

“Slow Mapping” in Children’s Learning of Semantic Relations

Gedeon O. Deák (deak@cogsci.ucsd.edu)

Department of Cognitive Science, 9500 Gilman Dr.
La Jolla, CA 92093-0515 USA

Jennifer Hughes Wagner

Department of Psychology and Human Development, Box 512 GPC, Vanderbilt University
Nashville, TN 372003 USA

Abstract

To investigate how young children learn categorical semantic relations between words, 4- to 7-year-olds were taught four labels for novel categories in an “alien” microworld. After two play sessions, where each label was given, with defining information, at least 20 times, comprehension and production were tested. Results of two experiments show that 6-7-year-olds learned more words and correct semantic relations than 4-5-year-olds. The exclusion relation between contrasting category labels was easy to learn, and some findings suggested that hierarchical words are more easily learned than overlapping ones. Both studies showed no advantage to explicitly telling children semantic relations between words (e.g., “All fegs are wuddles.”). The results qualify a common assumption that preschool children have precocious abilities to infer word meaning; such an ability does not seem to extend to semantic relations between words.

Is Word Learning Specialized Induction?

There is a pervasive assumption that young children have precocious abilities to infer novel word meanings. The assumption fits evidence that children can learn a closed-class word, or at least its approximate meaning, from only one or a few exposures. First shown by Carey and Bartlett (1978), this *fast mapping* is replicable (Dollaghan, 1987; Heibeck & Markman, 1987), and it might explain how children learn an average of 5-6 words *per* day over the few years preceding kindergarten (Anglin, 1993).

Beyond Fast Mapping

Although fast mapping implies a system of constraints specialized for acquisition of word meanings, it is unclear how large a role it plays in children’s lexical development. Perhaps, for instance, young children work out the meanings of many words in parallel, over long periods. It is also possible that fast mapping operates only in very controlled, simplified situations, or with a narrow range of word types. More generally, perhaps fast mapping induces only unstable, partial, and fragmentary representations of new words. Vocabulary growth statistics do not address this because standardized tests assess only shallow word knowledge (Deák, 2000).

In sum, we do not know how quickly children learn (accurate and complete) meanings of words in their lexicons. We also do not know what sort of input this

demands. Conversely, we know little about limitations of 4- to 7-year-olds’ word meaning representations, especially for recently learned words. Perhaps fast mapping yields minimal knowledge of meaning, for example the referent category’s relation to other labeled categories.

Learning Semantic Relations

Knowledge of semantic relations between words is a critical aspect of word meaning. Knowing, for instance, that a collie is a kind of dog supports certain inferences (i.e., collies must inherit all properties of dogs); knowing that some dogs are pets (and vice versa) supports different inferences (i.e., *possibility* of shared properties). Finally, knowing no dogs are cats supports other inferences. These relations—*inclusion, overlap, and exclusion, respectively*—are basic logical/categorical semantic relations.

Inhelder and Piaget (1964) claimed that children younger than 7-8 years do not grasp the logical implications of different category relations. This should prevent learning of correct semantic relations. Though some of these claims are discredited (e.g., Trabasso et al., 1978), few studies have examined children’s abilities to infer logical relations among referents of words as part of inferred word meanings. One study (Smith, 1979) found 4- and 5-year-olds are above chance in making inferences about semantic relations involving novel words, given information about another familiar category. For example, when told “A Pug is a kind of dog. Is a Pug an animal?” children were more likely to answer “yes” than when told “A Pug is an animal” and asked “Is a Pug a dog?” Thus, 4- and 5-year-olds have at least minimal ability to reason about inclusion relations. Yet study has tested whether children differentiate between three types of set relations (inclusion, overlap, exclusion), or what input facilitates this. Although some fast mapping studies used markers of exclusion relations to teach a new word (e.g., “...the *chromium* tray, not the red one”; Carey & Bartlett, 1978), the situation was highly constrained (e.g., the teacher pointed towards two trays, one red and the other an ambiguous non-focal color), and the tests did not require inferring the new word’s relation to multiple familiar words.

Other studies have focused on parental input that might specify semantic relations. Callanan (1985, 1989) found parents produce markers to differentiate superordinate category labels during book reading, and preschool children differentiate word meanings based on these markers.

However, the learning effects were small. Finally, no study has assessed children's ability to differentiate inclusion from overlap relations.

Questions addressed:

1. Can children “fast map” semantic relations between new words? Children were taught novel words for categories of novel creatures in a microworld. Some words referred to biological categories (akin to species or genus, or perhaps gender, types); others referred to occupational or vocational categories. Deák and Maratsos (1998) showed that 3- and 4-year-old children almost perfectly accurately answer questions about a referent of *familiar* biological and vocational categories that are inclusive or overlapping: for example, they can affirm that a character described in a 1-minute vignette is, for instance, simultaneously a “woman,” “person,” “mother,” and “doctor.” Such categories not only represent critical set relations (inclusion vs. overlap), but socially and biologically important categories. How do children learn these semantic relations? Is it in the process of forming initial mappings of novel word meanings?

2. Are some semantic relations easier to learn than others? By 4 or 5 years, children are sensitive to property inheritance in inclusion relations, at least in some tasks. However, they might not distinguish inclusion from overlap relations (e.g., “dog” and “pet”). Because young children have trouble discriminating possibility from necessity (Piéaut-Bonniec, 1980), they might misconceive overlap relations, which are based on possible co-extension. Conversely, studies of children's *mutual exclusivity* bias (Merriman & Bowman, 1989) suggest exclusion relations are easier to learn because children's “default” assumption is that words' extensions do not overlap.

3. Does explicit input matter? Studies show that parents provide contextual cues to help children learn novel word meanings (Gelman et al., 1998). We tested whether explicit markers of inclusion (“All Xs are Ys”) and exclusion (“Xs are *not* Ys”) help children learn appropriate semantic relations, more than information about semantic relations that must be inferred from ostension and definitions.

4. Developmental changes: In order to assess whether preschool children are especially skilled at inductive inferences about word meanings, we compared younger (4- and 5-year-old) and older (6- and 7-year-old) children.

Experiment 1

We introduced children to an appealing microworld of “alien” creatures (i.e., cute, painted clay model animates) in a landscape with unusual buildings and structures (described below). During two training sessions, the experimenter named each category repeatedly, and gave information about defining features (Mervis, Johnson, & Mervis, 1994). Care was taken during training not to label any particular exemplars with two words, so we could later test the children's ability to infer the co-extension of two or more related (non-exclusive) category labels to the same exemplars. A specific question was whether children can

infer the overlap of biological and occupational categories, in distinction from the hierarchical inclusion relation between some biological categories.

Method

Participants. 48 children aged 48-86 months participated: 38 4-5-year-olds (mean = 59 months, range 48-71) and 10 6-7-year-olds (mean = 82 months, range 77-86). Children were recruited from schools in Nashville, TN, and were primarily white and middle-class.

Materials. Children were tested in a 3 ft² U-shaped diorama (plywood covered with Astroturf) equipped with odd-shaped buildings, a “construction area” stocked with building materials (e.g., brick-like blocks) and an “animal pen” with alien clay quadrupeds (i.e., livestock).

Referents were four categories of molded “alien” creatures, constructed as two basic-level categories from each of two orders or classes (i.e., bipeds and lizard-like kinds). Each biological category was defined by four features that differentiated its members from the contrasting basic-level kind (e.g., skin color, eye placement, tail, and arm thickness). Similarly, the superordinate classes were differentiated by four defining features (i.e., orientation, number of eyes, leg type, color spectrum region). At least 10 distinct exemplars of each category were constructed.

Creatures could be outfitted and placed in structures indicate their membership in an occupational “basic-level” category within one of two “industries”: construction and animal husbandry. The basic-level occupational kinds were defined by uniform color, “patient” (e.g., large vs. small herd animals), location (pen 1 or 2), and activity (e.g., washing vs. feeding animals). The higher-order industry categories also were defined by four features.

Children learned four category labels. Basic-level biological kinds were assigned monosyllabic nonsense words (e.g., “feg”), superordinate categories were bisyllabic (“wuddle”), and occupation categories terminated in the agentive *-er* (“cragger”). The words therefore provided some phonological and morphological cues to meaning. Otherwise, words were randomly assigned to categories.

Design. Each child was assigned to one of four conditions. One was defined by category relations: half of children learned words that were inclusive, including one basic-level and one superordinate biological category label, and one basic-level and one superordinate occupation label. Between any biological and any occupation category label was an overlap relation. The other group learned words that were exclusive or overlapping, including two basic-level biological kind labels, and two basic-level occupational kind labels. Thus, both groups could infer overlap relations between biological and occupational labels, but only the former group could (correctly) infer inclusion relations within a domain.

Within each group, half of the children heard *explicit* input about the inclusion or exclusion relation (e.g., “All fegs are wuddles” or “A feg can't be a blib”).

Procedure. All children participated in two sessions (1-2 days apart). During the first (training) session, children were taught each word on two prototypical exemplars. The exemplars were unique for each word. The experimenter said the word, six times per exemplar, while unambiguously indicating the exemplar. The experimenter ensured that the child was attentive to the object before saying the word.¹ While presenting each word, the experimenter described two defining features (chosen from the four), for instance, “It is a blib because it has a tail, and it is green.” After all four words were presented, the experimenter reviewed all four words, and encouraged the child to repeat each word so that failure to produce the word at testing could not be attributed to articulation difficulty.

In the second (reminder) session, children were shown two new exemplars of each category, reminded of the words and definitions, and encouraged to produce each word (with feedback). During the reminder session children heard each word in an ostensive context, paired with defining information, nine times. Thus, before testing began, children heard at least 21 tokens of each word, paired with descriptions of defining features.

Children in the *explicit input* condition heard inclusion or exclusion statements about word pairs during training.

Production Test: Immediately after the reminder session, children were shown 5 new exemplars, with features of 1, 2, or 4 named categories (in the exclusion/overlap condition an exemplar could belong to a maximum of two categories, whereas in the inclusion/overlap condition it could belong to all four). Children were asked to teach the words to a puppet, to encourage them to produce the labels. After the child produced a correct word, the experimenter gave positive feedback, to maintain task motivation. The experimenter also used semantic contrast, if possible, to elicit multiple labels (see Deák & Maratsos, 1998).

Comprehension Test: After the production test, children saw novel exemplars of each category, including both typical and atypical exemplars of named and unnamed categories. This tested children’s discriminative knowledge of each word’s referential meaning, and how broadly they would generalize it. Children were asked to show the puppet “...all the fegs, but *only* the fegs.” The experimenter also pointed to each exemplar and asked whether it was an member of the labeled class (e.g., “Is this a feg, or not?”).

To adequately test production and comprehension of occupation category words, exemplars were outfitted with uniforms and accoutrements, and placed in the appropriate place in the diorama.

Results

Production. Number of words correctly produced in the test (range = 0-4) were submitted to an ANOVA with age (younger vs. older children) and condition (inclusion/

overlap vs. exclusion/overlap) between subjects. The age effect was significant, $F(1, 44) = 13.5, p < .002$: 6-7-year-olds correctly produced $M = 3.0$ ($SD = 0.7$) words, whereas 4-5-year-olds produced only $M = 1.5$ ($SD = 1.2$). Neither condition, $F(1, 44) < 1$, nor its interaction with age, $F(1, 44) = 1.2$, was significant.

A separate *t*-test showed no effect of explicit statements of category relations, $t(46) < 1$, with means of 2.1 ($SD = 1.4$) and 1.7 (1.2) in the explicit and implicit conditions, respectively. Closer inspection revealed no benefit of explicit statements even in older children.

A central question is whether, and how often, children who produced at least two non-exclusive words extended them to referents with defining features of both categories (i.e., *co-extension*). Children in the inclusion/overlap condition could co-extend hierarchically related biological terms (analogous to “dog” and “canine”) or occupation terms (analogous to “doctor” and “health care provider”) as well as overlapping words from both domains (akin to “fish” and “pet”). However, 14 of 24 children in this group co-extended words for only 0 or 1 exemplar. The remaining children co-extended words for 3 to 9 exemplars. Though older children tended to co-extend more words pairs than younger children did (means = 1.9 vs. 3.4, SD s = 2.9 and 3.6), the difference was not statistically reliable. There was (predictably) less co-extension in the exclusion/overlap group, but of the 6 children who produced at least three words (thus ensuring some opportunities for correct co-extension), 5 co-extended words for only 1-2 exemplars.

For a more contextualized analysis, we compared the number of observed instances of co-extension with the number of expected instances, for each child, based on the words the child produced for any object. For instance, if a child might have co-extended two words (because she produced the words correctly at other times), but did not do so when appropriate, this would increase the negative observed-expected difference. Thus, negative scores indicate failure to appropriately co-extend available words. For children in the inclusion/overlap condition, separate observed-expected difference scores were calculated for inclusive word pairs and for overlapping word pairs. *T*-tests showed that the difference for inclusion pairs ($M = .01, SD = .04$) was not different than zero, $t(23) = 1.3, ns$. However, the difference for overlapping words ($M = -.05, SD = .06$) was significant, $t(49) = 5.6, p < .001$, indicating that children failed to co-extend overlapping words even when they had produced both words.

Comprehension. The numbers of words on which children showed receptive knowledge were compared by ANOVA, with age (younger vs. older) and condition (inclusion/overlap vs. exclusion/overlap) between-subjects. Again, older children understood more words ($M = 2.4, SD = 1.3$) than younger children ($M = 1.2, SD = 1.1$), $F(1, 44) = 9.7, p < .005$. In contrast to production data, there was a significant advantage of the exclusion/overlap condition ($M = 1.9, SD = 1/2$) over the inclusion/overlap condition ($M = 1.0, SD = 1.1$), $F(1, 44) = 7.4, p < .01$.

¹ Videotapes of a randomly chosen subset ($n = 8$) were examined to verify that children attended to the exemplar while the experimenter labeled it; this was true in $M = 95\%$ of coded trials.

Again, however, there was no effect of explicit statements about category relations, $t(46) < 1$, *ns*.

The critical question is whether children understood relation between words, and whether this depended on age or type of relation. To assess this, we classified children by whether or not they showed evidence in the comprehension test of having learned the relation between word pairs (e.g., for a hierarchically related pair, selecting a subset of the referents chosen for the superordinate term, when invited to find all examples of the basic-level term). For biological words (inclusive or exclusive), 22 of the 48 children showed understanding of the correct semantic relation; for occupational terms only 6 children did, and only 9 children seemed to represent the overlap between biological and occupational word pairs. Thus, biological kind words seemed privileged, but the effect is mediated by age. For each type of semantic relation, 40-60% of 6-7-year-olds showed comprehension of at least one representative word pair. Among 4-5-year-olds, however, 42% showed comprehension of the biological word pair, but only 5% and 11% showed comprehension of the other pair types (occupational-occupational and biological-occupational).

Discussion

The first experiment suggests specific limitations of children's fast mapping ability. We presented novel words (discrete, pronounceable mono- or bi-syllabic English non-words) more than 20 times over two sessions, while unambiguously indicating the referent object. Children were oriented to the task and stimuli. Nonetheless, immediately after training, 4- and 5-year-olds showed productive competence over only 1 or 2 words. The problem was not ambiguity of the referent set, because children were trained on at least four discriminable but prototypical exemplars of each category, and two defining features of each category were described during training. Also, articulation or motor production problems were not indicated, because children had practiced production of each word. Older children performed somewhat better, showing productive competence over 2-4 words. More importantly, older children co-extended words more frequently than younger children. This trend called for replication with a larger sample (Experiment 2). Overall, the production data do not indicate that children readily co-extended words: only six of the 17 younger children who produced two or more words co-extended any two words to more than one referent. By comparison, half of older children co-extended two or more words to several referents.

Children's comprehension showed a similar trend. Older children showed receptive knowledge of twice as many words (2 or 3) as younger children (0 to 2). Also, more older children understood the relation between the two occupation category words, and between some biological-occupational word pairs. Perhaps younger children simply do not understand occupational categories or labels. There is evidence, however, that by 6 years or younger, most children understand some occupational category terms and

can co-extend them with familiar biological or kinship kinds (Deák & Maratsos, 1998; Watson & Fischer, 1980).

The data do not provide a simple answer to whether children more readily induce inclusive than overlapping semantic relations. Specifically, children's production showed no difference between the inclusion and the exclusion/overlap condition (but a slight trend in favor of the former), whereas comprehension significantly favored the group that learned exclusive basic-level terms but no hierarchically related word pairs. One interpretation is that referential meanings of mutually exclusive novel words are learned somewhat faster than meanings of words with more complex semantic relations. This is consistent with other recent findings (Deák, 2001). Another interpretation, however, is that the overlap/exclusion condition benefited from a basic-level advantage in all words.

A final question is whether explicit input about semantic relations helps children learn correct semantic relations. Surprisingly, no such evidence was seen in either production or comprehension. Perhaps, however, the form of explicit input was not easy for children to process. For this reason, this factor was tested again in Experiment 2.

Experiment 2

The paradigm in Experiment 1 was extended and modified to further address the questions outlined in the introduction. First, we recruited a sufficiently large sample of 6-7-year-olds to satisfactorily answer questions about age differences. Second, the training and reminder sessions were made more play-like by encouraging children to engage in pretense scenarios with the stimuli, and by presenting the words during more natural conversation. These changes addressed concerns about both children's motivation and ecological validity. Third, to eliminate some possible artifacts (e.g., motivation; pronunciation problems) from production test data, children were reinforced for producing words in training. Fourth, a possible ambiguity in Experiment 1 is that occupational kinds were taught on sets of aliens that were dissimilar from the biological kinds. This was done to assess whether children could infer, without direct input, potential for overlap between occupational and biological categories. Unfortunately, this might have encouraged children to infer that the occupational roles were restricted to different, unnamed biological kinds, and exclusive from the named biological kinds. In the revised procedure, we taught occupation categories on a wider range of biological kinds. Finally, minor improvements were made in stimuli and test procedures.

Method

Participants. 48 4- to 7-year-old children participated: 24 4-5-year-olds (mean age = 60 months, range 50-71) and 24 6-7-year-olds (mean = 83 months, range 76-95). Children were recruited and tested at private schools in Nashville, TN, and were primarily white and middle-class.

Materials. The materials from Experiment 1, with slight modifications, were used.

Design. Each child was randomly assigned to one of four conditions, as in Experiment 1: children learned either *inclusive and overlapping* words, or *exclusive and overlapping* (i.e., basic-level) words. Half of each of these conditions were given *explicit* statements about category relations; the other half had to infer these relations from *implicit* evidence.

Procedure. All children completed a training session and, 2-3 days later, a reminder and testing session. Children were taught the words on unique prototypical exemplars. However, after initial presentation of exemplars and words, the experimenter suggested pretense scenarios to children, and more generally encouraged pretend play with the stimuli. During play, the experimenter asked questions and made statements to elicit labels from the child. An assistant monitored the number of times the experimenter presented each word and definition, and prompted additional repetitions if necessary. During the first session children heard each word used by ostension for training exemplars, and heard defining features mentioned, 20 times. They heard the words 8 more times during the reminder session. Thus, children heard 28 uses per word, in clear contexts and with simple definitions, before the tests.

Explicit semantic relation input was altered slightly. Inclusion relations were explained with “kind of” constructions (e.g., “A feg is a kind of wuddle”), which parents use during picture book reading (Callanan, 1985; Gelman et al., 1998).

The experimenter encouraged children to produce the words, but used more natural play discourse contexts (e.g., asking the child “Which one do you want? Who should come to the buildings?”). To increase motivation and elicit pre-test production from all children, a colorful sticker was awarded for each production during training.

Production and comprehension tests were similar to Experiment 1.

Results

Production. Number of correct words was submitted to an ANOVA, with age and condition (inclusion/overlap vs. exclusion/overlap) between subjects. The age effect was significant, $F(1, 44) = 13.9$, $p < .001$: 6-7-year-olds produced $M = 3.2$ ($SD = 1.0$) words, and 4-5-year-olds produced $M = 1.8$ ($SD = 1.4$). Neither the condition effect, $F(1, 44) < 1$, nor the age-by-condition interaction, $F(1, 44) = 0$, was significant.

Given the apparent difference in acquisition of biological and occupation words in Experiment 1, we compared the number of words produced in each domain. Children produced $M = 1.4$ biological kind words ($SD = 0.8$) and $M = 1.1$ (0.8) occupation words, a significant difference, $t(47) = 3.0$, $p < .01$. The age difference was significant (at $p < .01$ in post-hoc tests) for both biological and occupation words.

There was no effect of explicit statements of category relations on production of biological, occupational, or total words, each $t(46) < 1$.

A critical question is whether children produced correct co-extensions in production. In the inclusion overlap group, 13 of 24 children (54%) labeled at least one test exemplar with two hierarchically related words. There was no difference in proportions between age groups, $\chi^2(1, N = 24) < 1$. However, the incidence of overlap co-extension (i.e., naming an exemplar with both a biological and occupational word) did increase with age, $\chi^2(1, N = 48) = 8.4$, $p < .005$. Only 8 of 24 younger children co-extended overlapping words (33%), compared to 18 of 24 (75%) older children.

Comprehension. Initial analyses concern whether or not children inferred the correct relation (inclusion or exclusion) between the two biological words or between two occupation words. In the inclusion condition, each child had two opportunities to infer an inclusion relation. Summed across ages, then, there were a total of 48 possible opportunities to infer this relation. Of these, children inferred only 8 inclusion relations, in addition to 16 inferred exclusion relations, 9 overlap relations, 8 synonymy relations, and 7 indeterminate relations. Surprisingly, there were no apparent age differences in accuracy. Thus, children seldom showed, by selecting a superset of basic-level referents for the superordinate term, correct induction of an inclusion relation. Rather, they seemed to infer a wide range of relations between hierarchical words.

The other group, which should have inferred exclusion relations between same-domain word pairs, showed much greater accuracy and less variability. Out of a total of 48 cases, these children inferred 2 cases (each) indeterminate and synonymous relations, 1 (each) inclusion and overlap relations, and 42 exclusion relations. This is consistent with the claim that children initially assume that referents of novel words are mutually exclusive (Markman, 1994).

Discussion

The results largely confirm conclusions from the first Experiment, despite a number of procedural changes and increased size of the older sample. Despite clear and extensive input about novel words and their definitions, children infrequently showed evidence of learning hierarchically related word pairs. In production, they rarely co-extended overlapping (biological-occupational) word pairs. In contrast, most children showed comprehension of exclusive within-domain word pairs, indicating that they readily learn contrasting basic-level kind labels.

Production improved significantly with age, for both biological and occupational words, and in co-extension of overlapping word pairs. The analyses so far do not show age-related improvement in receptive competence.

As in Experiment 1, there was no positive effect on learning of providing explicit input about semantic relations between words, even when the form of this input was based on parents' input.

General Discussion

These data provide partial answers to the initial questions. First, fast mapping does not provide accurate inferences

about word meanings, even in 6-7-year-old children. Representations of semantic relations (i.e., referent class relations) were often inaccurate or disorganized. An exception is a robust ability, even in preschool children, to infer that labels of clearly contrasting categories (e.g., basic-level kinds within a domain) are mutually exclusivity. Of course, we do not know whether children inferred exclusivity by the 2nd presentations of labels, or by the 20th.) This addresses our second question: exclusive relations seem easier to learn than others semantic relations. Of course, there might well be different circumstances that facilitate, for example, fast inferences about synonymy or inclusion. But overall children's ability to differentiate inclusive and overlapping semantic relations seems fragile or sluggish, even when abundant, explicit input about relations is provided. Some production test evidence suggested that accurate co-extension is more robust for inclusive than for overlapping word pairs (e.g., younger children in Experiment 2). Perhaps, especially for animate kinds, hierarchical relations are more easily inferred by analogical transfer from familiar inclusion relations among labels for biological kinds (e.g., "dog" and "animal"; see Gelman et al., 1998).

One unresolved issue concerns possible divergence of comprehension data between the two experiments. The advantage of biological kind word pairs in Experiment 1 might indicate that the exclusion/overlap group readily inferring exclusion relations between basic-level biological kinds, or that children in the inclusion group were able to transfer knowledge of familiar hierarchical relations among biological kinds. In Experiment 2, however, no such trend was found. Further analyses and follow-up studies might resolve this discrepancy.

Finally, there was no advantage from hearing statements about inclusion or exclusion relations between words within a domain. This raises an important question, because many researchers assume parents' use of inclusion statements facilitates children's category learning. Our data suggest they do not, at least not when first learning words or concepts. Interestingly, such statements were not effective even for 6- to 7-year-olds.

In sum, these data provide balance to the popular assumption that preschool children are precocious word learners. When word learning is measured at a surface level, children show a grasp of new words, but this grasp is weak. It is unlikely to include knowledge of meaning relations, or incorporation into a differentiated semantic network, even after many unambiguous exposures to the new words.

Acknowledgments

This work was supported by a fellowship from the National Academy of Education/Spencer Foundation. Thanks to Michelle Gendreau and Mary Love for assistance.

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