

RECENT DEVELOPMENTS AND TRENDS IN LOGIC

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1. *Introduction*

The main stream of the development of modern logic since the pioneering days from Boole to Frege has moved very decidedly in the direction of *mathematical* interests and applications. And, in fact, mathematics continues to the present day to occupy a central position on the logical stage. This may be illustrated — among many other ways — by the current prominence of what might be characterized as «the arithmetical sector» of logic, including algorithmic theory, recursive functions, the calculi of lambda conversion, the logical theory of computability and of effective processes generally, among other less components of lesser renown. The computer, and the whole host of technical issues that revolve about it, have had an enormous and reciprocally stimulative impact on recent work in logic. Results of great importance and interest continue to be obtained in this mathematical sector of logic, witness Paul J. Cohen's remarkable proof of the independence of the continuum hypothesis.

However, the continuing of this long-standing mathematical tendency has masked and obscured a highly significant cluster of developments in logic of a more recent vintage. The eventuation to

which I allude is the phenomenal recent spurt of growth of logic in directions bearing on philosophical considerations. The last 15 years especially — though there were, to be sure, earlier stirrings — have seen the flourishing growth of branches of logical theory developed specifically with such philosophical applications in mind.

The principal objective of the present paper is to give a brief but synoptic survey of this important phase of the ongoing history of logic. Moreover, I should like to offer some observations regarding the significance of these developments, and especially to give some consideration to the prospects that augur for the future.

2. A Notable Feature of the Current Situation

In Appendix A an attempt has been made to construct a map of the terrain of logic as it appears at the present day. In this enterprise we have not concerned ourselves with matters of detail or with the minutiae of alternative approaches, but have endeavored to give a somewhat gross overview of the «big picture.»

The material of Appendix A can for the most part safely be left to speak for itself. However, one particular feature of the map requires to be singled out for explicit consideration and discussion. I advert here to the size, scope, richness, and diversity of category E («Philosophical Developments»). This phenomenon is so striking as to warrant explicit remark all of itself. Moreover, material of substantially philosophical bearing and interest is by no means confined to this category. For virtually the whole of the subcategories A3 («Unorthodox Modern Logic») and B («Metalogic») cannot but also be regarded in this light, being of preeminently philosophical bearing. A very sizeable sector of current logic is thus clearly oriented in specifically philosophical directions. This fact is all the more striking when one considers it in an historico-bibliographical perspective.

In Appendix B we have given a concise and selective bibliography of recent literature of philosophical logic. In many or most cases the works that have been listed are not only significant expository sources, but actually pioneering contributors to the specific topic at issue. This feature serves to bring out in a very forceful and strik-

ing way the *recentness* of the cultivation of the philosophical reaches of modern logic. The bibliography provides a clear indication not only of the lively activity on this particular sector of the subject, but also of the element of newness that is present here.

3. *Prospects and Portents*

We have noted as a significant recent tendency in the development of modern logic the extensive and energetic cultivation of philosophically oriented branches of the subject. In general terms, the prospect for the future seems clear. There is little if any room for doubt that this tendency will not only continue, but intensify and develop in the years ahead. I should like to offer a few observations as to what this means for philosophy, for logic, and for the relationship between the two.

(i) *What It Means for Philosophy*

For philosophy, the intensified cultivation of philosophical logic means, first of all, the creation of a tremendously valuable *opportunity*. With respect to a certain not insignificant class of philosophical problems, the instrumentalities are now in hand for dealing with the relevant issues in an exact, precise, incontrovertible, and essentially decisive manner. Beginning in the area of epistemology and ontology, this tendency to the precise and formally exact treatment of philosophically relevant problems has recently made its way into other areas: especially in the area of ethical and normative concepts (deontic logic, preference logic, the logic of action). In certain sectors of the subject, there is now a genuine prospect of a continuing, cumulative, and collaborative progress — of the sort that philosophy has long envied the sciences. This trend — which one cannot but regard as now established beyond retrogress — may be viewed as perhaps the major permanent heritage of logical positivism in promoting and popularizing the philosophical application of logical technique.

It should be stressed, on the other hand, that the phenomenon

which we have just cast in the role of a valuable opportunity also has certain significant inherent dangers. The existence of a method of investigation that holds good promise of success in a given area of a subject exercises a potent magnetic influence in attracting attention and effort to this sector. In consequence a danger arises that attention may be diverted from those issues — generally of no less and frequently of much greater intrinsic interest and importance — that are not amenable to resolution by the instrumentalities and techniques at issue. Significant progress in the subject as a whole may thus come to be sacrificed in the course of securing minor achievements in some of its branches: workers may be diverted from fruitful efforts in the less tidy areas of philosophy only to deploy logico-analytical virtuosity on substantively trivial issues.

(ii) *What It Means for the Relationship Between
Logic and Philosophy*

During the 1930's and early 1940's, a thoughtful observer might well have tended towards the conclusion that logic would break off from the ancient moorings that kept it joined to philosophy, and either to link itself to mathematics, or (more probably) go its own way as an independent discipline. This development would have seemed only natural against the backdrop of the long series of special sciences which, following the lead of *philosophia naturalis*, cut themselves off from philosophy to set up as special sciences in their own right. It has by now become plain as a pikestaff that this — from the angle of philosophy much to be regretted — development will not come to pass. The phenomenon upon which our attention has here been centered, the extensive and intensive development of branches of logic specifically philosophical applicability, will of itself assure a continuing close connection between these disciplines.

(iii) *What It Means for Logic*

Finally we must consider the matter from the standpoint of

logic itself. Here, alas, the outlook is not so unmixedly favorable as one might wish for. There is, I am convinced, nothing for it but that in the fullness of time there will increasingly come to be a fission in the subject. There will come to be an increasingly wide gap between mathematical and philosophical logic, a gulf only occasionally bridged over by a rare mind of more than ordinary capacity and versatility. I am firmly persuaded that this development, which cannot but be viewed as intrinsically unfortunate, is, in effect, inevitable in the long run. Its impact cannot be prevented: the most that can be done is to cushion it against consequence of the most dire sort. Its seriousness can, I believe, be mitigated only by a resolute determination on the part of those responsible for the training of specialists in logic in departments of philosophy and of mathematics to insist that students being trained on either side of the divide also attain a thorough familiarity with the way in which things are done on the other side. This would, however, require acts of transdisciplinary nonparochialism of virtually heroic proportions. No one alive to the chilly realities of academic life could be highly sanguine regarding the prospects of this happy eventuation.

4. *Conclusion*

Our brief survey of the structure of modern logic has brought into clear focus a current trend of substantial significance: the increasingly flourishing growth of the philosophically oriented sector of logic in the past two decades. We have scrutinized this trend and have endeavored to assess its significance for logic, for philosophy, and for the relationship between them. We are led inescapably to the view that — certain inherent liabilities notwithstanding — this notable development is greatly to be welcomed from every point of view, excepting perhaps one alone, namely that of logic viewed as a unified discipline exhibiting, across the whole of its great extent, a tight integrative cohesion.

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APPENDIX A

A Map of Logic

A. *Basic Logic*

1. Traditional Logic
 - a. Aristotelian logic
 - i. theory of categorical propositions
 - ii. immediate inference
 - iii. syllogistic logic
 - b. other developments
 - i. the medieval theory of *consequentiae*
 - ii. discussions of the «laws of thought» in idealistic logic
2. Orthodox Modern Logic
 - a. propositional logic
 - b. quantificational logic
 - i. predicate logic
 - ii. logic of relation
3. Unorthodox Modern Logic
 - a. modal logic
 - i. alethic modalities
 - ii. physical modalities (see D1b)
 - iii. deontic modalities (see E1b)
 - iv. epistemic modalities (see E3b)
 - b. many-valued logic
 - c. nonstandard systems of implication
 - i. strict implication
 - ii. intuitionistic propositional logic
 - iii. entailment and relevant implication
 - iv. connexive implication
 - d. nonstandard systems of quantification (see B² cv, E2a)

B. *Metalogic*

1. Logical Syntax
2. Logical Semantics
 - a. basic semantics (denotation, extension/intension, truth, satisfiability, validity, completeness)
 - b. theory of models

- c. special topics
 - i. theory of definition
 - ii. theory of terms (abstraction)
 - iii. theory of descriptions
 - iv. theory of identity
 - v. logic of existence (existents and nonexistents) (see A3d, E2a)
 - vi. logic of information and information-processing (see E3d)
- 3. Logical Pragmatics
 - a. logical analysis of «ordinary usage»
 - b. rhetorical analysis (Aristotelian «topics»)
 - c. «contextual implication» (in the sense of Grice)
 - d. theory of informal (or *material*) fallacies
 - e. unorthodox applications of logic

C. *Mathematical Developments*

- 1. Arithmetical
 - a. algorithms
 - b. theory of computability
 - c. computer programming
- 2. Algebraic
 - a. Boolean algebra
 - b. lattice logic
- 3. Function-Theoretical
 - a. recursive functions
 - b. Lambda conversion
 - c. combinatory logic
- 4. Proof Theory (theory of axiomatizability, Gentzenization)
- 5. Probabilistic Logic (see E4b)
- [6. Theory of Sets]
- [7. Foundations of Mathematics]

D. *Scientific Developments*

- 1. Physical Applications
 - a. quantum-theoretic logic
 - b. theory of «physical» or «causal» modalities (see A3aii)

2. Biological Applications
 - a. Woodger-style developments
 - b. cybernetic logic
3. Social-Science Applications
 - a. logic of norms (see Elb)
 - b. logic of valuation
 - c. legal applications

E. *Philosophical Developments*

1. Ethical Applications
 - a. logic of action
 - b. deontic logic (see D3a)
 - c. logic of commands (logic of imperatives)
 - d. logic of preference and choice (utility, cost, logical issues in the theory of games and decisions)
2. Metaphysical Applications
 - a. logic of existence (see B2cv, A3d)
 - b. chronological logic (tense-logic, change-logic, logic of process)
 - c. logic of part/whole (mereology, the calculus of individuals)
 - d. Lesniewski's «ontology»
 - e. constructivistic logic (logical reductionism, *Aufbau-ism*)
 - f. ontology (in the sense of the nominalism-realism debate)
3. Epistemological Applications
 - a. logic of questions (and answers)
 - b. epistemic logic (belief, knowledge, relevance, «about» and other intentional concepts)
 - c. logic of supposition (hypothetical reasoning, counterfactuals)
 - d. logic of information and information-processing (see B2cvi)
 - e. inductive logic (see B4)
4. Inductive Logic (see E3e)
 - a. logic of evidence and confirmation, acceptance (rules of acceptance)
 - b. probabilistic logic (see C5)

APPENDIX B

A Concise Bibliography of Philosophical Logic

The coverage of this bibliography is restricted to the three regions of the map of Appendix A which we have designated as

comprising the area of philosophical logic (viz. A3, B, and E). Even over this limited range, the listing is highly selective, indicating only one or two key systematic expositions in each case. The reader interested in further bibliographic data should consult these works in turn.

(A3a) *Modal Logic*

G.H. VON WRIGHT, *An Essay on Modal Logic* (Amsterdam, 1951).

A.N. PRIOR, *Formal Logic* (Oxford, 1955).

Saul KRIPKE, «Semantical Considerations on Modal Logic», *Acta Philosophica Fennica*, vol. 16 (1963), pp. 83-94. (Cf. also J. HINTIKKA, *ibid.*, pp. 65-81.)

(A3b) *Many-Valued Logic*

A.N. PRIOR, *Formal Logic* (*op. cit.*)

J.B. ROSSER and A.R. TURQUETTE, *Many-Valued Logics* (Amsterdam, 1952).

(A3c) *Nonstandard Systems of Implication*

Wilhelm ACKERMANN, «Begründung einer strengen Implikation», *The Journal of Symbolic Logic*, vol. 21 (1956), pp. 113-128.

A.R. ANDERSON, «Completeness Theorems for the System E of Entailment and the System EQ of Entailment with Quantification», *Zeitschrift für mathematische Logik und Grundlagen der Mathematik*, vol. 6 (1960), pp. 201-216.

A.R. ANDERSON and N.D. BELNAP, Jr., «The Pure Calculus of Entailment», *The Journal of Symbolic Logic*, vol. 27 (1962), pp. 19-52.

(A3d) *Nonstandard Systems of Quantification*

H. WANG, «The Logic of Many-Sorted Theories», *The Journal of Symbolic Logic*, vol. 17 (1952), pp. 105-116.

N. RESCHER, «On the Logic of Existence and Denotation», *The Philosophical Review*, vol. 68 (1959), pp. 157-180.

N. RESCHER, «Plurality-Quantification and Quasi-Categorical Propositions», *The Journal of Symbolic Logic*, vol. 27 (1962), pp. 373-374.

N. RESCHER, «Predicate Logic Without Predicates», *Logique et Analyse*, vol. 7 (1964), pp. 101-103.

(B1) *Logical Syntax*

R. CARNAP, *Logical Syntax of Language* (London, 1937).

(B2) *Logical Semantics*

R. CARNAP, *Introduction to Semantics*, (Cambridge, Mass., 1946).

(B3) *Logical Pragmatics*

J. GRICE, «Meaning», *The Philosophical Review*, vol. 66 (1957), pp. 377-388.

- S. TOULMIN, *The Uses of Argument* (Cambridge, 1958).
 R. M. MARTIN, *Towards a Systematic Pragmatic* (Amsterdam, 1959).
- (E1a) *Logic of Action*
 G.H. VON WRIGHT, *Norm and Action* (London, 1963).
 N. RESCHER (ed.), *The Logic of Decision and Action* (Pittsburgh, 1967).
- (E1b) *Deontic Logic*
 G.H. VON WRIGHT, *An Essay in Modal Logic* (op. cit.)
 A.R. ANDERSON, *The Formal Analysis of Normative Systems* (New Haven, 1956), reprinted in N. RESCHER (ed.), *The Logic of Decision and Action* (Pittsburgh, 1967).
- (E1c) *Logic of Commands*
 L. BERGSTORM, *Imperatives and Ethics* (Stockholm, 1962).
 N. RESCHER, *The Logic of Commands* (London, 1966).
- (E1d) *Logic of Preference and Choice*
 S. HALLDEN, *On the Logic of 'Better'* (Uppsala, 1957; Library of Theoria, no. 2).
 G.H. VON WRIGHT, *The Logic of Preference* (Edinburgh, 1964).
 R. C. JEFFREY, *The Logic of Decision* (New York, 1965).
- (E2a) *Logic of Existence*
 DANA SCOTT, «Existence and Description in Formal Logic» in R. SCHOENMAN (ed.), *Philosopher of the Century: Essays in Honor of Bertrand Russell* (London, 1967).
- (E2b) *Chronological Logic*
 A.N. PRIOR, *Time and Modality* (Oxford, 1957).
 G.H. VON WRIGHT, «And Next,» *Acta Philosophica Fennica*, fasc. 18 (1965), pp. 293-304.
 N. RESCHER, «On the Logic of Chronological Propositions,» *Mind*, vol. 75 (1966), pp. 75-96.
 A. N. PRIOR, *Past, Present and Future* (Oxford, 1967)
- (E2c) *Logic of Part/Whole*
 A. TARSKI, «Appendix E» to J.H. Woodger, *Axiomatic Method in Biology* (London, 1937).
 N. GOODMAN and H.S. LEONARD, «The Calculus of Individuals,» *The Journal of Symbolic Logic*, vol. 5 (1940), pp. 45-55.
- (E2d) *Lesniewsky's «Ontology»*
 E.C. LUSCHEI, *The Logical Systems of Lesniewski* (Amsterdam, 1962).
- (E2e) *Constructivist Logic*
 N. GOODMAN, *The Structure of Appearance* (Cambridge, Mass., 1951).

(E2f) *Ontology (Nominalism/Realism)*

W.F. QUINE, «On What There Is», *The Review of Metaphysics*, vol. 2 (1948); reprinted in *idem*, *From a Logical Point of View* (Cambridge, Mass., 1953).

A. CHURCH, «The Need for Abstract Entities in Semantic Analysis», *Proceedings of the Amer. Acad. of Arts and Sciences*, vol. 80 (1951), pp. 100-112.

(E3a) *Logic of Questions*

D. HARRAH, *Communication: A Logical Model* (Cambridge, Mass., 1963).

Nuel D. BELNAP, Jr., *An Analysis of Questions: Preliminary Report* (Santa Monica, 1963).

L. ÅQVIST, *A New Approach to the Logical Theory of Interrogatives*, Pt. I (Uppsala, 1965).

(E3b) *Epistemic Logic*

J. HINTIKKA, *Knowledge and Belief* (Cornell, 1962).

N. RESCHER, «The Problem of a Logical Theory of Belief Statements», *Philosophy of Science*, vol. 27 (1960), pp. 88-95.

(E3c) *The Logic of Supposition*

S. JASKOWSKI, «On the Rules of Suppositions in Formal Logic», *Studia Logica*, no. 1 (Warsaw, 1934).

N. RESCHER, *Hypothetical Reasoning* (Amsternan, 1964).

(E3d) *Logic of Information*

David HARRAH, *Communication: A Logical Model* (*op. cit.*).

Y. BAR-HILLEL, *Language and Information* (Jerusalem, 1964).

(E4a) *Logic of Evidence and Confirmation*

R. CARNAP, *Logical Foundations of Probability* (Chicago, 1950).

H.E. KYBURG, Jr., «Recent Work in Inductive Logic», *American Philosophical Quarterly*, vol. 1 (1964), pp. 249-287.

(E4b) *Probabilistic Logic*

R. CARNAP, *Logical Foundations of Probability* (*op. cit.*).

N. RESCHER, «A Probabilistic Approach to Modal Logic», *Acta Philosophica Fennica*, fasc. 16 (1963), pp. 215-225.