The Long History of (De)Formalisation of/in Mathematics

Andrei Rodin

SPHERE

23 February 2026

1. Formalisation from Euclid to Descartes to Leibniz to Peano to Coquand
2. Deformalisation of mathematics from the Stone Age to Egyptian scribes to Euclid
3. Where are we, and where are we going?

Euclid: Pythagorean Theorem 1, ca 300 BC

μζ΄.

Ἐν τοῖς ὀρθογωνίοις τριγώνοις τὸ ἀπὸ τῆς τὴν ὀρθὴν γωνίαν ὑποτεινούσης πλευρᾶς τετράγωνον ἴσον ἐστὶ τοῖς ἀπὸ τῶν τὴν ὀρθὴν γωνίαν περιεχουσῶν πλευρῶν τετραγώνοις.

Ἔστω τρίγωνον ὀρθογώνιον τὸ ΑΒΓ ὀρθὴν ἔχον τὴν ὑπὸ ΒΑΓ γωνίαν· λέγω, ὅτι τὸ ἀπὸ τῆς ΒΓ τετράγωνον ἴσον ἐστὶ τοῖς ἀπὸ τῶν ΒΑ, ΑΓ τετραγώνοις.

Ἀναγεγράφθω γὰρ ἀπὸ μὲν τῆς ΒΓ τετράγωνον τὸ ΒΔΕΓ, ἀπὸ δὲ τῶν ΒΑ, ΑΓ τὰ ΗΒ, ΘΓ, καὶ διὰ τοῦ Α ὁποτέρᾳ τῶν ΒΔ, ΓΕ παράλληλος ἤχθω ἡ ΑΛ· καὶ ἐπεζεύχθωσαν αἱ ΑΔ, ΖΓ. καὶ ἐπεὶ ὀρθή ἐστιν ἑκατέρα τῶν ὑπὸ ΒΑΓ, ΒΑΗ γωνιῶν, πρὸς δή τινι εὐθείᾳ τῇ ΒΑ καὶ τῷ πρὸς αὐτῇ σημείῳ τῷ Α δύο εὐθεῖαι αἱ ΑΓ, ΑΗ μὴ ἐπὶ τὰ αὐτὰ μέρη κείμεναι τὰς ἐφεξῆς γωνίας δυσὶν ὀρθαῖς ἴσας ποιοῦσιν· ἐπ᾽ εὐθείας ἄρα ἐστὶν ἡ ΓΑ τῇ ΑΗ. διὰ τὰ αὐτὰ δὴ καὶ ἡ ΒΑ τῇ ΑΘ ἐστιν ἐπ᾽ εὐθείας. καὶ ἐπεὶ ἴση ἐστὶν ἡ ὑπὸ ΔΒΓ γωνία τῇ ὑπὸ ΖΒΑ· ὀρθὴ γὰρ ἑκατέρα· κοινὴ προσκείσθω ἡ ὑπὸ ΑΒΓ· ὅλη ἄρα ἡ ὑπὸ ΔΒΑ ὅλῃ τῇ ὑπὸ ΖΒΓ ἐστιν ἴση. καὶ ἐπεὶ ἴση ἐστὶν ἡ μὲν ΔΒ τῇ ΒΓ, ἡ δὲ ΖΒ τῇ ΒΑ, δύο δὴ αἱ ΔΒ, ΒΑ δύο ταῖς ΖΒ, ΒΓ ἴσαι εἰσὶν ἑκατέρα ἑκατέρᾳ· καὶ γωνία

Proposition 47

In a right-angled triangle, the square on the side subtending the right-angle is equal to the (sum of the) squares on the sides surrounding the right-angle.

Let ABC be a right-angled triangle having the right-angle BAC. I say that the square on BC is equal to the (sum of the) squares on BA and AC.

For let the square $BDEC$ have been described on BC, and (the squares) GB and HC on AB and AC (respectively) [Prop. 1.46]. And let AL have been drawn through point A parallel to either of BD or CE [Prop. 1.31]. And let AD and FC have been joined. And since angles BAC and BAG are each right-angles, then two straight-lines AC and AG, not lying on the same side, make the (sum of the) adjacent angles equal to two right-angles at the same point A on some straight-line BA . Thus, CA is straight-on to AG [Prop. 1.14]. So, for the same (reasons), BA is also straight-on to AH. And since angle DBC is equal to FBA, for (they are) both right-angles, let ABC have been added to both. Thus, the whole (angle) DBA is equal to the whole (angle) FBC. And since DB is equal to BC, and FB to BA,

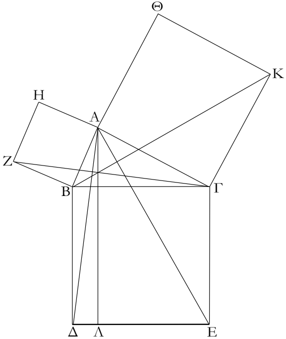
Euclid: Pythagorean Theorem 2, ca 300 BC

ΣΤΟΙΧΕΙΩΝ α΄. ELEMENTS BOOK 1

ἡ ὑπὸ ΔΒΑ γωνίᾳ τῇ ὑπὸ ΖΒΓ ἴση· βάσις ἄρα ἡ ΑΔ βάσει τῇ ΖΓ [ἐστιν] ἴση, καὶ τὸ ΑΒΔ τρίγωνον τῷ ΖΒΓ τριγώνῳ ἐστὶν ἴσον· καί [ἐστι] τοῦ μὲν ΑΒΔ τριγώνου διπλάσιον τὸ ΒΛ παραλληλόγραμμον· βάσιν τε γὰρ τὴν αὐτὴν ἔχουσι τὴν ΒΔ καὶ ἐν ταῖς αὐταῖς εἰσι παραλλήλοις ταῖς ΒΔ, ΑΛ· τοῦ δὲ ΖΒΓ τριγώνου διπλάσιον τὸ ΗΒ τετράγωνον· βάσιν τε γὰρ πάλιν τὴν αὐτὴν ἔχουσι τὴν ΖΒ καὶ ἐν ταῖς αὐταῖς εἰσι παραλλήλοις ταῖς ΖΒ, ΗΓ. [τὰ δὲ τῶν ἴσων διπλάσια ἴσα ἀλλήλοις ἐστίν·] ἴσον ἄρα ἐστὶ καὶ τὸ ΒΛ παραλληλόγραμμον τῷ ΗΒ τετραγώνῳ. ὁμοίως δὴ ἐπιζευγνυμένων τῶν ΑΕ, ΒΚ δειχθήσεται καὶ τὸ ΓΛ παραλληλόγραμμον ἴσον τῷ ΘΓ τετραγώνῳ· ὅλον ἄρα τὸ ΒΔΕΓ τετράγωνον δυσὶ τοῖς ΗΒ, ΘΓ τετραγώνοις ἴσον ἐστίν. καί ἐστι τὸ μὲν ΒΔΕΓ τετράγωνον ἀπὸ τῆς ΒΓ ἀναγραφέν, τὰ δὲ ΗΒ, ΘΓ ἀπὸ τῶν ΒΑ, ΑΓ. τὸ ἄρα ἀπὸ τῆς ΒΓ πλευρᾶς τετράγωνον ἴσον ἐστὶ τοῖς ἀπὸ τῶν ΒΑ, ΑΓ πλευρῶν τετραγώνοις.

the two (straight-lines) DB, BA are equal to the two (straight-lines) CB, BF,† respectively. And angle DBA (is) equal to angle FBC. Thus, the base AD [is] equal to the base FC, and the triangle ABD is equal to the triangle FBC [Prop. 1.4]. And parallelogram BL [is] double (the area) of triangle ABD. For they have the same base, BD, and are between the same parallels, BD and AL [Prop. 1.41]. And parallelogram GB is double (the area) of triangle FBC. For again they have the same base, FB, and are between the same parallels, FB and GC [Prop. 1.41]. [And the doubles of equal things are equal to one another.]‡ Thus, the parallelogram BL is also equal to the square GB. So, similarly, AE and BK being joined, the parallelogram CL can be shown (to be) equal to the square HC. Thus, the whole square $BDEC$ is equal to the (sum of the) two squares GB and HC. And the square $BDEC$ is described on BC, and the (squares) GB and HC on BA and AC (respectively). Thus, the square on the side BC is equal to the (sum of the) squares on the sides BA and AC.

Euclid: Pythagorean Theorem 3, ca 300 BC



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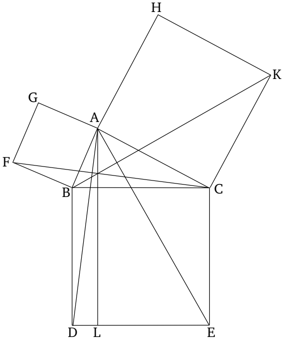


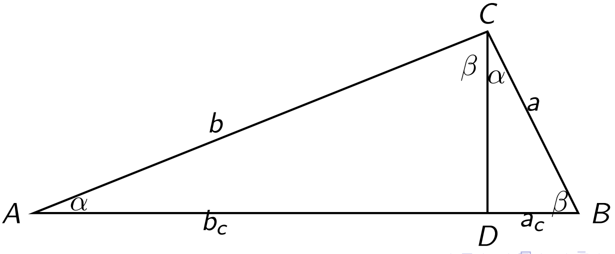
Thus, in a right-angled triangle, the square on the side subtending the right-angle is equal to the (sum of the) squares on the sides surrounding the right-[angle]. (Which is) the very thing it was required to show.

Pythagorean Theorem in a modern textbook

Theorem: Let a, b, c are sides of rectangular triangle and c its hypothenuse. Then $a^2 + b^2 = c^2$.

Proof: Let a_c, b_c be projections of a, b on the hypothenuse c. Then, by the equality of angles, $\triangle ABC \sim \triangle ACD \sim \triangle DCB$. It follows that

$$\frac{a}{c} = \frac{a_c}{a}, \quad \frac{b}{c} = \frac{b_c}{b} \Rightarrow a^2 = a_c c, \quad b^2 = b_c c \Rightarrow a^2 + b^2 = c^2 \blacksquare$$



Pythagorean Theorem in a modern textbook

The above modern textbook proof of the Pythagorean theorem involves ideas and notation first systematically introduced by René Descartes in 1637.

It does not essentially use any mathematical technique or knowledge obtained later on.

Descartes *La géométrie* 1637

GEOMETRIA,
à
RENATO DES CARTES
Anno 1637 Gallicè edita; poſtea autem
Vnà cum Notis
FLORIMONDI DE BEAVNE,
In Curia Bleſenſi Conſiliarii Regii, Gallicè conſcriptis in
Latinam linguam verſa, & Commentariis illuſtrata,
Operâ atque ſtudio
FRANCISCI à SCHOOTEN,
in Acad. Lugd. Batava Matheſeos Profeſſoris.
Nunc demum ab eodem diligenter recognita, locupletioribus Commentariis inſtructa, multiſque egregiis acceſſionibus, tam ad ulteriorem explicationem, quam ad ampliandam hujus Geometriæ excellentiam facientibus, exornata.
Quorum omnium Catalogum pagina verſa exhibet.

INDEFESSUS AGENDO

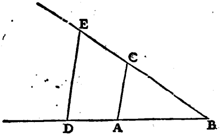
AMSTELODAMI,
Ex Typographia BLAVIANA, MDCLXXXIII.
Sumptibus Societatis.

Descartes *La géométrie* 1637

reſve mediæ proportionales, quod idem eſt, quod radicis Quadratæ, aut Cubicæ, &c. extractio. Neque enim hoſce Arithmetices terminos, ut faciliùs intelligi poſſim, in Geometriam introducere verebor.

Quomodo Geometrice fiat.

Multiplicatio,

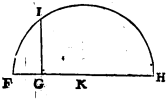


Sit, exempli gratiâ, A B unitas, oporteatque multiplicare B D per B C: jungo puncta A & C, ductâque D E parallelâ A C, erit B E productum hujus multiplicationis.

Diviſio,

Vel ſi dividenda ſit B E per B D, junctis punctis E & D, duco A C parallelam ipſi D E, eritque B C quotiens hujus Diviſionis.

Extractio radicis Quadratæ.



Vel denique ſi ex G H extrahere oporteat radicem Quadratam, adjungo ipſi in directum lineam rectam F G, quæ unitas eſt; diviſâque F H bifariam in puncto K, centro K intervallo F K ſeu K H deſcribo circulum. quo facto, erit G I, quæ ex puncto G perpendicularis ducitur ſuper F H uſque ad I, radix quæſita.

Al-Khwarizmi, Algebra, ca 820 CE

(12)

the number of the roots must be halved. And know, that, when in a question belonging to this case you have halved the number of the roots and multiplied the moiety by itself, if the product be less than the number of dirhems connected with the square, then the instance is impossible;* but if the product be equal to
(8) the dirhems by themselves, then the root of the square is equal to the moiety of the roots alone, without either addition or subtraction.

In every instance where you have two squares, or more or less, reduce them to one entire square,† as I have explained under the first case.

Roots and Numbers are equal to Squares;‡ for instance, "three roots and four of simple numbers are equal to a square." Solution: Halve the roots; the moiety is one and a half. Multiply this by itself; the product is two and a quarter. Add this to the four; the sum is

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* If in an equation, of the form $x^2+a=bx$, $(\frac{b}{2})^2 \angle a$, the case supposed in the equation cannot happen. If $(\frac{b}{2})^2=a$, then $x=\frac{b}{2}$

† $cx^2+a=bx$ is to be reduced to $x^2+\frac{a}{c}=\frac{b}{c}x$

‡ 3d case $cx^2=bx+a$

Example $x^2=3x+4$

$$x^2=\sqrt{[(\tfrac{3}{2})^2+4]}+\tfrac{3}{2}$$
$$=\sqrt{(1\tfrac{1}{4})^2+4}+1\tfrac{1}{2}$$
$$=\sqrt{2\tfrac{1}{4}+4}+1\tfrac{1}{2}$$
$$=\sqrt{6\tfrac{1}{4}}+1\tfrac{1}{2}$$
$$=2\tfrac{1}{2}+1\tfrac{1}{2}=4$$

Johann Faulhaber, *Miracula Arithmetica*, 1622

Ich setze den vnbekandten Zahlen 1 ℞ 1 A. vnd 1 B. dergestalt.

÷ 1 ℨ + 1 ℞ + 1 A.
+ 1 ℨ + 1 ℞ ÷ 1 B.

Nota. mit + vnd ÷ muß man ein grosse experienz haben/wann man dises gnugsamb obseruiren will/ 2c.

÷ 1 ℨℨ + 1 ℭ + 1 A.
÷ 1 ℭ + 1 ℨ + 1 ℞ A
+ 1 B ÷ 1 ℞ B ÷ 1 A B.

÷ 1 ℨℨ -- 1 + 1 ℨ + 1 A + 1 B | + 1 ℞ A ÷ 1 ℞ B | ÷ 1 A B.

Auß disem folgt.

Das 1 ℨ + 1 A + 1 B gleich ist 10
vnd 1 ℞ B ÷ 1 ℞ A gleich —— 4 NB.
deßgleichen 1 A B —— gleich —— 8.

Leibniz, *De arte characteristica ad perficiendas scientias ratione nitentes*, 1688 (I)

Si daretur vel lingu a quaedam exacta (qualem quidam Adamicam vocant) vel saltem genus Scripturae vere philosophicae, qua notiones revocarentur ad Alphabet um quoddam cogitatio num humanarum, omnia quae ex datis ratione assequi licet, inveniri possent, quodam genere calculi, perinde ac resolvuntur problemata Arithmeticae aut Geometriae.

If we could find either a certain exact language (some people call it *Adamic*) or at least a sort of truly philosophical Scripture, in which [fundamental] notions were represented in the form of Alphabet of human thought, then everything that can be obtained from these notions by reasoning will be obtainable with computations similar to those used for solving arithmetical and geometrical problems.

Leibniz, *De arte characteristica ad perficiendas scientias ratione nitentes*, 1688 (II)

[I]ta sentio nunquam temere controversias finiri neque sectis silentium imponi posse, nisi a ratiocinationibus complicatis ad calculos simplices, a vocabulis vagae incertaeque significationis, ad characteres determinatos revocemur.

Thus I feel that controversies can never be definitely settled, nor can silence be imposed, unless we manage to represent complicated reasoning by simple [syntactic] computations, and represent [*but note fully replace!* – A.R.] vague and uncertain words by well-determined characters..

Leibniz, *De arte characteristica ad perficiendas scientias ratione nitentes*, 1688 (III)

Quae vero facti sunt, et a fortuna vel casu pendent eatenus ad artem inveniendi non pertinere manifestum est.

But those truths which depend on fortune or chance [i.e., which are contingent], are clearly not to be found by this art of discovery.

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Commentary: Leibniz does not assume completeness of his projected logical calculus. But he might be nevertheless surprised to learn that some arithmetical truths are contingent.

Why Hilbert is missing

I leave now aside Hilbert's foundational project aiming at a *meta-mathematical* study of formal calculi rather than the introduction of formal methods in the everyday mathematical practice and mathematical education.

Giuseppe Peano, *Formulario* 1895

Formulario: How an ultimate formalisation looks like in practice.

III.

§ 1.

$a, b, c, k \,\varepsilon\, \mathrm{n} \,.\, \supset :$

1. $0 \,\varepsilon\, \mathrm{n}\, a \,.$

2. $a \,\varepsilon\, \mathrm{n} \times 1 \,.$

3. $a \,\varepsilon\, \mathrm{n}\, a \,.$

4. $ab \,\varepsilon\, \mathrm{n}\, a \,.$

5. $a \,\varepsilon\, \mathrm{n}\, b \,.\, b \,\varepsilon\, \mathrm{n}\, a \,.=.\, a = \pm b \,.$

6. $a \,\varepsilon\, \mathrm{n}\, b \,.\, b \,\varepsilon\, \mathrm{n}\, c \,.\supset.\, a \,\varepsilon\, \mathrm{n}\, c \,.$

7. $a, b \,\varepsilon\, \mathrm{n}\, c \,.\supset.\, a + b, a - b \,\varepsilon\, \mathrm{n}\, c \,.$

8. $a \,\varepsilon\, \mathrm{n}\, b \,.\supset.\, ac \,\varepsilon\, \mathrm{n}\, bc \,.$

9. » $.\supset.\, ac \,\varepsilon\, \mathrm{n}\, b \,.$

10. $a \,\varepsilon\, b + \mathrm{n}\, k \,.\, b \,\varepsilon\, c + \mathrm{n}\, k \,.\supset.\, a \,\varepsilon\, c + \mathrm{n}\, k \,.$

11. » $.\, a' \,\varepsilon\, b' + \mathrm{n}\, k \,.\supset.\, a + a' \,\varepsilon\, b + b' + \mathrm{n}\, k \,.$

12. » $.\supset.\, ca \,\varepsilon\, cb + \mathrm{n}\, k \,.$

13. » $.\, a' \,\varepsilon\, b' + \mathrm{n}\, k \,.\supset.\, aa' = bb' + \mathrm{n}\, k \,.$

14. » $.\supset.\, a^m \,\varepsilon\, b^m + \mathrm{n}\, k \,.$

15. $ca \,\varepsilon\, cb + \mathrm{n}\, ck \,.\supset.\, a \,\varepsilon\, b + \mathrm{n}\, k \,.$

Giuseppe Peano, *Formulario* 1901

Deformalisation of *Formulario*: a historical precursor of MALINCA project:

✱ 4. Propositions primitives

·0 $N_0 \; \varepsilon \; \mathrm{Cls}$ Pp ·1 $0 \, \varepsilon \, N_0$ Pp

·2 $a \varepsilon N_0 . \supset . a+ \; \varepsilon \; N_0$ Pp

·3 $s \varepsilon \mathrm{Cls} \,.\, 0 \varepsilon s : x \varepsilon s . \supset_x . \, x+ \; \varepsilon s : \supset . \, N_0 \supset s$ Pp

{ P·3 = Induct = « loi d'induction » }

{ Pascal a.1654 t.3 p.298 :

« Premier lemme ... cette proposition se rencontre dans la seconde base...

Deuxième ... si cette proposition se trouve dans une base quelconque, elle se trouvera nécessairement dans la suivante.

D'où il se voit qu'elle est nécessairement dans toutes les bases. » }

Les idées primitives sont déterminées par les propositions primitives que nous venons d'énoncer et par les P6·2 P8·4, desquelles découlent toutes les P de l'Arithmétique.

Dans la lecture des propositions il convient de se rapprocher autant que possible du langage ordinaire. On lira les P4 p. ex. comme il suit:

·0 « N_0 est une classe » ·1 « à laquelle appartient 0 »

·2 « Tout nombre est suivi par un nombre. »

·3 « Soit s une classe; supposons que 0 appartienne à cette classe; et que toutes les fois qu'un individu appartient à cette classe, son suivant y appartienne aussi; alors tous les nombres appartiennent à cette classe. »

On appelle "principe d'induction" cette Pp. On peut aussi la lire : « Si une

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Lebombo bone, the estimated age is 42-43 Kyears

30 notches found on this bone may correspond to the Lunar month.

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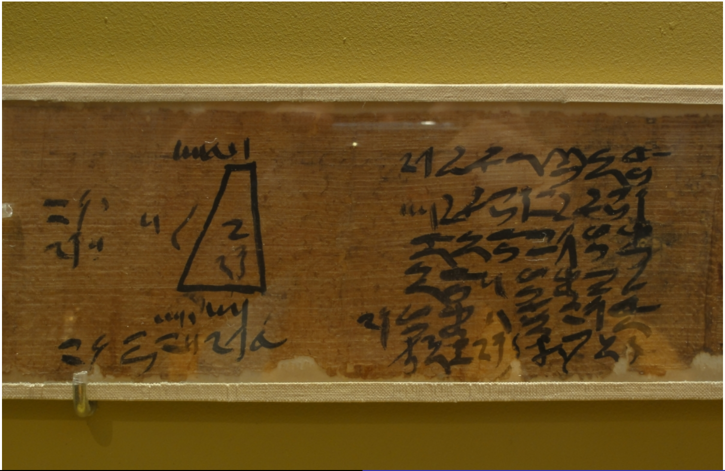
30 notches found on this bone may correspond to the Lunar month. Human *mathematical* scripts (or samplings) historically (by far) predates *writing* (in the usual sense of graphical representation of spoken language).

Clay accounting tokens from Tello (anc. Girsu), excavations Genouillac 1930-31, ca. 3500-2900 BC.

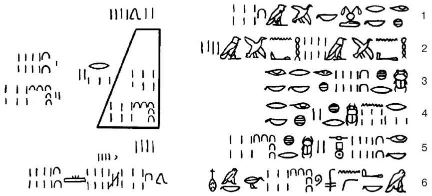
Moscow (Golenischev) papyrus, ca. 2000 BC

Combining a mathematical script with writing (a text in natural language) as a form of (meaning-giving?) *deformalisation*.



Moscow (Golenischev) papyrus, ca. 2000 BC

If you are told [problem]: a truncated pyramid of 6 for the vertical hight by 4 on the base by 2 on the top. [Solution:] You to square this 4; result 16. You are to double 4; result 8. You are to square this 2; result 4. You are to add the 16 and the 18 and the 4; result 28. You are to take $\frac{1}{3}$ of 6; result 2. You are to take 28 twice; result 56. See, it is of 56. You found it right.



Moscow (Golenischev) papyrus: commentary

Text in the right column is written in Ancient Egyptian language using hieratic writing along with standard arithmetical symbols. It parallels the formal computation presented in the left column.

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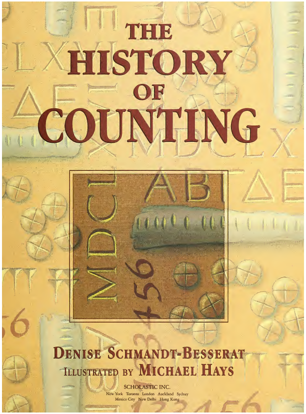
Text in the right column is written in Ancient Egyptian language using hieratic writing along with standard arithmetical symbols. It parallels the formal computation presented in the left column.

Why the author of the document opted for supporting the formal computation with a text in (the hieratically written) Egyptian?

Denise Schmandt-Besserat: all forms of early human writing derive from mathematical scripts.



Theoretical Mathematics: back to Euclid

It appears that the *theoretical* mathematics concerned with proof, reasoning and understanding — as we know it, in particular, via Euclid's *Elements* — would be impossible without using the natural language in a systematic way.

Adamic Language

The idea of *Adamic Language* (or *Adamic Script*) in the form of logical calculus which directly reflects basic ontological structures of our universe and thus enables us to know things in this universe and to reason about them correctly is a anti-scientific myth, which underlies a good deal of (so called *Analytic* Philosophy in the 20th century.

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Leibniz himself referred to the notion of *Adamic Language* rather ironically, but two centuries later Bertrand Russell took the idea of *Adamic Script* quite seriously.

Russell on Peano

The Congress [of Philosophy that was held in Paris in 1900]was a turning point in my intellectual life, because I there met Peano. I already knew him by name and had seen some of his work, but had not taken the trouble to master his **notation**. ...

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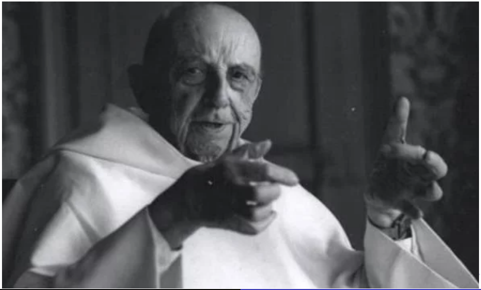
It became clear to me that his **notation** afforded an instrument of logical analysis such as I had been seeking for years. [*Autobiography*, 1967]

Neo-Scholasticism

In the course of the 20th century a large part of the Analytic Philosophy developed into a new form of dogmatic medieval-style Scholasticism where Aristotle's syllogisms were replaced by the elements of the Classical First-Order Logic.

Józef Maria Bocheński (1902-1995)

Józef Bochenski's fully embraced and emphasised the conceptual ties of Analytic Philosophy to the Medieval Scholasticism. He believed that his contemporary Analytic Scholasticism was an appropriate antidote against his contemporary Marxism and the related doctrine of *Dialectical Materialism* promoted by Kremlin ideologues and their heirs in other countries of the Communist Block (including Poland where Bocheńsky was born).



An exit strategy

The recent booming development of new formal calculi in Mathematical Logic and Computer Science, and the implementation of many of those calculi in the form of executable programs, undermines the monopoly of the Classical FOL in its pretended role of *the* language of rational argument and thought (i.e., of the *Adamic Script*) and calls for a revision of our current ideas about formal calculi and their epistemic roles.

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What we need today is not yet another replacement of Classical FOL by some more fashionable formal calculus but rather a reconsidering of the relationships between formal calculi, natural languages and other related symbolic tools used in our scientific, educational, and cultural practices.

Open questions:

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- How formal calculi obtain meaning via the natural language and otherwise?

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- (Dually:) What are criteria of the adequacy of a deformalisation (aka interpretation) of some given symbolic content?
- . . .

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I hope that our today's workshop will contribute towards this goal.

Thank you!