SOLOMON FEFERMAN

INSPIRATION, MENTOR
COLLEAGUE & FRIEND

IN APPRECIATION THEN AND NOW

“

I would like to thank Professor Solomon Feferman for agreeing to undertake the task of being my thesis advisor, and for his interest, encouragement, and support. I am grateful to him for many helpful discussions which have provided a deeper understanding of relations and distinctions between foundational work in logic and computer science. These discussions have been fundamental in clarifying the ideas, motivations, and goals of my work and in relating it to logic.

”

— Carolyn Talcott, Essence of Rum, acknowledgements

A LITTLE BACKGROUND

- As a PhD student, my interest was in foundations for reasoning about programs
- This lead to an interest in logic
  - reading Curry over the summer
  - attending Feferman's logic classes
  - studying his papers on formal theories
- I needed a thesis advisor (I had funding from the AI Lab)
  - I invited Sol to my office and showed him my ideas
  - I asked if he would be my thesis advisor
  - I think he was surprised, but happily he agreed

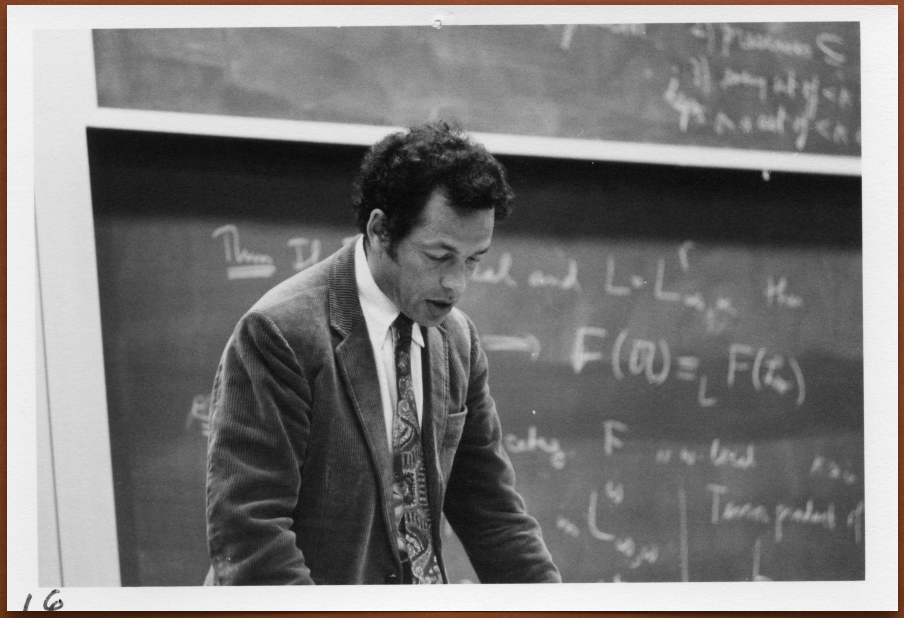
FEFERMAN AS MENTOR

SOME STORIES

- On the way to the Forum*
  - Sol introduced my Stanford Computer Forum presentation
  - He spent > 5 minutes describing my background and work!
    - How did Sol find out all that stuff about me?
    - There was no Google in those days
- The ultimate challenge: getting my thesis read.
  - Sol was very busy with Volume I of the Godel collected works
  - There were typesetting issues -- need for special fonts/characters.
  - We made a deal: I would make fonts while he read the thesis.

* *The Stanford Computer Forum is provides CS&EE industry with access to recruiting, faculty liasons, students interns, workshops/courses ... in return for many $$$s*

FEFERMAN AS INSPIRATION



1971 Tarski Symposium
Feferman honoring his mentor

FOUNDATIONAL GOALS

MATHEMATICS

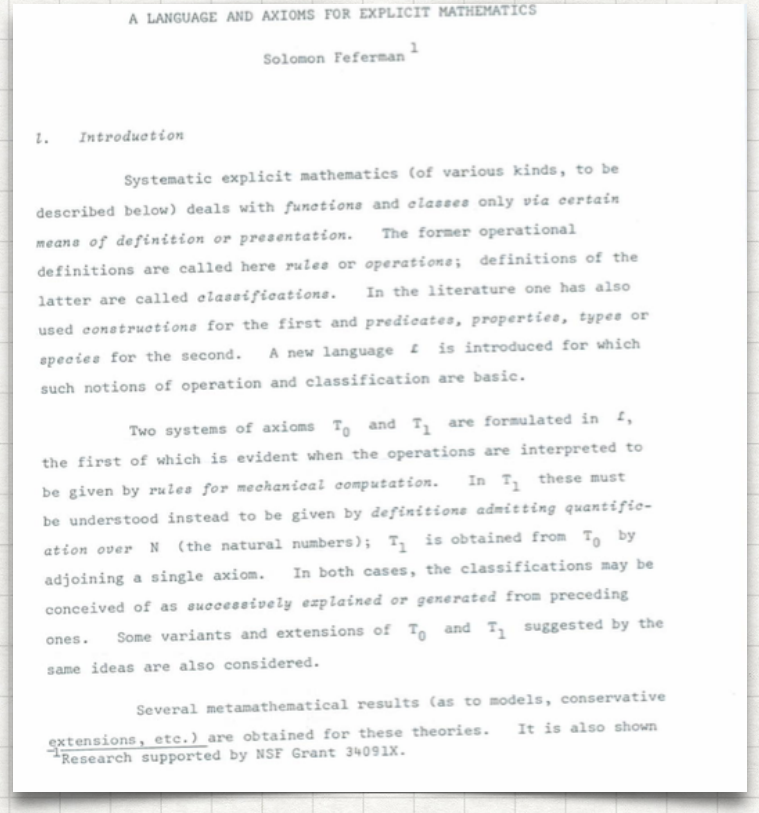
- Goals for foundations of mathematics
  - to account for practice -- to provide precise definitions of informal concepts so that formal proofs can be carried out
  - to isolate underlying principles for definition and proof and to determine what principles are needed for what parts of mathematics
  - to isolate the proof theoretic strength of various fragments of mathematics

FOUNDATIONAL GOALS

COMPUTING

- Goals for foundations of computing
  - to account for practice -- to provide precise definitions of informal concepts so that formal proofs can be carried out
  - to improve practice — an understanding of
    - the mathematical properties of computation and of operations combining various mechanisms is a valuable tool for writing, debugging, and verifying programs
    - the mathematical consequences of combinations of computation mechanisms and of choice of computation structures and their representation is important for the design and implementation of programming systems

KEY FEFERMAN PAPERS TOWARDS FOUNDATIONS FOR COMPUTING



A LANGUAGE AND AXIOMS FOR EXPLICIT MATHEMATICS

Solomon Feferman [1]

1. *Introduction*

Systematic explicit mathematics (of various kinds, to be described below) deals with *functions* and *classes* only *via certain means of definition or presentation*. The former operational definitions are called here *rules* or *operations*; definitions of the latter are called *classifications*. In the literature one has also used *constructions* for the first and *predicates, properties, types* or *species* for the second. A new language $\mathcal{L}$ is introduced for which such notions of operation and classification are basic.

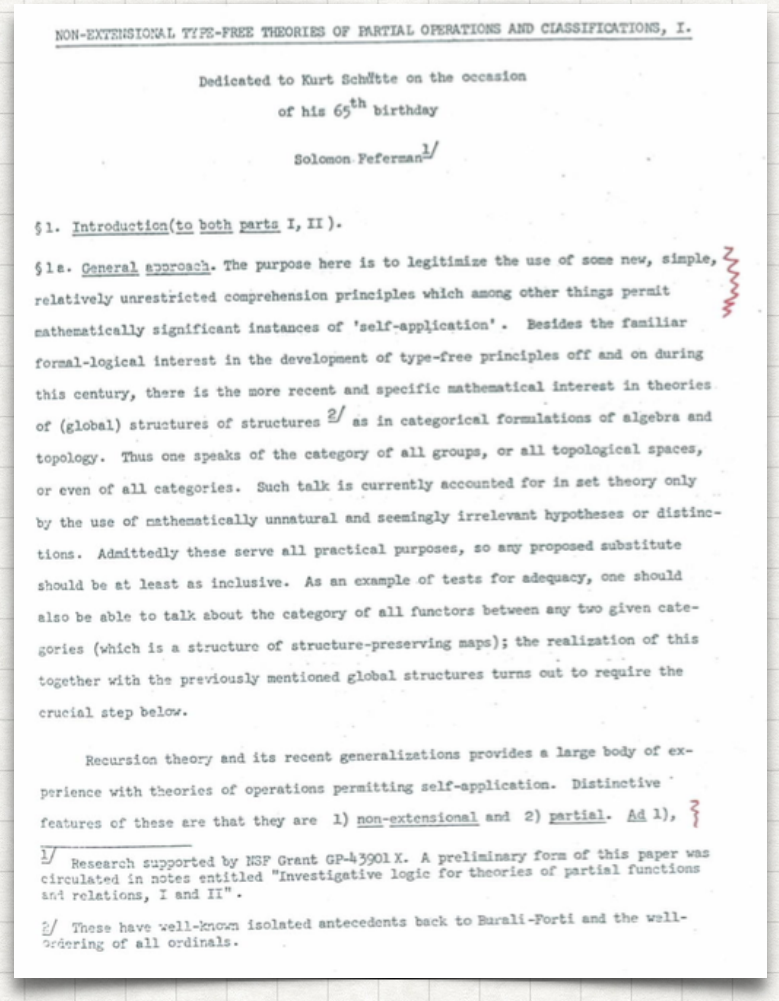
Two systems of axioms T_0 and T_1 are formulated in $\mathcal{L}$, the first of which is evident when the operations are interpreted to be given by *rules for mechanical computation*. In T_1 these must be understood instead to be given by *definitions admitting quantification over* N (the natural numbers); T_1 is obtained from T_0 by adjoining a single axiom. In both cases, the classifications may be conceived of as *successively explained or generated* from preceding ones. Some variants and extensions of T_0 and T_1 suggested by the same ideas are also considered.

Several metamathematical results (as to models, conservative extensions, etc.) are obtained for these theories. It is also shown

[1] Research supported by NSF Grant 34091X.

A language and axioms for explicit mathematics. In Algebra and Logic, volume 450 of Springer Lecture Notes in Mathematics, pages 87–139. Springer Verlag, 1975.

Constructive theories of functions and classes, in: Logic colloquium 78, edited by M. Boffa, D. van Dalen and K. McAloon (North Holland, Amsterdam) pp. 159–224. 1979 (not shown)



NON-EXTENSIONAL TYPE-FREE THEORIES OF PARTIAL OPERATIONS AND CLASSIFICATIONS, I.

Dedicated to Kurt Schütte on the occasion of his 65th birthday

Solomon Feferman [1/]

§1. Introduction (to both parts I, II).

§1a. General approach. The purpose here is to legitimize the use of some new, simple, relatively unrestricted comprehension principles which among other things permit mathematically significant instances of 'self-application'. Besides the familiar formal-logical interest in the development of type-free principles off and on during this century, there is the more recent and specific mathematical interest in theories of (global) structures of structures [2/] as in categorical formulations of algebra and topology. Thus one speaks of the category of all groups, or all topological spaces, or even of all categories. Such talk is currently accounted for in set theory only by the use of mathematically unnatural and seemingly irrelevant hypotheses or distinctions. Admittedly these serve all practical purposes, so any proposed substitute should be at least as inclusive. As an example of tests for adequacy, one should also be able to talk about the category of all functors between any two given categories (which is a structure of structure-preserving maps); the realization of this together with the previously mentioned global structures turns out to require the crucial step below.

Recursion theory and its recent generalizations provides a large body of experience with theories of operations permitting self-application. Distinctive features of these are that they are 1) non-extensional and 2) partial. Ad 1),

[1/] Research supported by NSF Grant GP-43901X. A preliminary form of this paper was circulated in notes entitled "Investigative logic for theories of partial functions and relations, I and II".

[2/] These have well-known isolated antecedents back to Burali-Forti and the well-ordering of all ordinals.

Non-extensional type-free theories of partial operations and classifications, I. in Proof theory symposium, Kiel 1974, edited by J. Diller and G. H. Müller, Lecture Notes in Mathematics, no. 500 (Springer, Berlin) pp. 73–118. 1975.

VARIABLE TYPE SYSTEMS IN A NUTSHELL

- Feferman's variable type systems [1975, 1975, 1979] are two sorted theories of operations and classes initially developed for formalization of (constructive) mathematics. Feferman continued development and application of these systems to study purely functional languages.
- In fact, these systems form the cornerstone for study of a much broader class of computation models ansd languages
- Main ideas for computing
  - Natural representation of mathematics
  - Explicit representation of operations and classes
  - Intensionality
  - Partiality
  - Essentially First Order

SO WHAT IS MISSING?

- `Real programs have effects'
  - From a paper in the Journal of ***Functional*** Programming by Agha, Mason, Smith & Talcott.
- Real programs don't just compute functions, they
  - read and write memory
  - manipulate their own control structure (computable goto's)
  - describe distributed processes that interact with each other and with the physical world (including humans).
- Question: What does equivalence mean in this case?
  - Want substitution of equals for equals
  - Intuition: `not distinguishable by any context of use'

BUILDING ON FEFERMAN'S FOUNDATIONAL WORK
SEMANTIC MODELS

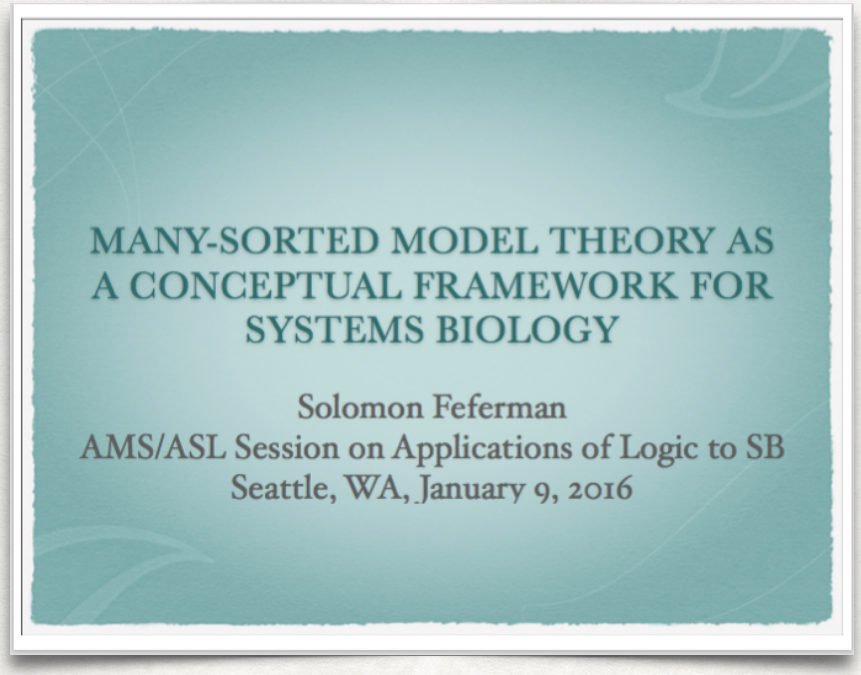
- Essence of Rum (Talcott thesis)
  - developed a theory of *control primitives*
  - defined combinators for computations
  - studied notions of program equivalence

- The Semantics of Destructive LISP (Mason thesis)
  - introduced memory structures to model destructive operations,
  - studied of equivalence relations
  - intentionality v extensionality

BUILDING ON FEFERMAN'S FOUNDATIONAL WORK
LOGICS

- VTLoE (Variable type Logic of Effects)
  - a first-order theory of individuals built on equality and contextual assertions (updatable memory)
  - a theory of classes and class membership (semantic types) -- supports construction of inductively defined sets and derivation of the corresponding induction principles.
- Feferman Landin Logic (presented at the Feferfest, 1998)
  - generalizes VTLoE to a wide collection of languages meeting simple conditions on rules defining the primitives, inspired by Landin's Next 700 Programming Languages)
  - includes axioms and reasoning principles adequate for treating existing reasoning bench marks and more.
  - Restricted to programs that are sequential / non-reactive
- Actors and Logical Analysis of Interactive Systems
  - Towards a foundational understanding of distributed interactive systems
    - language and principles for specification of and reasoning about such systems.
    - elucidation of the distinction between sequential (turing equivalent) computation and interactive computation
  - Result: the set theoretic models of the formal interaction theory have greater recursion theoretic complexity than analogous models of theories of sequential computation.

BIOLOGY!



- Rick asked me to talk about Sol's work in Biology.
- I only learned he was working on formal Biology when we were both invited to speak at a workshop at the AMS meeting in January 2016 (Applications of Logic, Model Theory, and Theoretical Computer Science (LMT&TCS) to Systems Biology.)
- Sol discussed ideas for modeling biological systems continuing the ideas of Variable Type Theories
  - top down -- systems view
  - many-sorted first-order structures with nested (sub)sorts and substructure
  - heterogeneity : multiple levels of abstraction with a model
  - sorts indexed by time to model dynamics
  - application of recursion theory to model homeostasis
- With further development, these ideas could result in a framework for integrating diverse models of specific aspects of a system. Currently an unsolved problem.

COLLEAGUE & FRIEND

- Joint student (Ian Mason)
  - Documented in "Two PhD Students for the Price of One" (a paper contributed to the 2011 Festschrift in my honor.)
- A joint NSF grant -- looking a data types from an operations and classes perspective.
- I had the honor to be a local organizer of the Feferfest (70th birthday, organized by Jon Barwise and Wilfried Sieg).
- As usual Sol says it better than I can: In 2 for 1 he says: "I have maintained warm personal relations with both of them over the years since they completed their respective doctoral theses."

Thank you Sol for being you.
Even though you are not physically here,
you remain a guiding light.