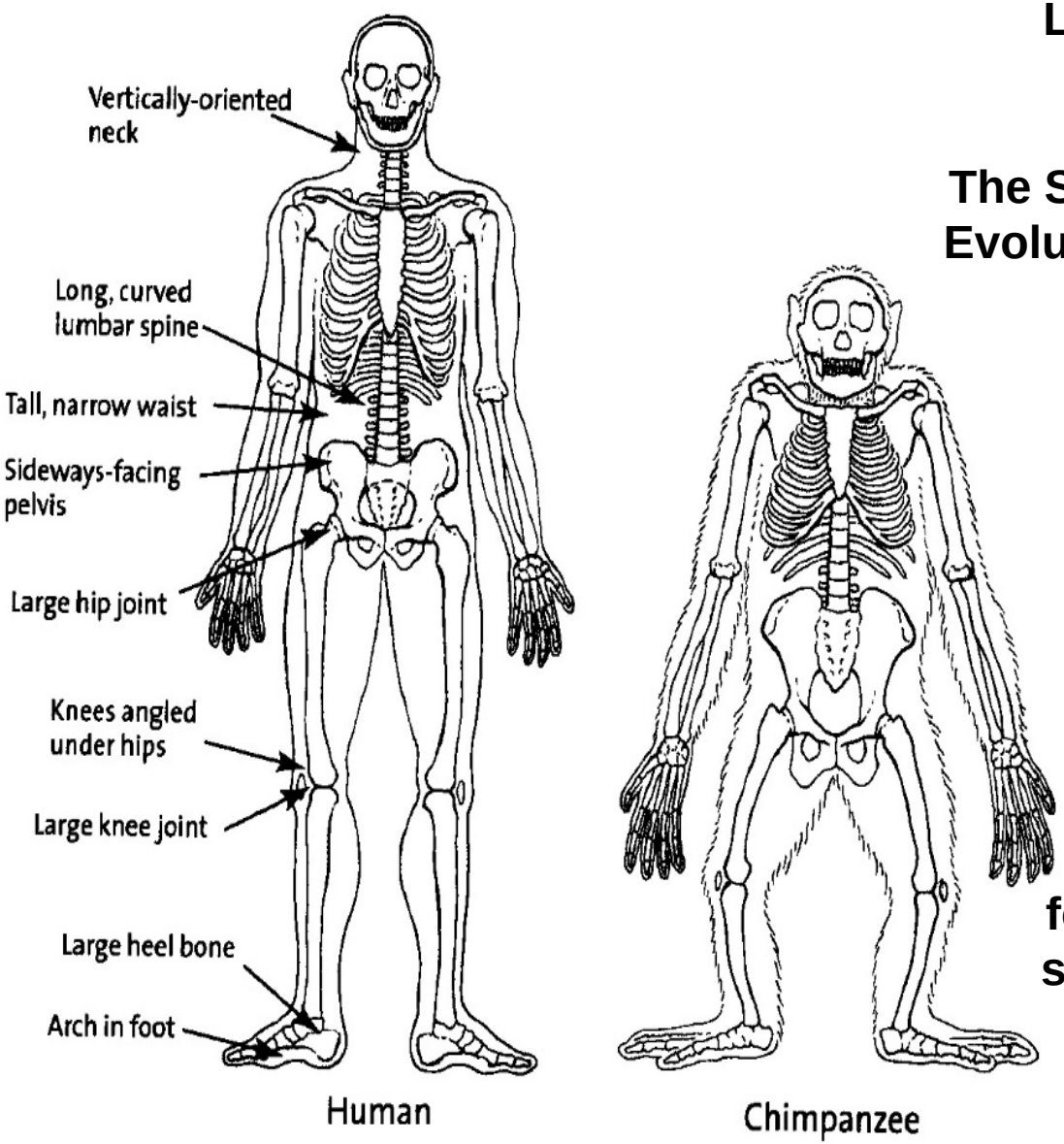
"An Englishman's way of speaking absolutely classifies him. The moment he talks he makes some other Englishman despise him. One common language I'm afraid we'll never get.

Oh, why can't the English learn to set a good example to people whose English is painful to your ears? The Scotch and the Irish leave you close to tears. There even are places where English completely disappears. In America, they haven't used it for years!"

Johanson, D. &
B. Edgar. 1996.
From Lucy to Language.
Simon & Schuster.

Lieberman, D.E. 2013.
Figure 3.

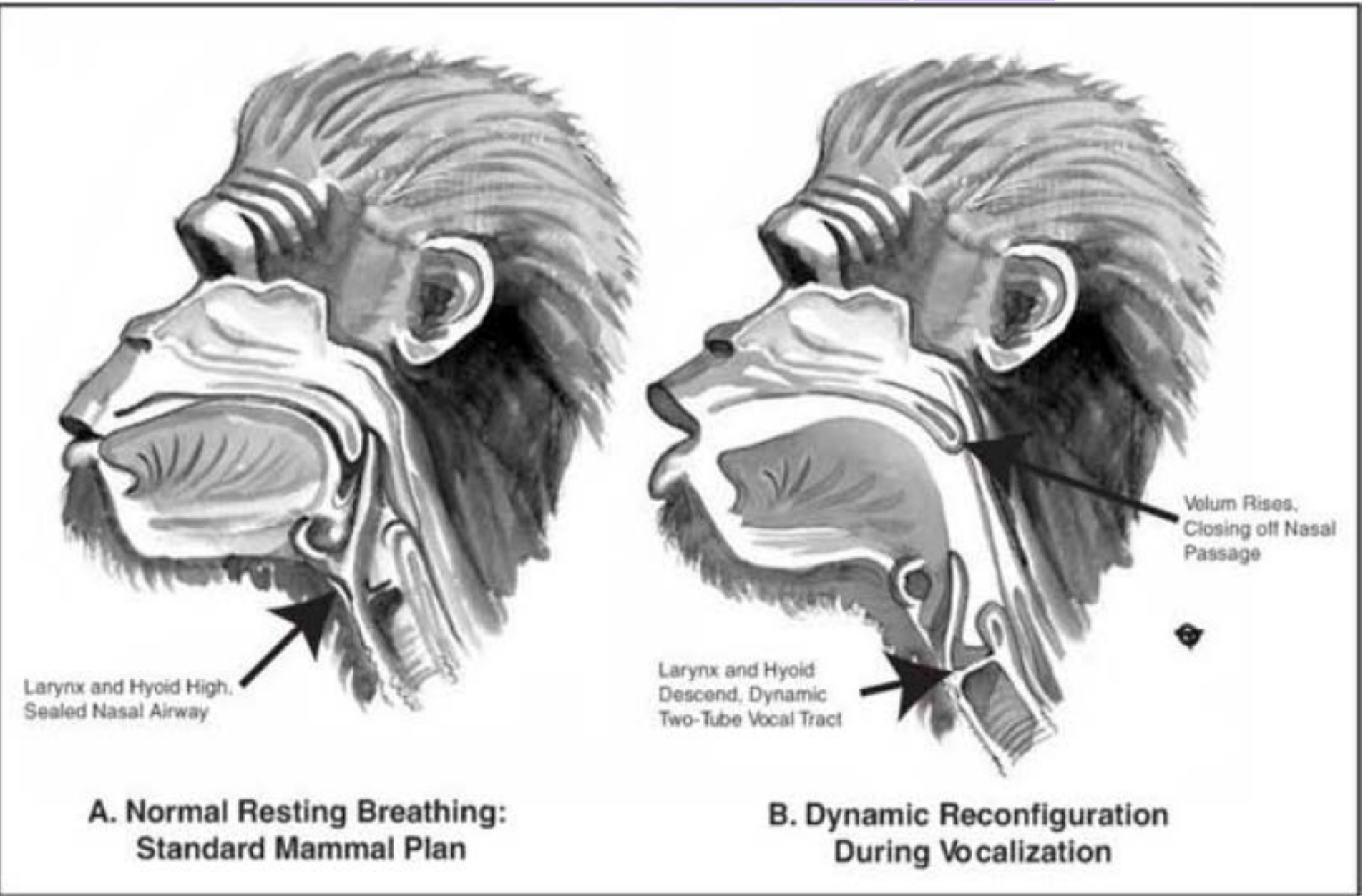
The Story of the Human Body: Evolution, health, and disease. Pantheon.

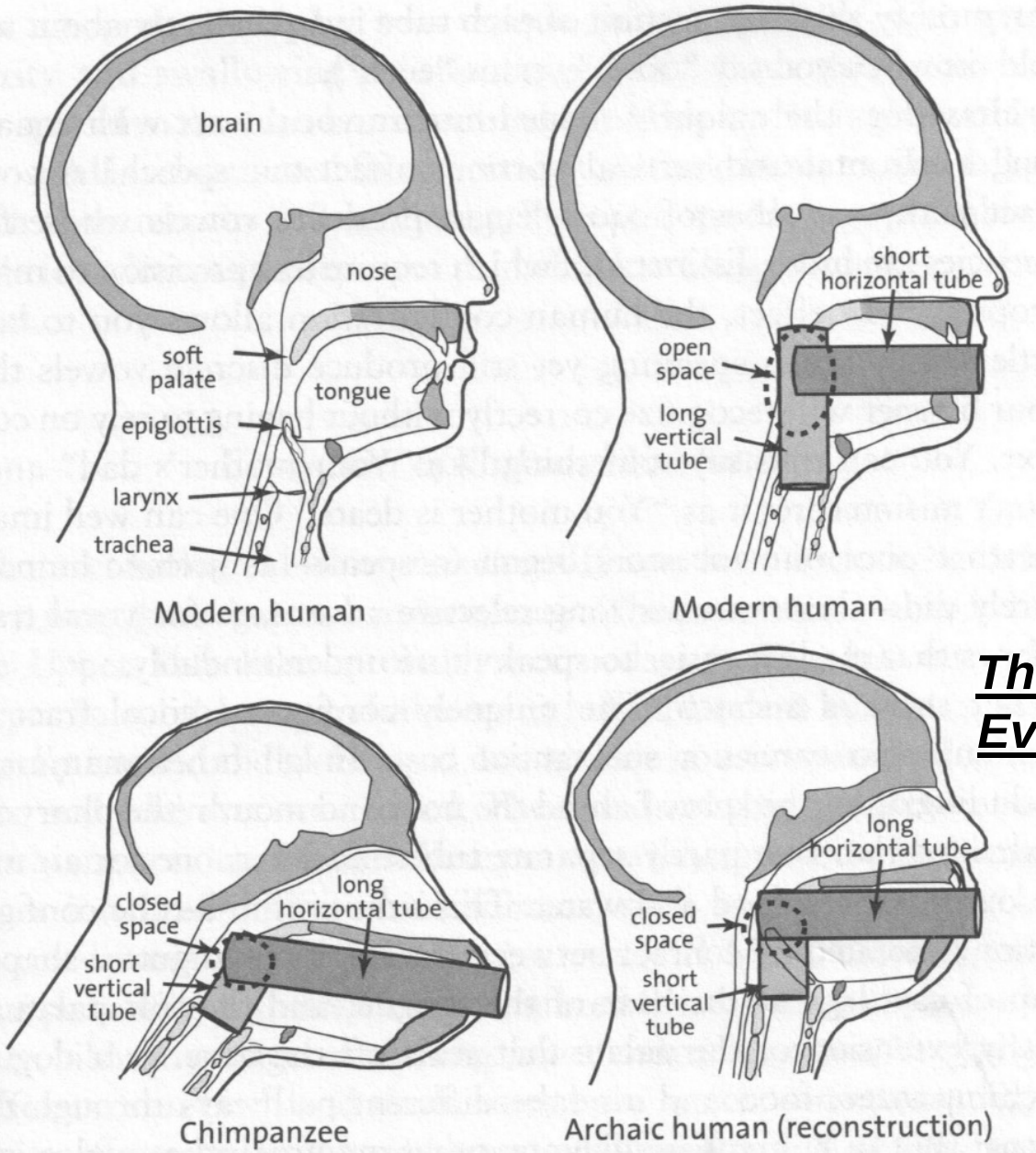


Adaptations for bipedal posture in standing and walking.

Twin-tube vocal tract.

W.T.Fitch. 2010. *The Evolution of Language*. Fig.8.5.

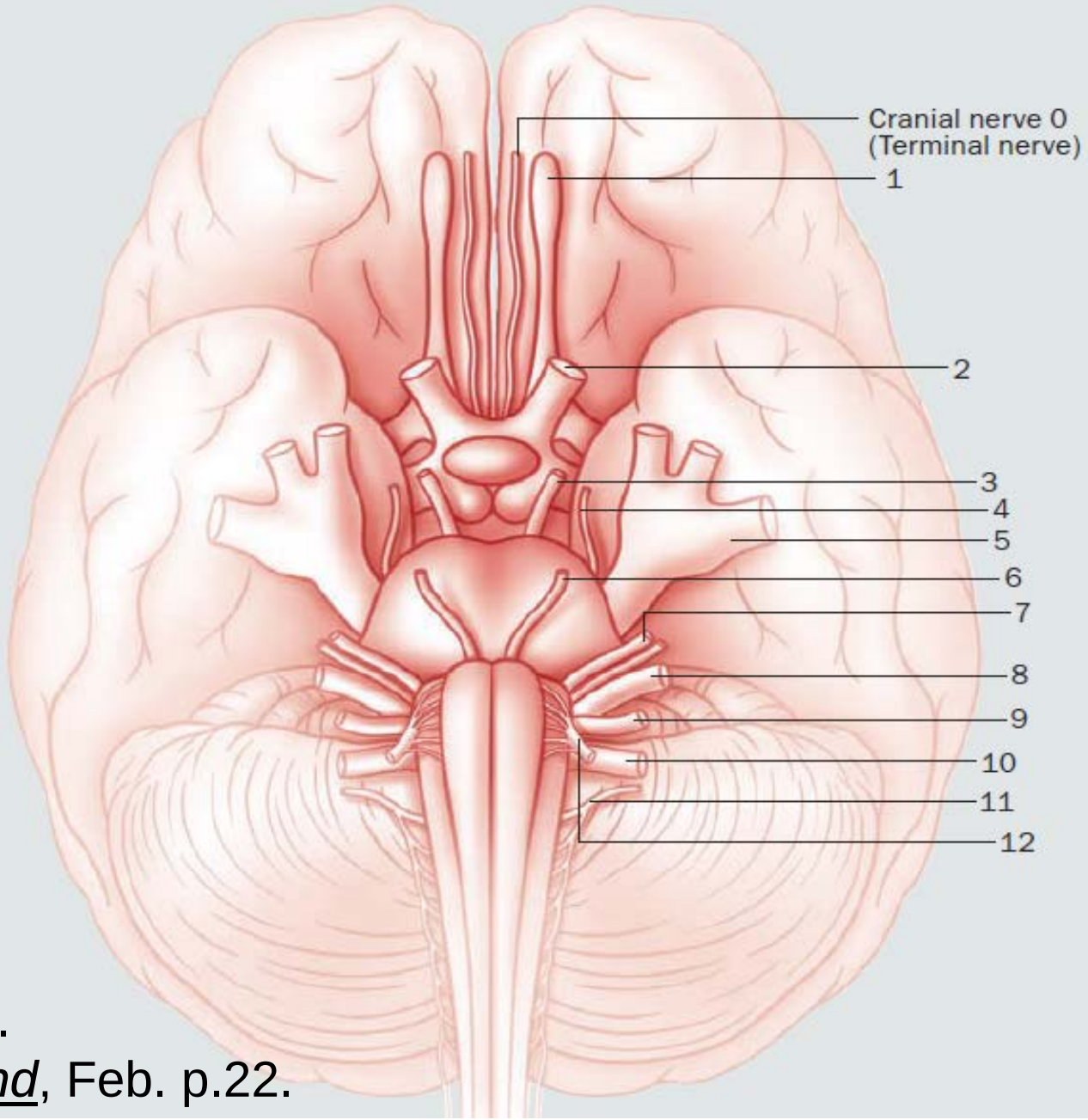




Lieberman, D.E. 2013. Figure 16.

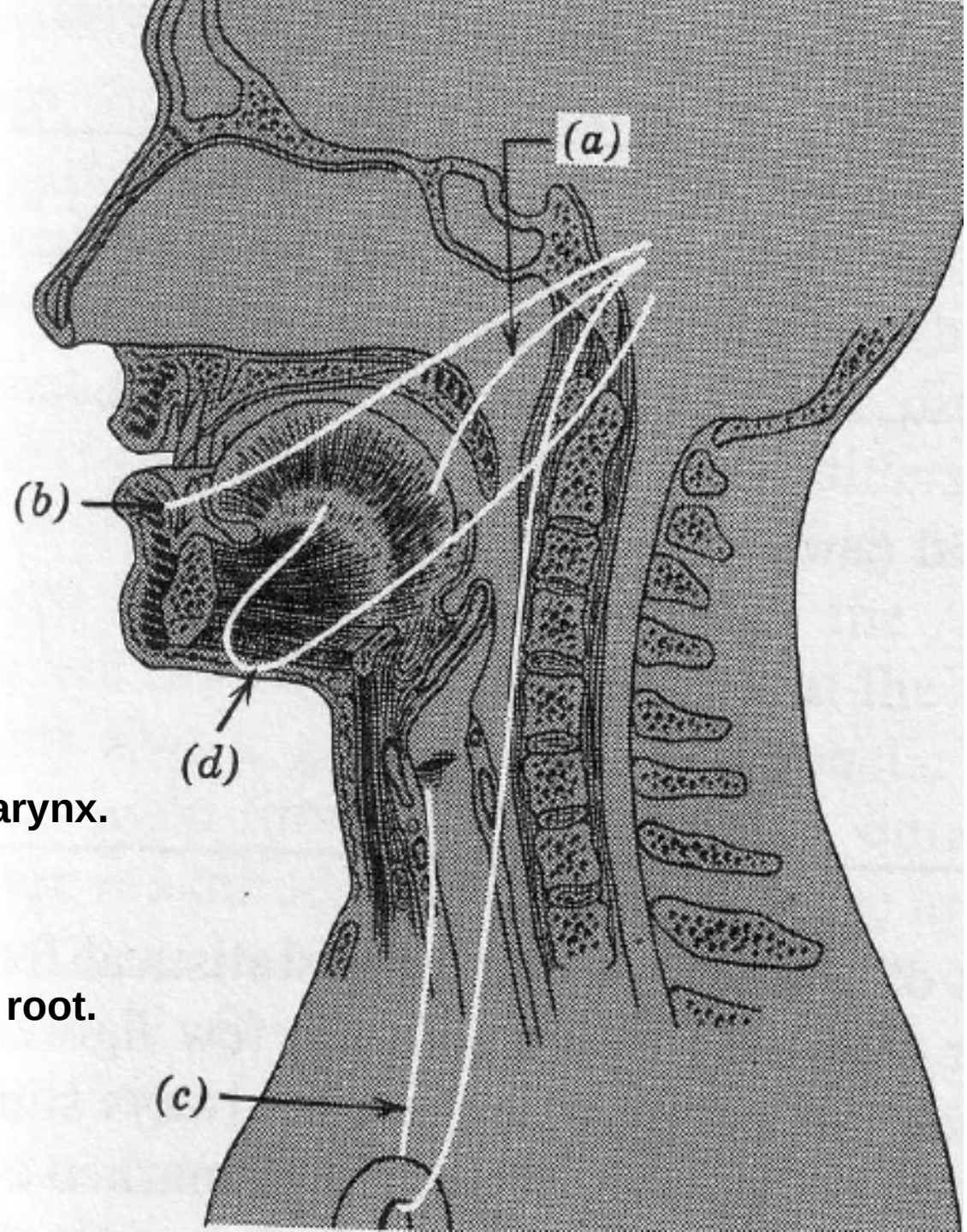
***The Story of the Human Body: Evolution, health, and disease*. Pantheon.**

Cranial nerves emerge from the floor of the brain in pairs; each pair is numbered from the front of the brain (closest to the forehead) to the back (near the spinal cord). Cranial nerve zero (also called the terminal nerve) is not in typical textbooks. Anatomists historically missed the thin nerve, perhaps because it is often inadvertently pulled off along with the tough membranes that wrap the brain.



R.D.Fields. 2007.
Sex & the secret nerve.
Scientific American Mind, Feb. p.22.

Lenneberg, E.H. 1967:95. Biological Foundations of Language.



a: V trigeminal – jaw.

b: VII facial – lips.

c: X vagus, recurrent nerve - larynx.

d: XII hypoglossal – tongue.

IX glossopharyngeal – tongue root.

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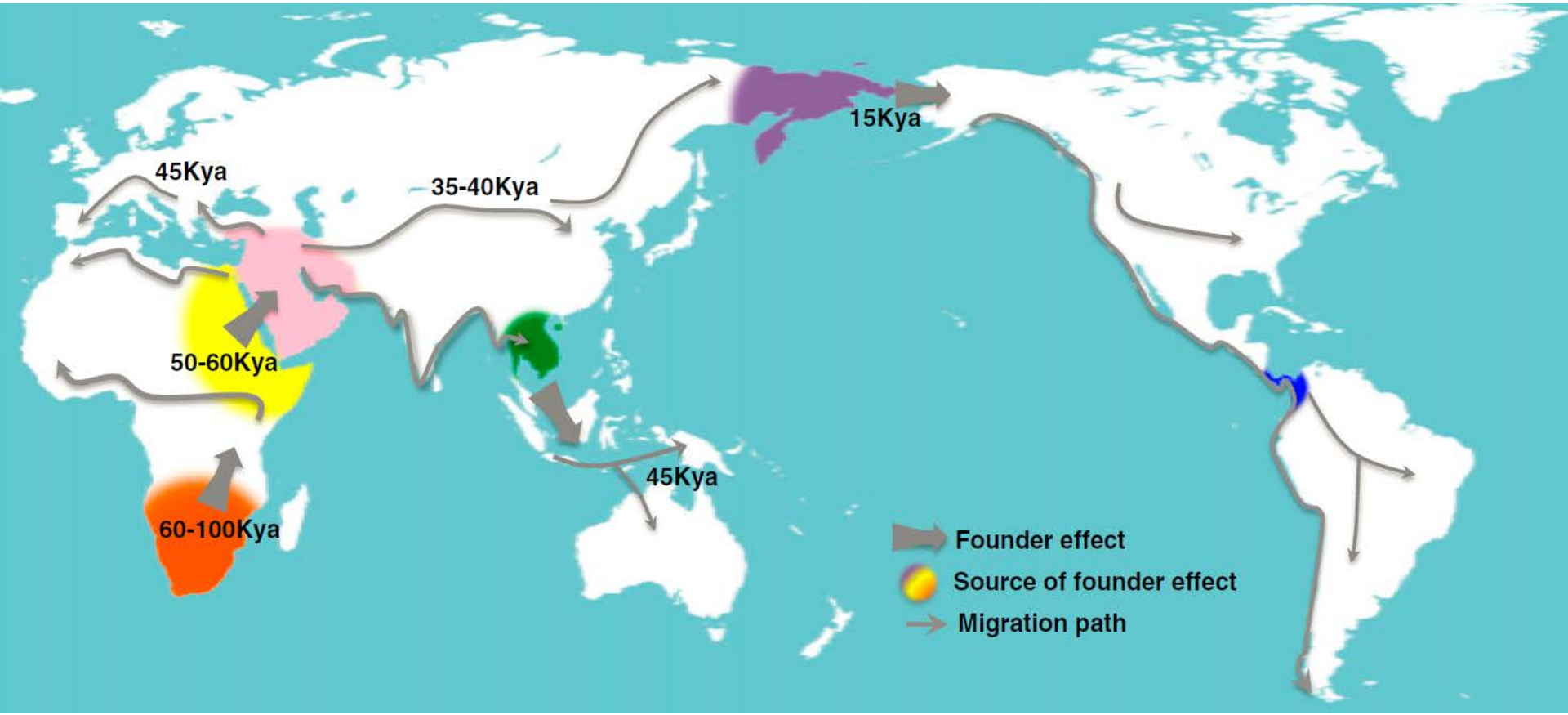
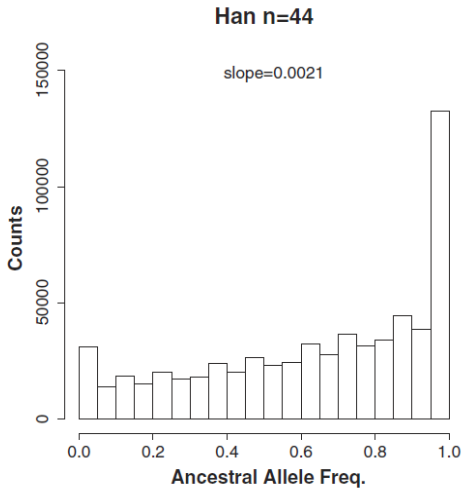
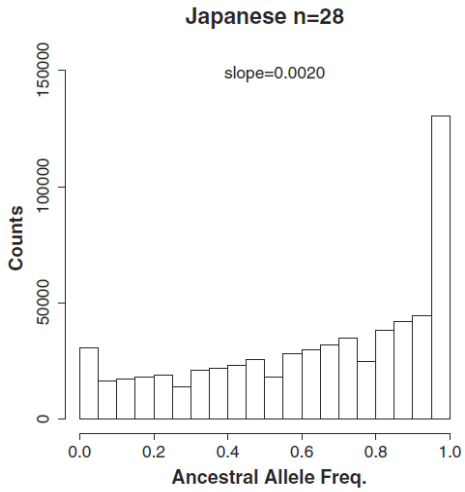


Henn, B.M., L.L.Cavalli-Sforza & M.W. Feldman. 2012. The great human expansion. *PNAS* 109.17758–64. Fig.1.





Maximum likelihood tree constructed from 938 individuals from 51 populations at 650,000 common single-nucleotide polymorphism loci. Branches colored by regions. * indicates the root of the tree, also where the chimpanzee branch is located.

Li, J.Z. et al. 2008. Worldwide Human Relationships Inferred from Genome-Wide Patterns of Variation. *Science* Fig.1 & 4.

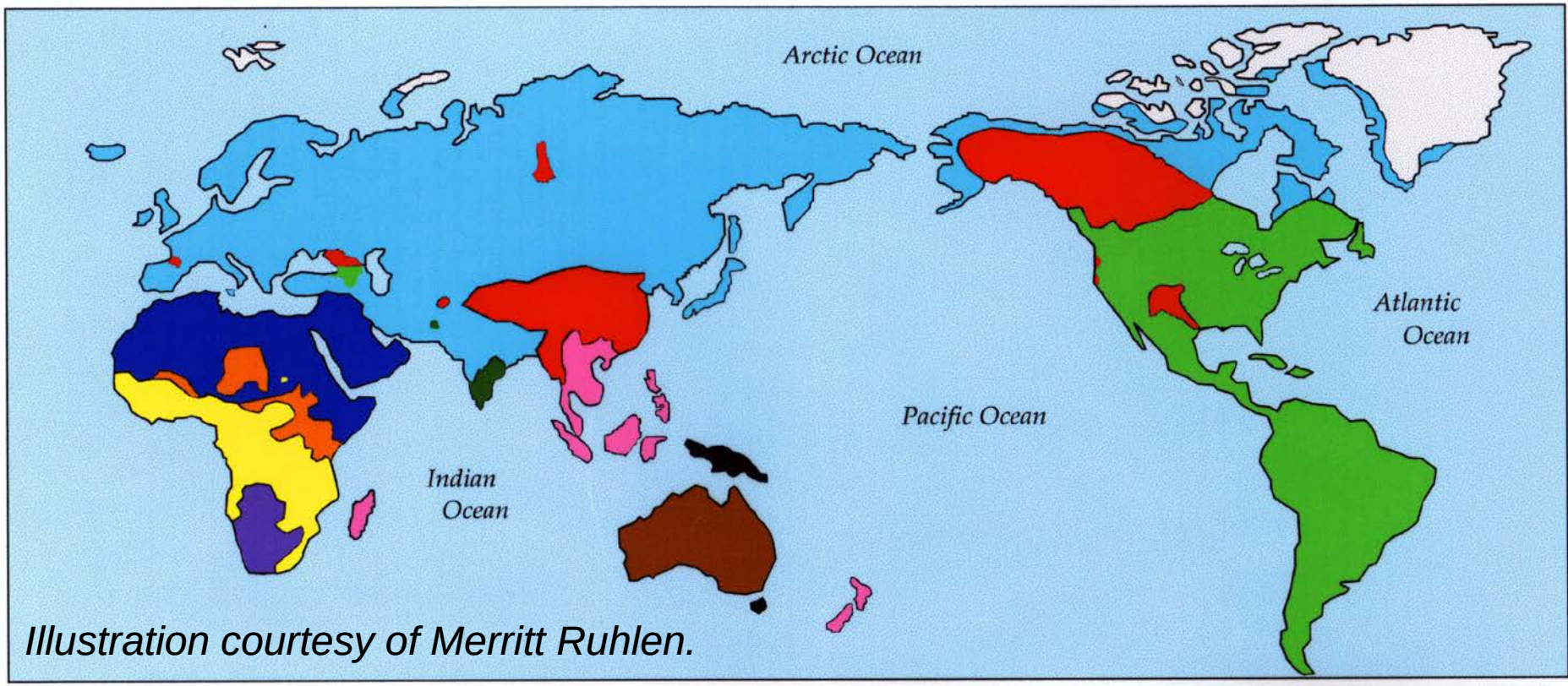


Illustration courtesy of Merritt Ruhlen.

Khoisan
Niger-Kordofanian
Nilo-Saharan
Afro-Asiatic
Dravidian
Kartvelian
Eurasiatic
Dene-Caucasian
Austric
Indo-Pacific
Australian
Amerind

Language Families of the World (after Greenberg)

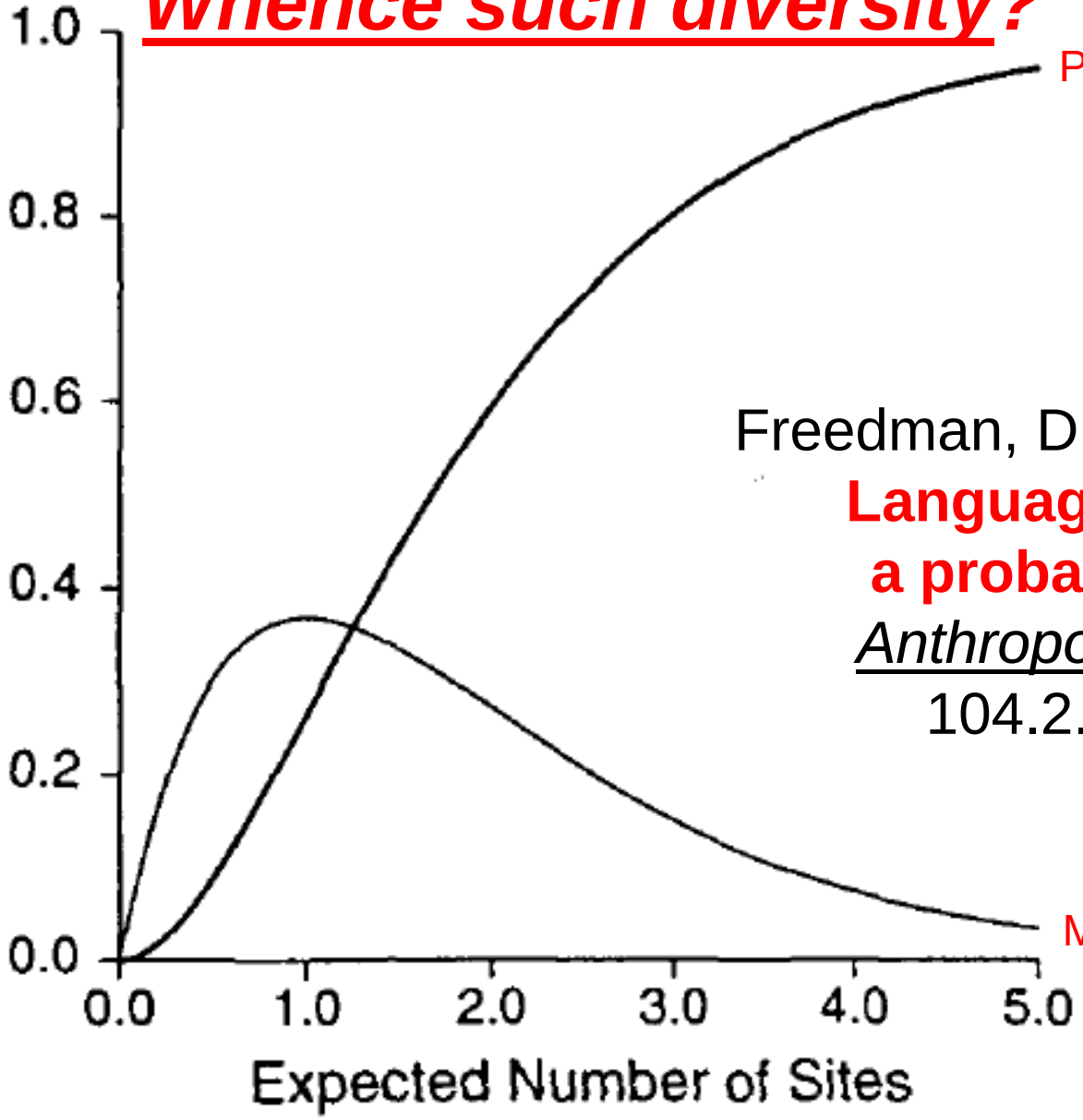
Table 1. Distribution of world languages by area of origin

Area	Living languages		Number of speakers
	Count	Percent	Total
Africa	2,146	30.2	810,209,997
Americas	1,060	14.9	51,456,819
Asia	2,303	32.4	3,770,496,032
Europe	285	4.0	1,656,808,477
Pacific	1,312	18.5	6,740,866
Totals	7,106	100.0	6,295,712,191

SIL International Publications
7500 West Camp Wisdom Road
Dallas, TX 75236-5629 USA

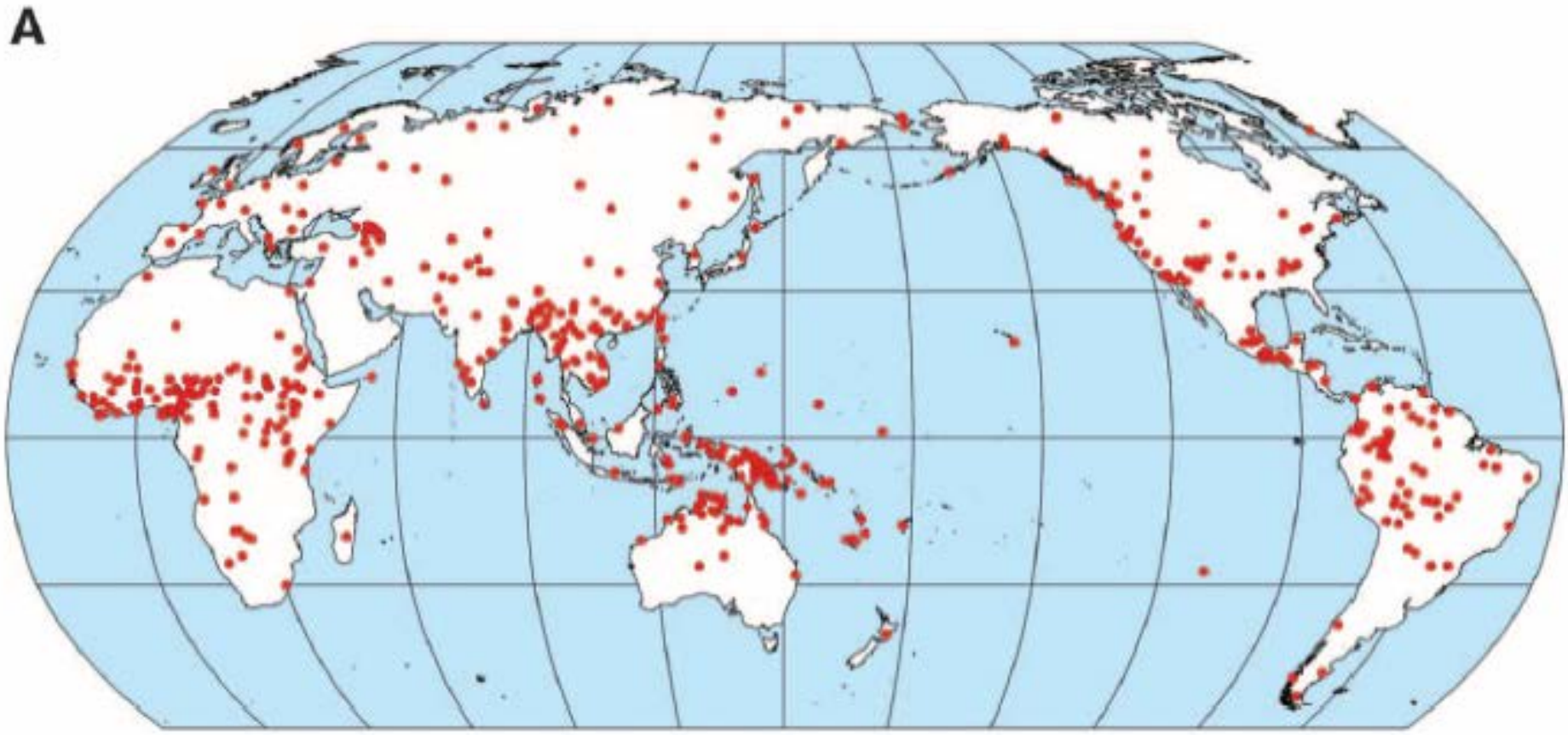
Ethnologue: Languages of the World.
17th edition.
http://www.ethnologue.com.

Whence such diversity?



Freedman, D.A. & W.S-Y. Wang..
Language polygenesis:
a probabilistic model.
Anthropological Science
104.2.131-8, 1996.

Atkinson, Q. D. 2011. **Phonemic Diversity Supports a Serial Founder Effect Model of Language Expansion from Africa.** *Science* 332.346-9.



Data on **504 languages** from: M. Haspelmath, M. S. Dryer, D. Gil, B. Comrie, Eds.,

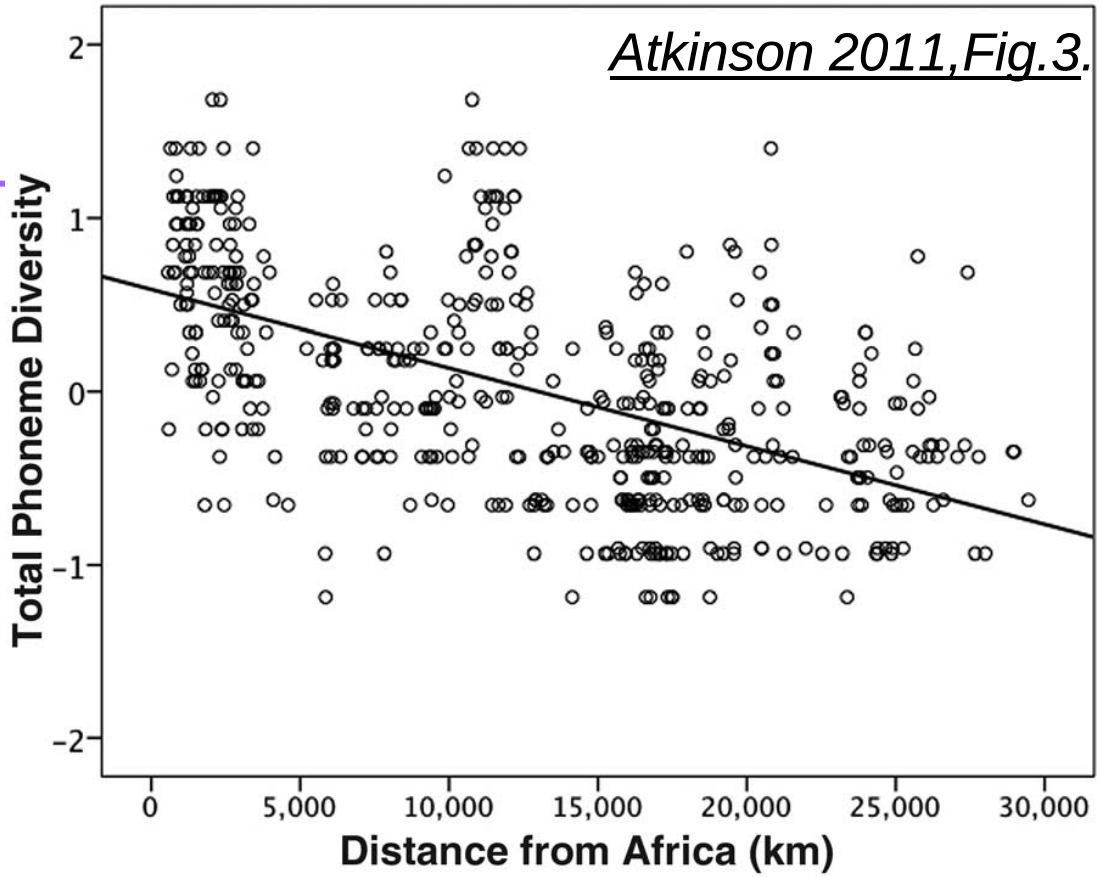
The World Atlas of Language Structures Online (WALS)

(Max Planck Digital Library, Munich, 2008).

Atkinson, Q. D. 2011.

Phonemic Diversity Supports a Serial Founder Effect Model of Language Expansion from Africa. *Science* 332.346-9.

".. Here I show that the number of phonemes used in a global sample of 504 languages is also clinal and fits a serial founder–effect model of expansion from an inferred origin in Africa. This result, which is not explained by more recent demographic history, local language diversity, or statistical non-independence within language families, points to parallel mechanisms shaping genetic and linguistic diversity and supports an African origin of modern human languages."



R. Van Tuyl, A. Pereltsvaig
M. Cysouw, D. Dediu, S. Moran,
C.-C. Wang, Q.-L. Ding, H. Tao, H. Li,

Critiques from the 3 groups of scholars, as well as Atkinson's response are available in *Science* 335, 657-b,c,d,e, Feb.10, 2012.

M.Cysouw, D.Dediu, S.Moran, Comments on Atkinson 2011. *Science* Feb.11, 2012.

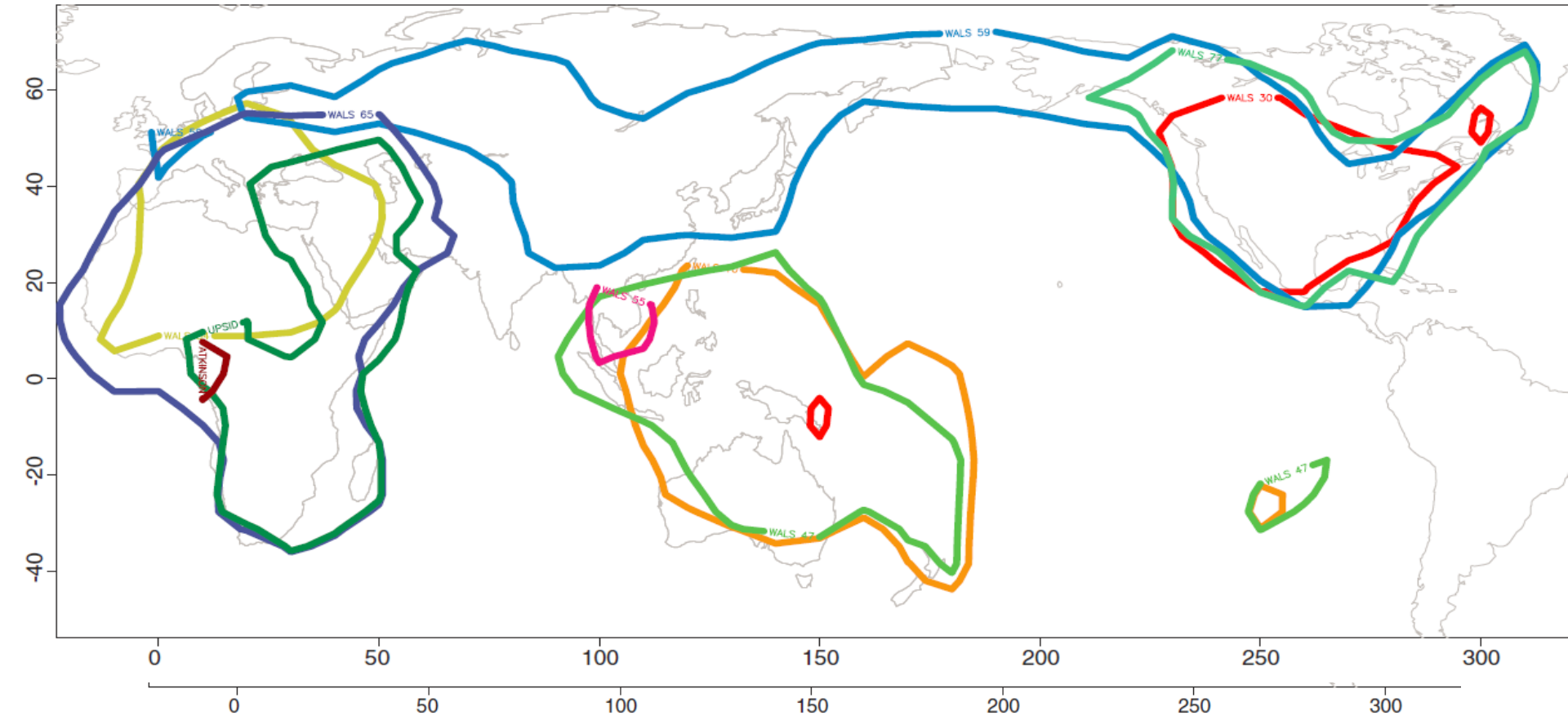


Fig.1. Areas of "origin" of various other inventory-like linguistic characteristics as identified using Atkinson's methodology. Notably, the origins are dispersed over the whole globe & not concentrated in Africa. The dark red area in Africa is the origin of phoneme inventories as proposed by Atkinson. … The small red area on the eastern tip of New Guinea is the origin for the UPSID phoneme inventory data using a quadratic geographical distance model.

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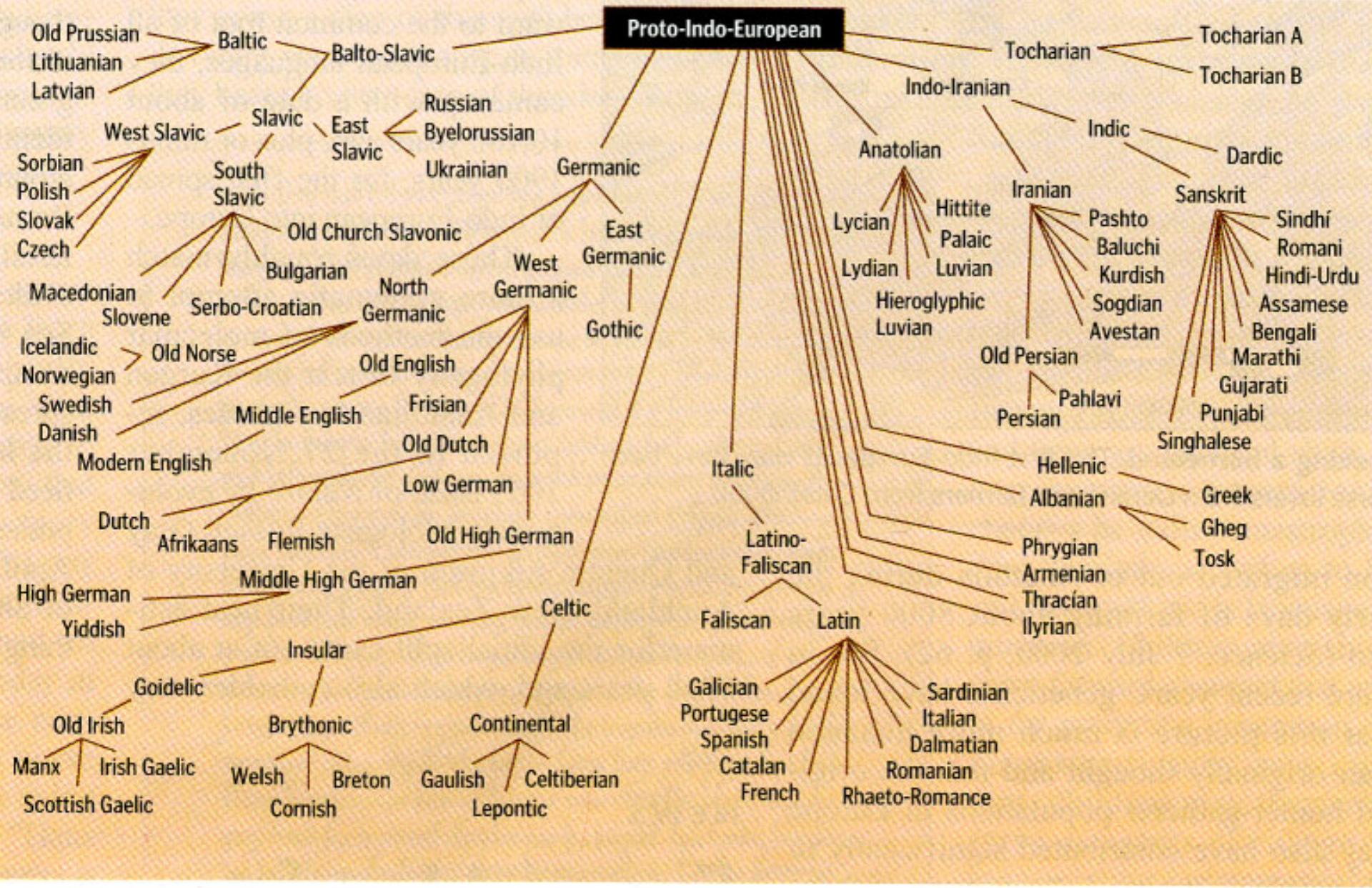
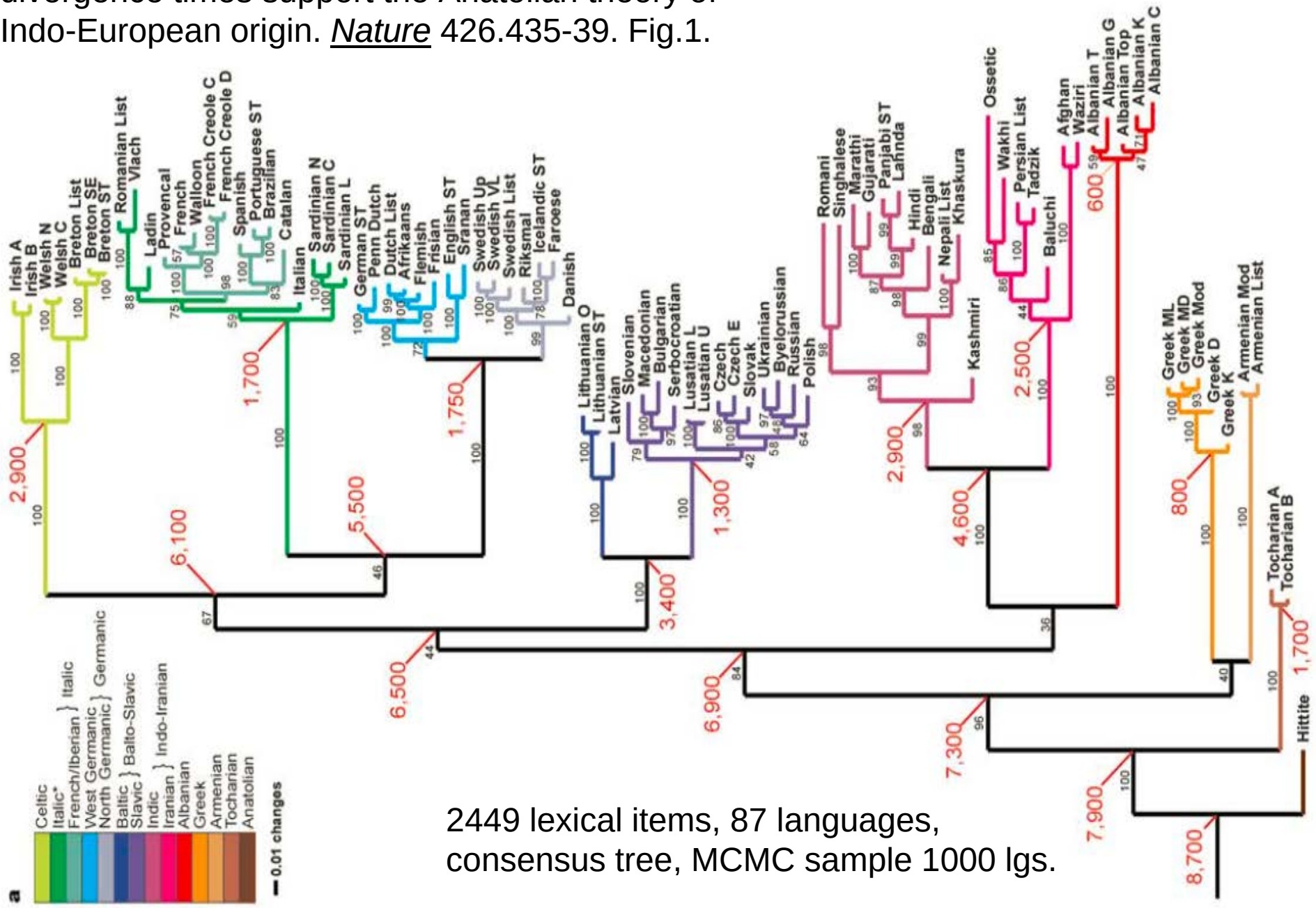
Science *Feb.27,2004.*

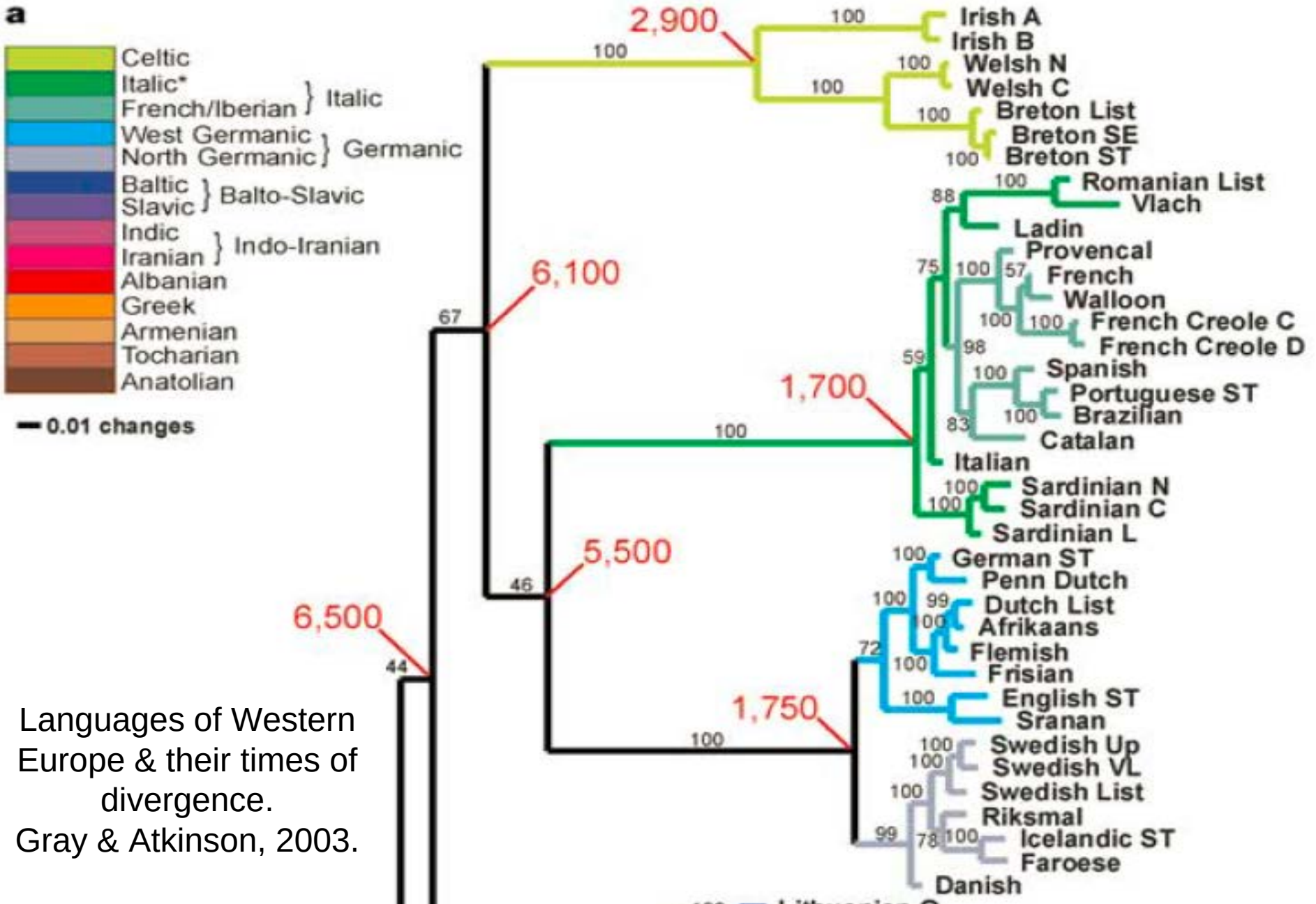


Say it in Indo-European. The 144 languages of this family descend from one ancient mother tongue.

Gray, R D. & Q. D. Atkinson. 2003. Language-tree divergence times support the Anatolian theory of Indo-European origin. *Nature* 426.435-39. Fig.1.



2449 lexical items, 87 languages, consensus tree, MCMC sample 1000 lgs.



Languages of Western Europe & their times of divergence.
Gray & Atkinson, 2003.

Words for low integers in some Indo-European languages.

from C.Renfrew 1989. Scientific American.

ENGLISH	GOTHIC	LATIN	GREEK	SANSKRIT	JAPANESE
ONE	AINS	UNUS	HEIS	EKAS	HITOTSU
TWO	TWAI	DUO	DUŌ	DVĀ	FUTATSU
THREE	THREIS	TRS	TREIS	TRAYAS	MITTSU
FOUR	FIDWOR	QUATTUOR	TETTARES	CATVĀRAS	YOTTSU
FIVE	FIMF	QUINQUE	PENTE	PANCA	ITSUTSU
SIX	SAIHS	SEX	HEKS	ṢAṬ	MUTTSU
SEVEN	SIBUN	SEPTEM	HEPTA	SAPTA	NANATSU
EIGHT	AHTAU	OCTO	OKTŌ	AṢṬĀ	YATSU
NINE	NIUN	NOVEM	ENNEA	NAVA	KOKONOTSU
TEN	TAIHUN	DECEM	DEKA	DAŚA	TO

Integer	*English*	*Gothic*	*Latin*	*Greek*	*Sanskrit*
two, ten	**t-**	**t-**	**d-**	**d-**	**d-**
three	**th-**	**th-**	**t-**	**t-**	**t-**
eight, ten	**‘-gh-’**	**-h-**	**-k-**	**-k-**	**-s-**
six, seven	**s-**	**s-**	**s-**	**h-**	**s-**

Indo-European correspondences in low integers.

Grimm's Law: PIE > Germanic

b^h > b

*b^hrat**r**, **b**ro**th**er*

b > p

*la**b**-, li**p***

p > f

*pe**d**-, **f**oo**t***

d^h > d

*mad^hu, mea**d***

d > t

***d**ec-, **t**en*

t > θ

d**en**t**-, **t**oo**th

g^h > g

g > k

*g**enu**, **k**nee*

k > h

***c**anis, **h**ound*

Great Vowel Shift.

a > e	**e > i**	**i > a^{i}**
sanity > sane	serenity > serene	divinity > divine
gratitude >grateful	kept > keep	Christmas > Christ
opacity > opaque	shepherd > sheep	hid > hide
tabular > table	obscenity > obscene	linear > line
chastity > chaste	leapt > leap	fifth > five

Jespersen, O. 1922. Language: Its Nature, Development, and Origin.

Wang, W.S-Y. 1968. Vowel features, paired variables and the English vowel shift. Language 44.695-708.

Longacre, R.E. 1952. Five phonemic pitch levels in Trique. *Acta Linguistica* 7.62-81.

- gu^{5} du^{5} ?we^{5} ku^{1} ‘I will see bones’
- gu^{5} du^{5} ?we^{5} jo^{2} ‘I will see palm baskets’
- gu^{5} du^{5} ?we^{5} ka^{3} ‘I will see squash’
- gu^{5} du^{5} ?we^{5} ?a^{4} ‘I will see nine’
- gu^{5} du^{5} ?we^{5} za^{5} ‘I will see eleven’

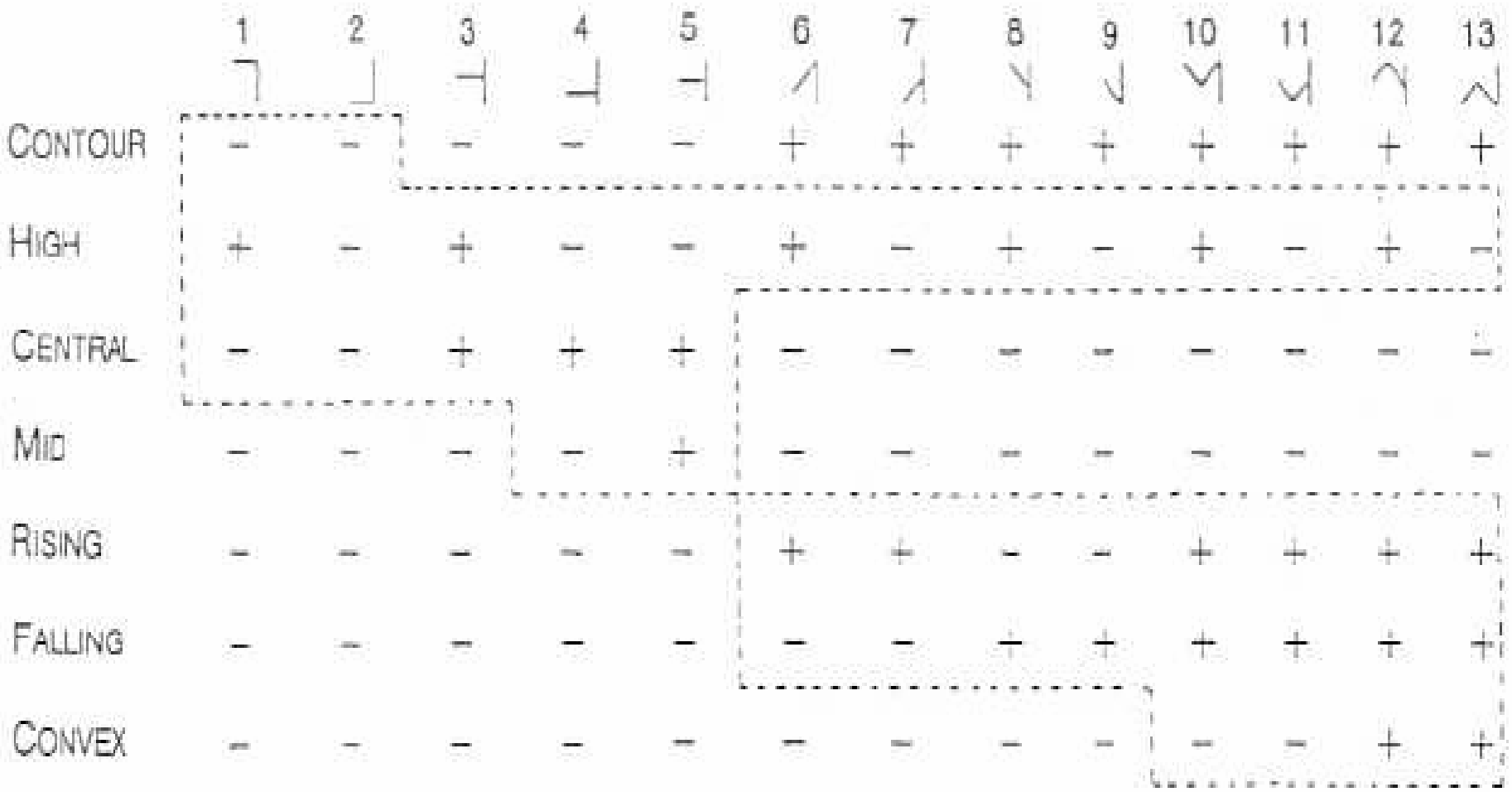
In these examples from Trique, 1 indicates high pitch.
CHAO, Yuen Ren. 1930. A system of tone letters. *Le Maître Phonétique 45: 24-27.*

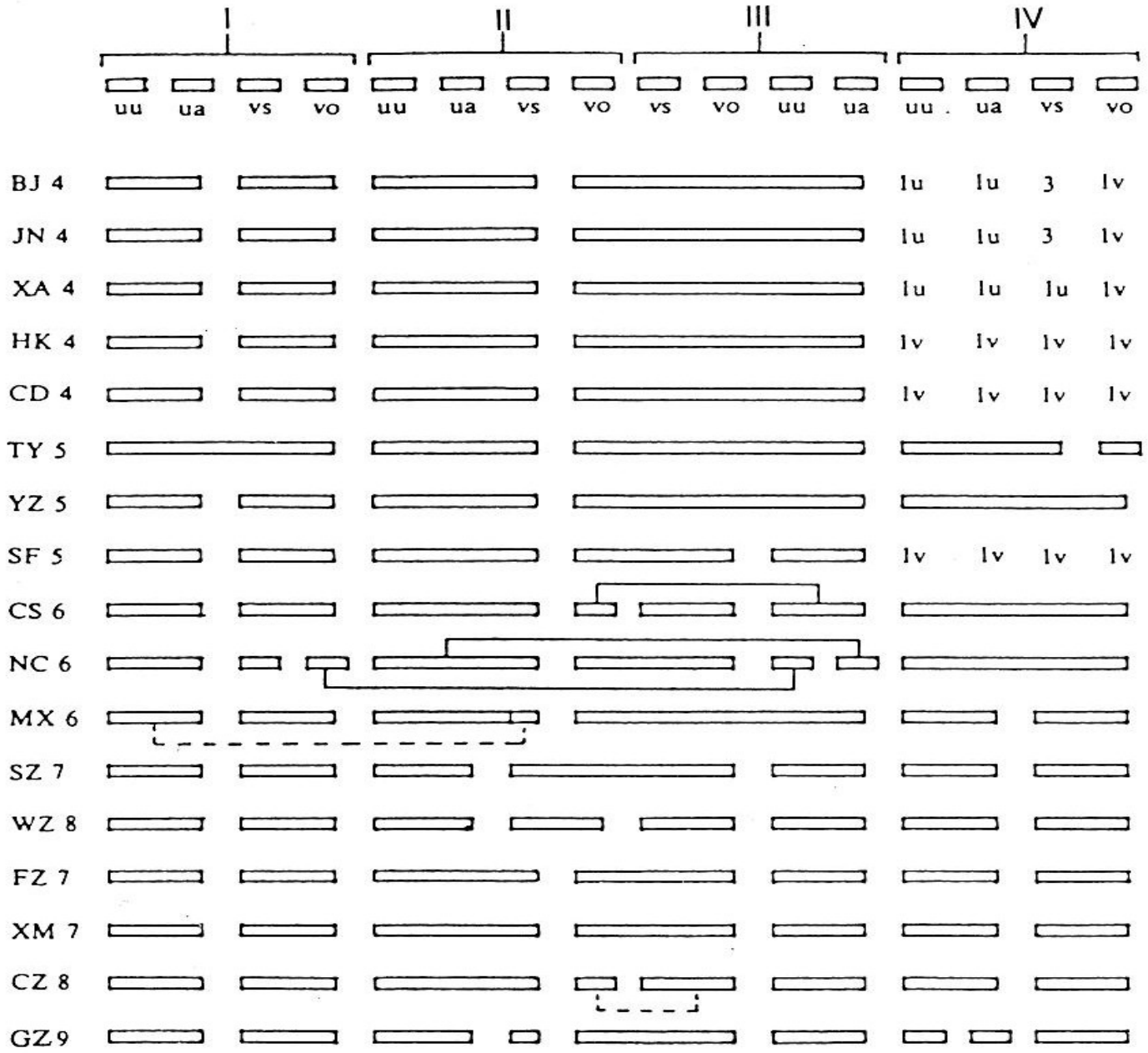
/kl-/ clusters in Old Chinese

京	ging^{1}	*capital*		涼	loeng^{4}	*cool*
各	gok^{3}	*each*		路	lou^{6}	*road*
監	gaam^{1}	*oversee*		藍	laam^{4}	*blue*
見	gin^{3}	*see*		覽	laam^{5}	*view*

粵語拼音字表，第二版。

Wang, W.S-Y. Phonological features of tone.
International Journal of American Linguistics 33.93-105, 1967.



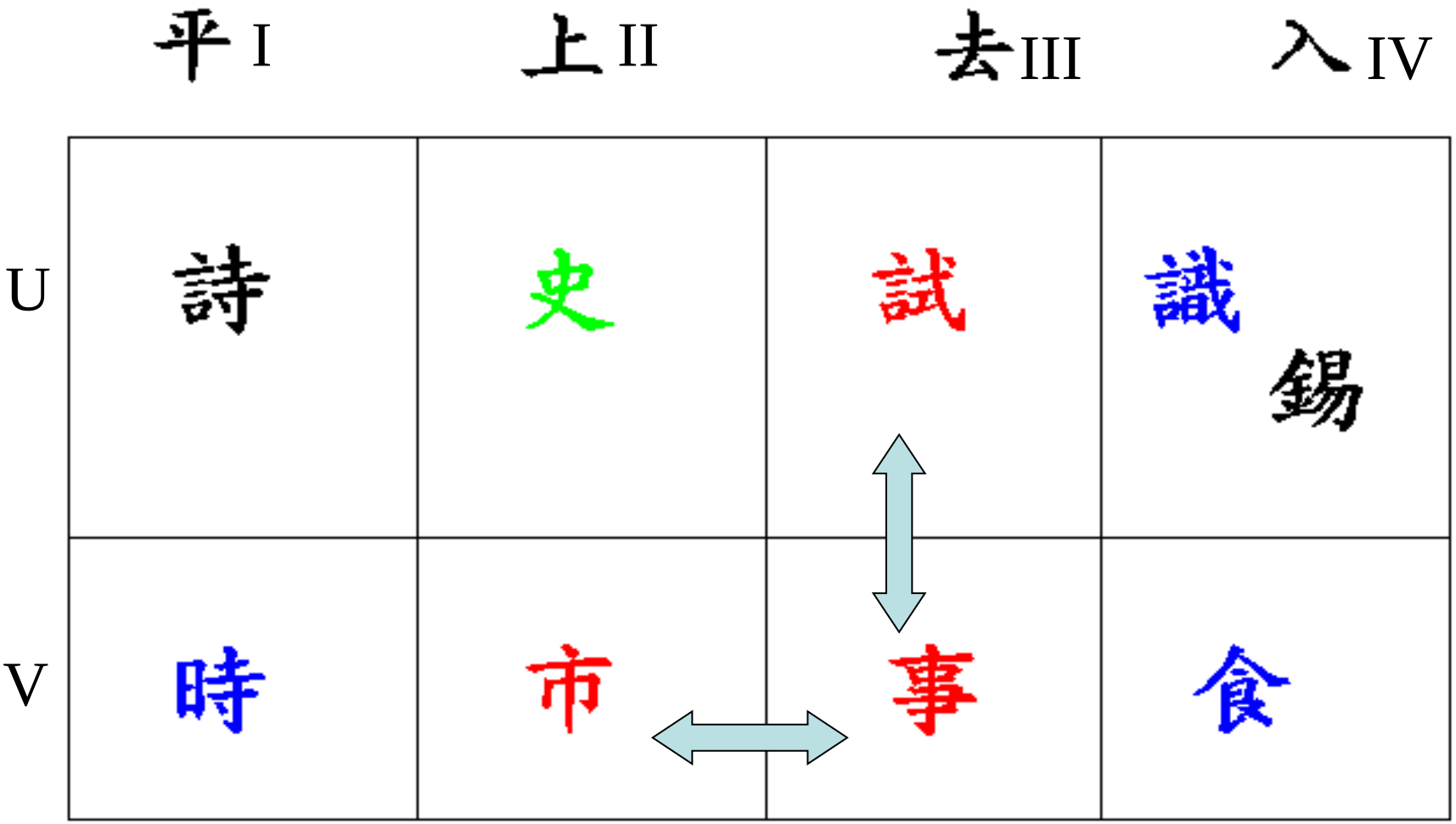


W.S-Y.Wang
& C.C.Cheng.
1987.

Middle Chinese tones in modern dialects.

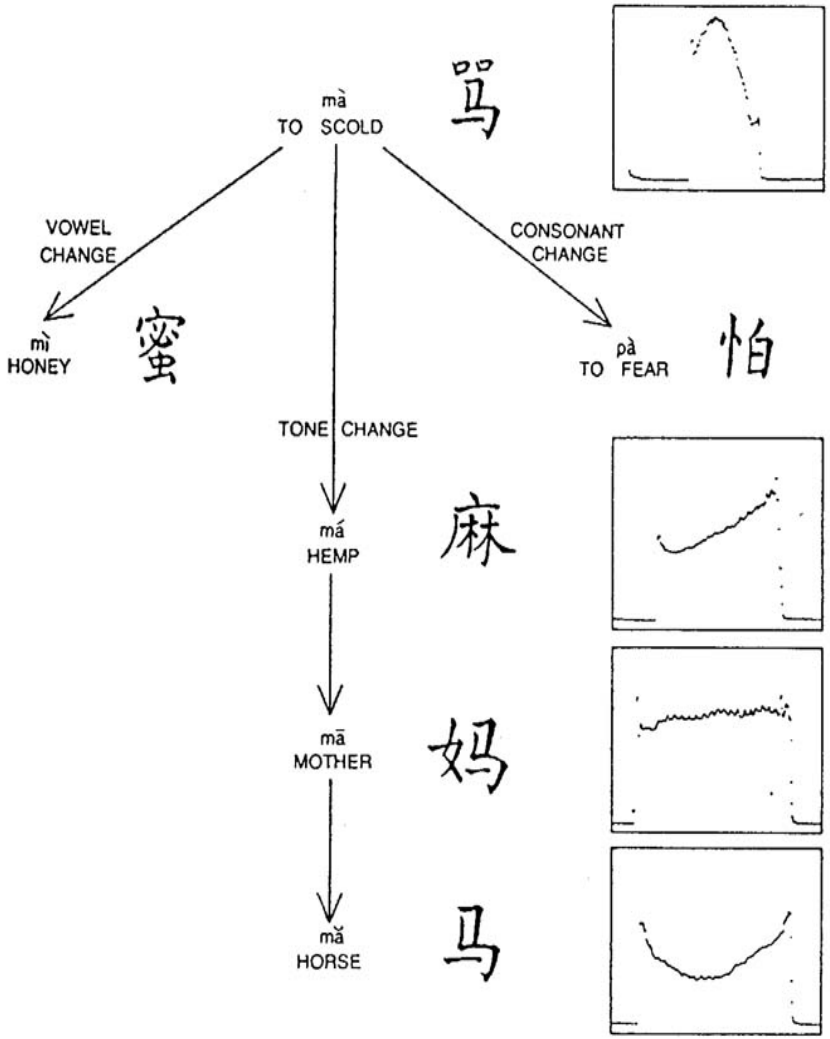
In Honor of Ilse Lehiste

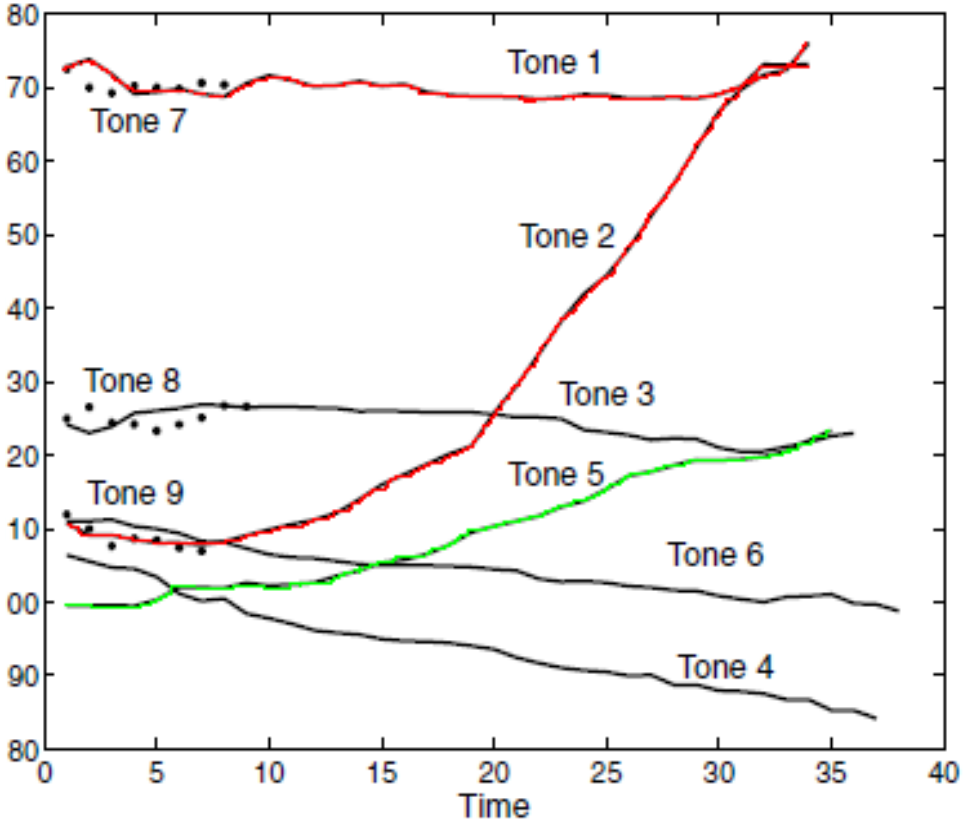
Four tones of Putonghua



Nine tones of Hong Kong Cantonese

	平	上	去	入
陰	詩 55	史 35	試 33	識 5 錫 3
陽	時 21	市 23	是 22	食 2

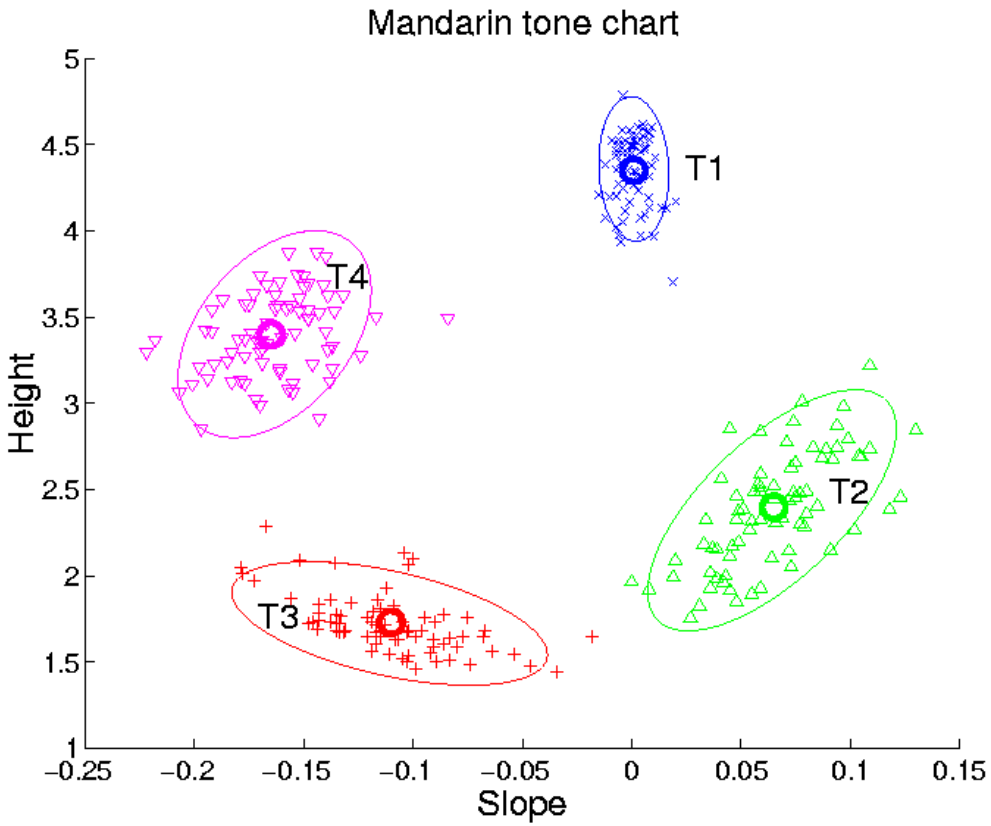


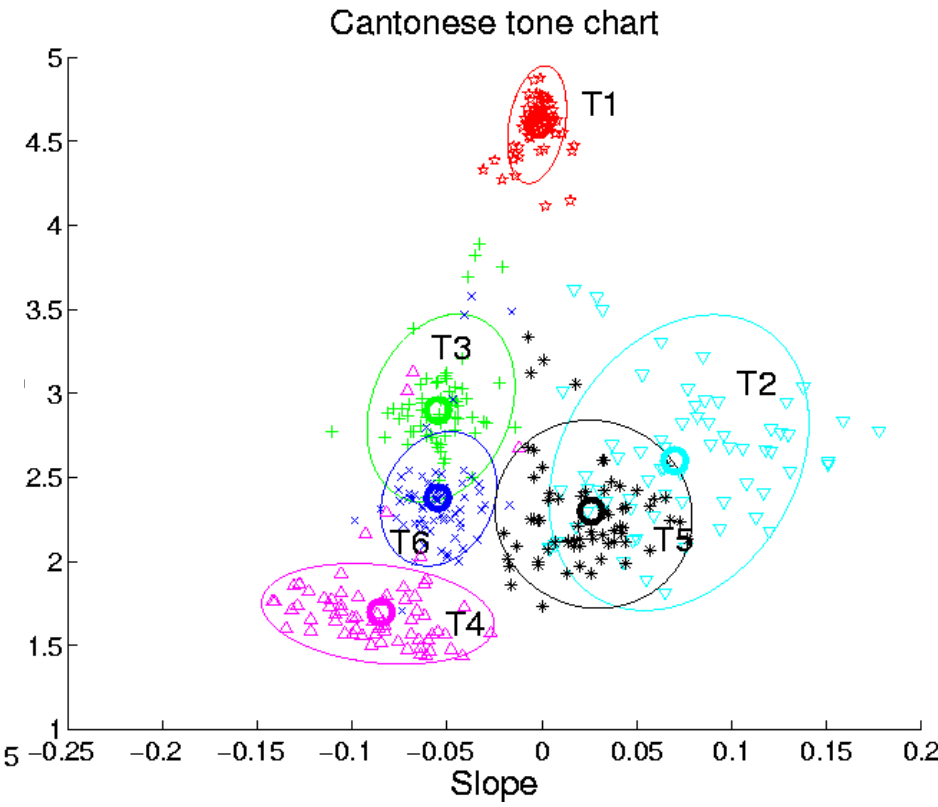


Cantonese tones in the monosyllable /i/ uttered in isolation. The solid lines are for long tones on unchecked syllables, while the dotted lines are for short tones on checked syllables. (Adapted from Peng & Wang, 2005)

W.S-Y.Wang.Feb.1973.
***Scientific American*.**

Peng, Gang and Wang, W. S-Y. (2005). "Tone recognition of continuous Cantonese speech based on support vector machines." *Speech Communication*, 45:49-62.



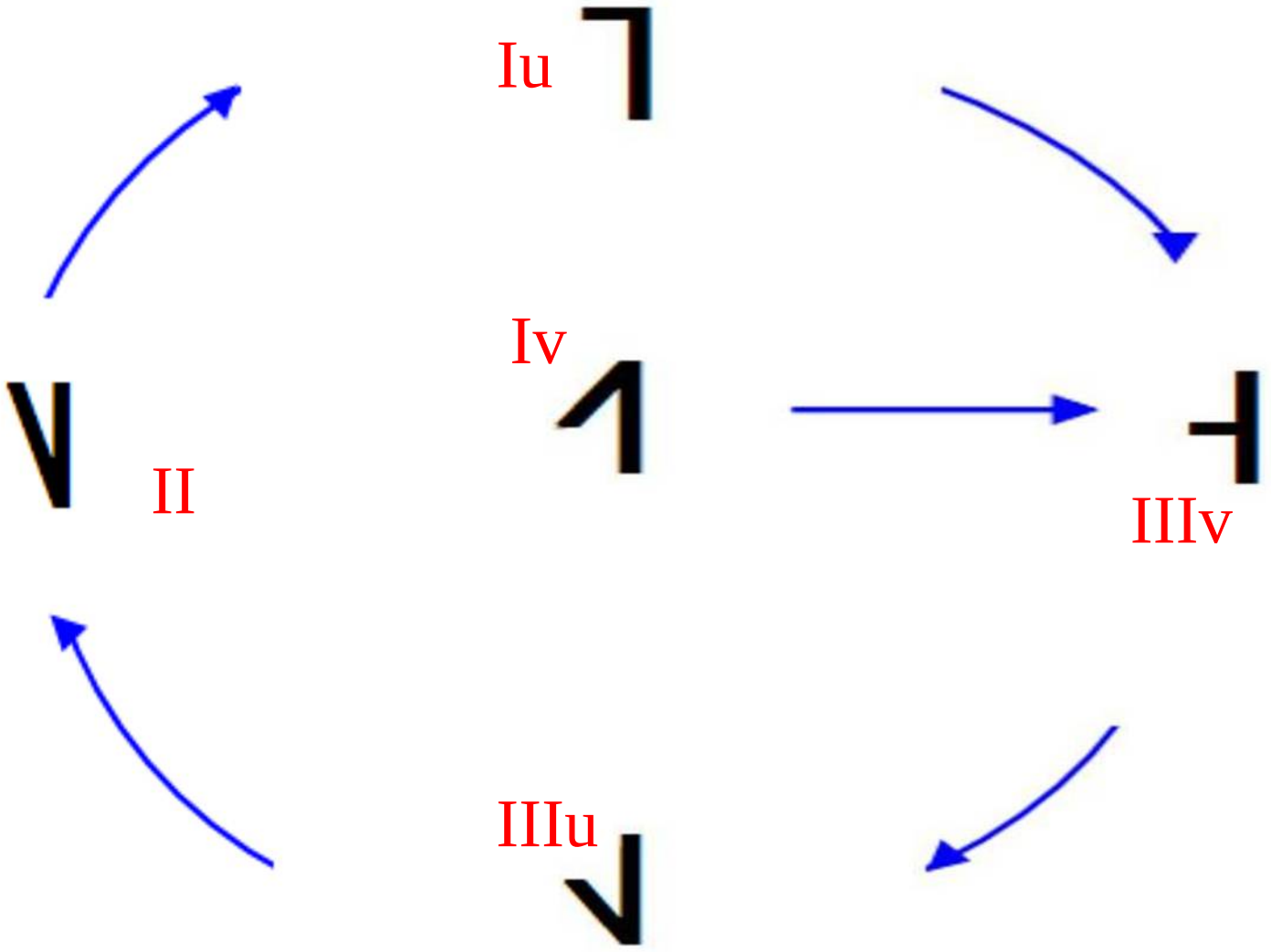


The Mandarin tones are relatively compact and discretely distributed, which allows for more successful tone recognition.

Citation tone	Sandhi tone	Example	
lu ˥ (55) ➔	˧ (33)	開 khui	車 tshia lu ˥ (55)
lv ˧ (24) ➔	˧ (33)	還 hîng	
ll ˩ (51) ➔	˥ (55)	買 bé	
lllu ˨ (21) ➔	˩ (51)	看 khuànn	
lllv ˧ (33) ➔	˨ (21)	賣 bē	

教育部
台灣閩南語
常用詞辭典

Tone circle in Taiwanese



Feature analysis of Taiwanese tone circle.

+ high	. . . . .	- high		- high	. . . . .	+ high		+ high
- falling		- falling	. . . . .	+ falling		+ falling	. . . . .	- falling

$$\begin{bmatrix} \alpha\text{high} \\ \beta\text{falling} \end{bmatrix} > \begin{bmatrix} \beta\text{high} \\ -\alpha\text{falling} \end{bmatrix}$$

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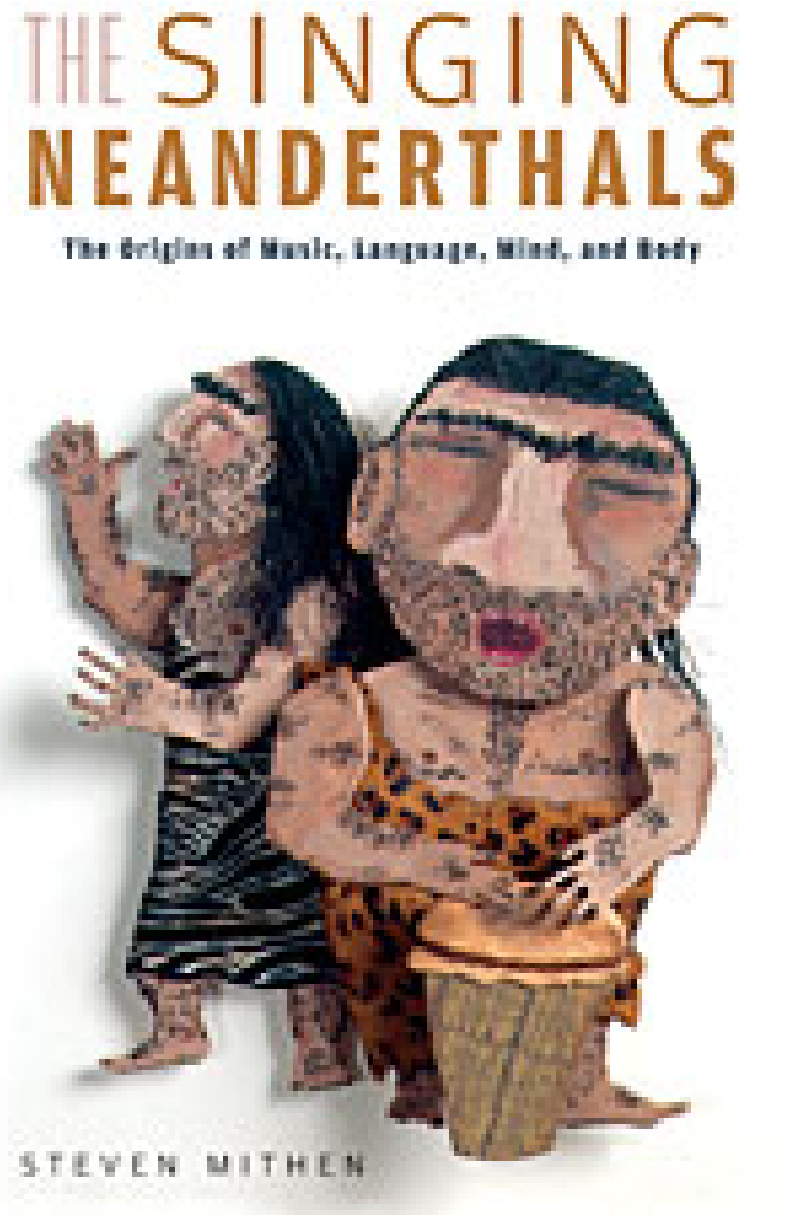
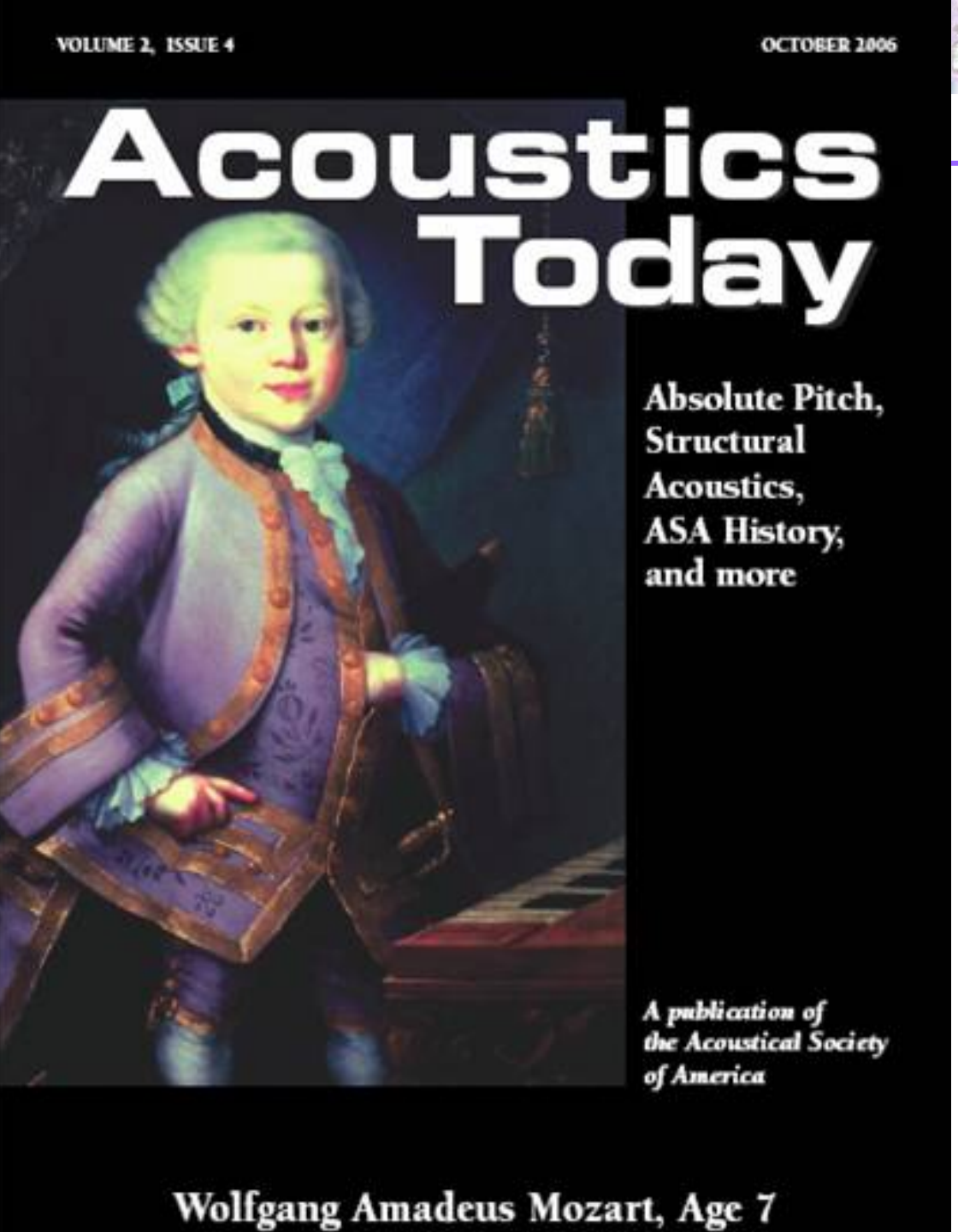
Mithen, Steven. 2006.
The Singing Neanderthals: Th Origins of Music, Language, Mind and Body.
Harvard University Press.

Fitch, W. Tecumseh 2010.
Musical protolanguage: Darwin's theory of language evolution revisited. Chapter 14 of
The Evolution of Language.
Cambridge University Press.



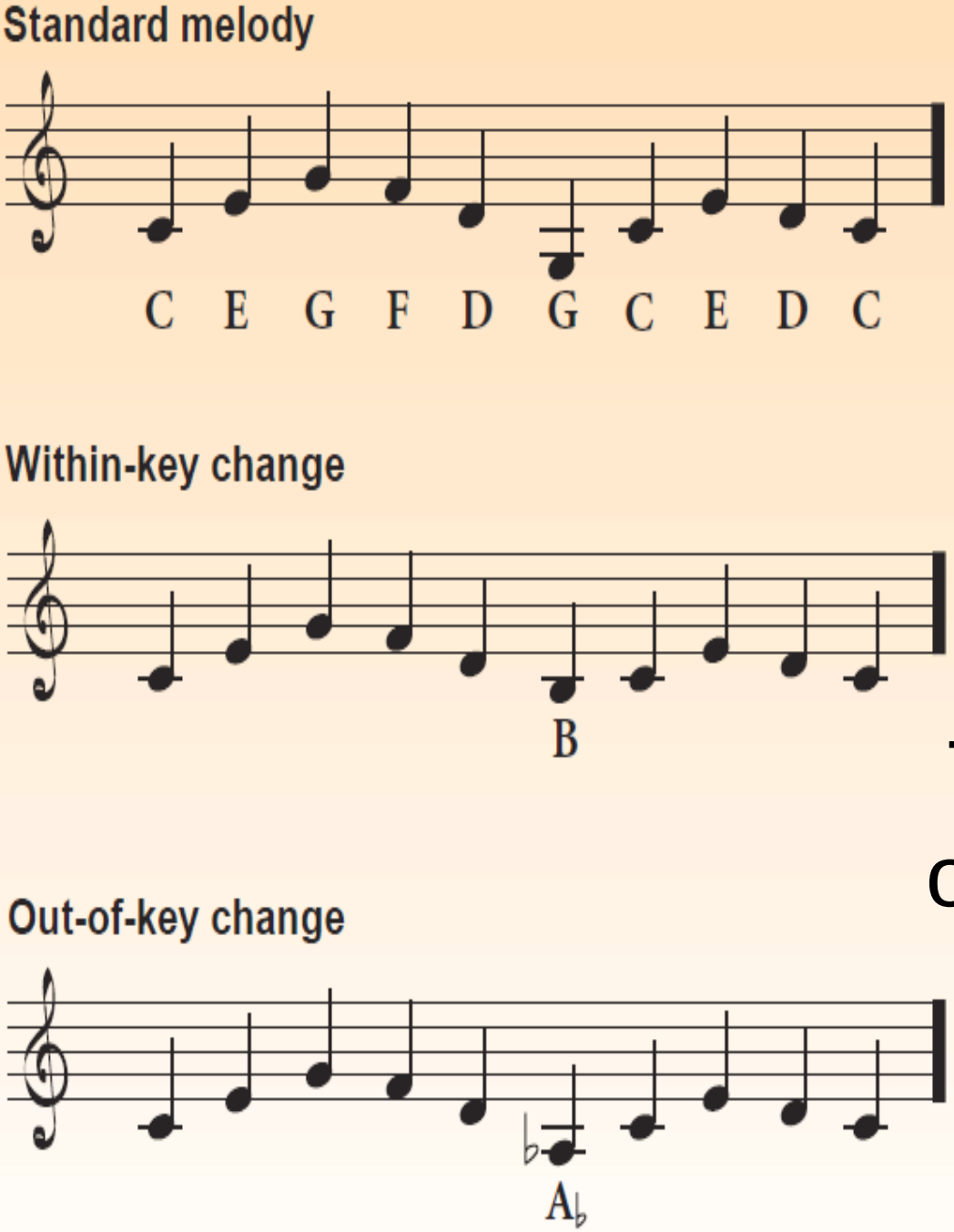


Deutsch, D. et al. 2009.

Absolute pitch among students in an American music conservatory: Association with tone language fluency. *J. Acoust. Soc. Am.* 125.2398-403.

Peng, G, et al. 2013.

Language experience influences non-linguistic pitch perception. *J. Chinese Linguistics* 41.447-67.



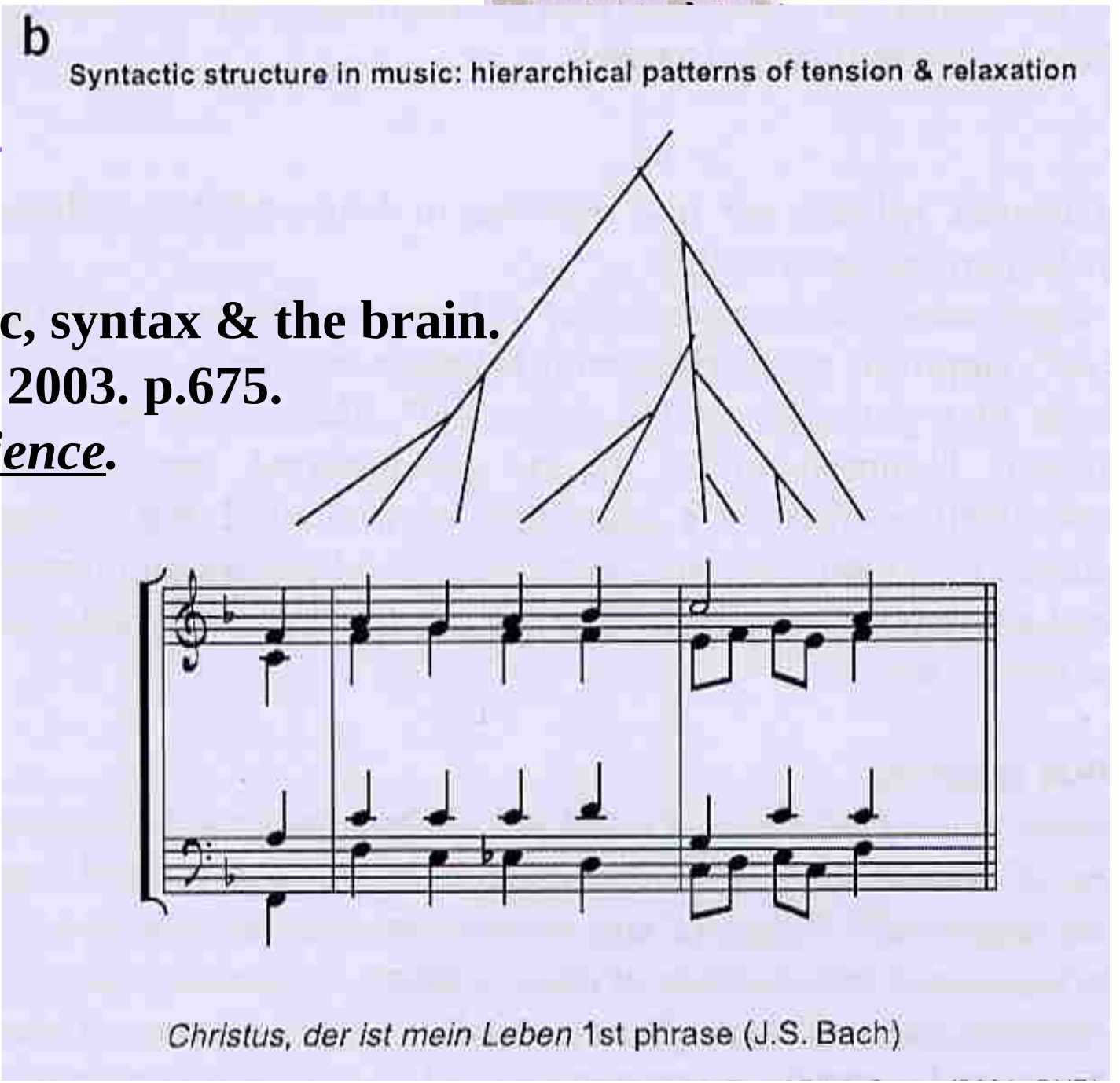
Trehub, S. E. 2003.

The developmental origins of musicality.

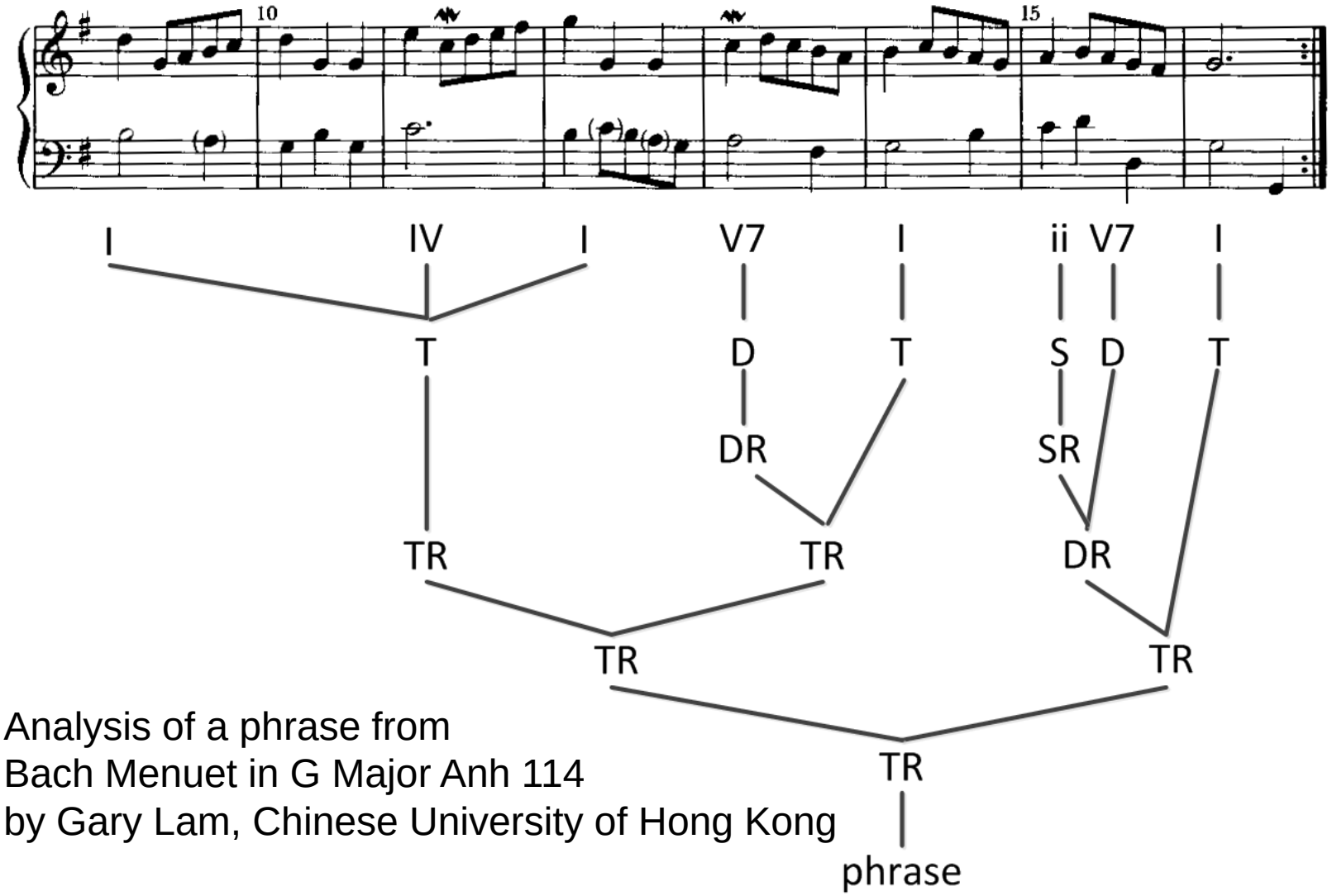
Nature Neuroscience 6.669-73.

Language, music, syntax & the brain.
A.R.Patel. July 2003. p.675.
***Nature Neuroscience*.**

Parsing in music:



A simplified grammar tree

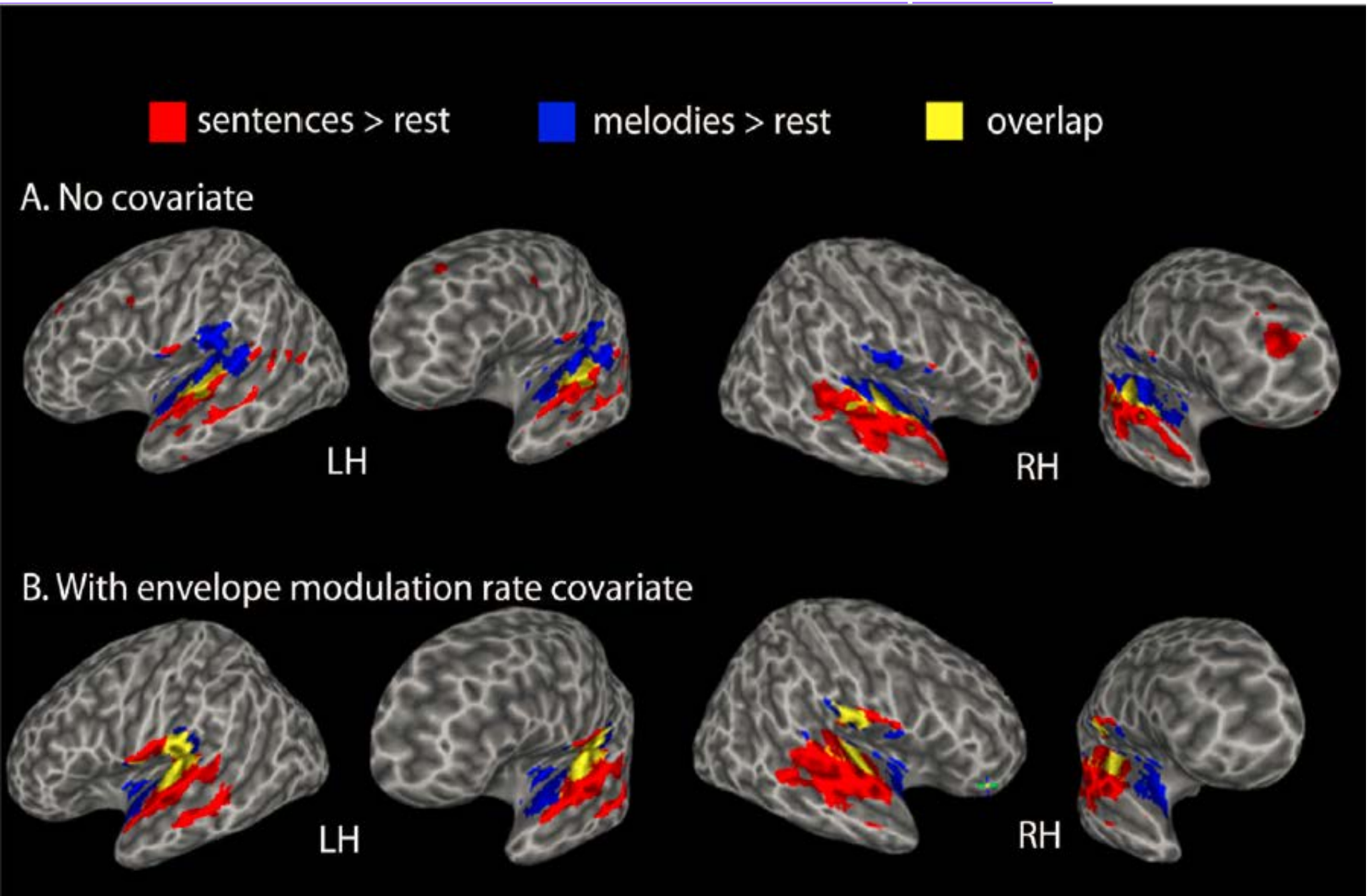


Analysis of a phrase from
Bach Menuet in G Major Anh 114
by Gary Lam, Chinese University of Hong Kong

Rogalsky, Corianne, Feng Rong, Kourosh Saberi & Gregory Hickok. 2011. Functional Anatomy of Language and Music Perception: Temporal and Structural Factors Investigated Using fMRI. *J Neurosci*. 31.3843-52.

"Music perception showed no overlap whatsoever with this network. Broca's area was not robustly activated by any stimulus type. Overall, these findings suggest that basic hierarchical processing for music and speech recruit distinct cortical networks, neither of which involve Broca's area. We suggest that previous claims are based on data from tasks that tap higher-order cognitive processes, such as working memory and/or cognitive control, which can operate in both speech and music domains." *from the Abstract*.

Rogalsky, C. et al. 2011. Functional Anatomy of Language & Music Perception. *J Neurosci*. 31.3843-52.



Sound Patterns in Language

- How is speech possible?
- African origins, diversity in genes & words.
- Three case studies of sound patterns in motion.
  - *Consonants & Grimm's Law.*
  - *Vowels & the Great Vowel Shift in English.*
  - *Tones & the Taiwanese Tone Circle.*
- Speech & music, two cultural universals.
- **Summary**.

Summary-1.

The roots of language reach back over 3 million years, when our remote ancestors transitioned to bipedal posture, restructuring the hands, the vocal tract, and the brain.

Speech, with its building blocks of syllables, vowels, consonants, and tones, is a powerful vehicle for language, and emerged over 100,000 years ago.

Language and music are both universal to our species and share evolutionary roots; they have similar functions of communication, and similar principles of organization.

Summary-2

Diversity in language is the cumulative product of culturally selected innovations made by numerous generations of speakers.

Spoken language has spawned various auxiliary forms, such as written language, signed language, & various electronic media, providing additional windows for studying how we communicate.

Ever more powerful technology of brain imaging & computer analysis for spoken language & music is already shedding much light on our mind, & promises to reveal much more..

谢谢!

THANK YOU!

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