Sweden and Finland in 1976 emanated from experiments at Semipalatinsk is problematic. The large distance (about 4000 km) and the failure to find trajectories for two of the five occasions argue against such an explanation, but the lack of a known source and the concentration of the observations in the first half of 1976, when the Semipalatinsk experiments were reportedly started (*1*), suggest that it should be considered.

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4. This is based on the facts that a ^{99}Mo activity of 1053 ± 76 pc-sec/kg was detected at Grindsjön between 12 and 20 April, that the detection limit for ^{132}Te in the same measurement was 5 pc-sec/kg, and that the ^{132}Te/^{99}Mo activity ratio at formation is larger than 0.56 for all common types of fission of ^{235}U and ^{238}U (the ratio then grows with a doubling time of 17.9 days). Much of the work concerning measurements and analysis of the samples has been done by R. Arntsing and I. Vintersved at this institute.

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Primordial Noble Gases in Chondrites: The Abundance Pattern Was Established in the Solar Nebula

Abstract. *Ordinary chondrites, like carbonaceous chondrites, contain primordial noble gases mainly in a minor phase comprising ≤0.05 percent of the meteorite, probably an iron-chromium sulfide. The neon-20/argon-36 ratios decrease with increasing argon-36 concentration, as expected if the gas pattern was established by condensation from the solar nebula, and was negligibly altered by metamorphism in the meteorite parent bodies. Meteoritic and planetary matter apparently condensed over a substantial range of temperatures.*

Chondrites (*1, 2*), Earth (*1*), and Mars (*3*) contain primordial noble gases in similar proportions, and hence presumably of similar origin. They seem to have been trapped in dust grains growing from the solar nebula (*1, 4*). Efforts to localize these gases in primitive, carbonaceous chondrites such as Allende (*5, 6*) have shown that they occur mainly in "phase Q," an ill-defined Fe,Cr-sulfide comprising 0.04 percent of the meteorite, which is insoluble in HCl-HF but soluble in HNO_3 (*5–8*). Smaller amounts of gas, of distinctive isotopic composition, are found in chromite and amorphous carbon, comprising some 0.4 percent of the meteorite (*5, 6*).

To test whether these results were applicable to less primitive chondrites, we have examined five LL chondrites by the same technique (*9*). They ranged from petrologic type LL3 to LL6, representing progressively greater metamorphism and equilibration (*10*) in the meteorite parent bodies, at temperatures ranging from ~400°C for LL3 (*11*) to 950° ± 100°C for LL6 (*12*). It has been known for some time that the content of Ar, Kr, and Xe correlates with metamorphism, decreasing by some two orders of magnitude from type 3 to type 6 (*2*). But there has been some controversy over the cause of this correlation. Dodd (*13*) and others (*11, 14*) argue that "all ordinary chondrites were derived from material similar to the type 3 chondrites" and lost progressively greater amounts of volatiles during "metamorphism in an open system" (*13*). Larimer and Anders (*4*) suggest instead that the differences are intrinsic and reflect cooling of the nebula: meteorites from the deepest, most metamorphosed parts of the parent body accreted first, when nebular temperatures were highest, and therefore trapped the smallest amounts of gas.

Our study has succeeded in shedding some light on this problem. All five meteorites examined contain most of their primordial gas in minor, gas-rich phases similar to those of carbonaceous chondrites. And the proportions of Ne and Ar strongly suggest that the noble gas pattern was established during condensation, not metamorphism.

Upon treatment with HCl-HF (*5*), all meteorites gave residues of 0.3 to 0.6 percent, consisting mainly of chromite (Table 1). The amount and Cr content fell gradually through the sequence. Krymka, the least equilibrated member of the group (*15*), had a markedly lower Cr content, and hence must have contained substantial amounts of other phases. In this respect it resembles Allende, where the extra phase has been identified as amorphous carbon (*5, 6*). Two etches with red fuming HNO_3 (overnight at 50° to 70°C) dissolved only a minor part of each sample, as shown by the weight losses and the Cr and Fe contents of the etch solutions. The Fe/Cr ratio of the dissolved fraction (1.5 to 13) is much higher than that of the chromite [~0.5 (*16*)], which suggests that some reactive, Fe-rich phase is being dissolved before the less reactive chromite. Chemically, this phase thus resembles phase Q of Allende in both HNO_3 solubility and high Fe/Cr ratio. But is it also the main host phase of the noble gases?

The answer is yes. Figure 1 shows that noble gases (*17*) are greatly enriched in the unetched residues (heavy solid lines) over the bulk meteorites (dashed lines), but are largely removed on etching with HNO_3 (open circles). Evidently the noble gases are located mainly in a minor phase that fits the operational definition of Q [insolubility in HCl-HF and solubility in HNO_3 (*5*)] and that also has other properties in common with Allende Q, namely Fe/Cr > 1 and total mass fraction ≤0.05 percent of the meteorite.

The enrichment factor, residue/bulk, shows some correlation with petrologic type. For the three heavy gases (Ar, Kr, and Xe), it rises from ~4 for St. Séverin to ~150 for Hamlet, before leveling off at ~120 for Parnallee and Krymka. The fraction of heavy gases removed by etching also rises, from ~60 percent for St. Séverin to >99 percent for Hamlet. Krymka again resembles Allende, by re-

Table 1. The HCl,HF-insoluble residues from LL-chondrites. The PMD is the percentage mean deviation of Fe content of olivine (*15*), a measure of disequilibrium. Chromite contents were calculated from the Cr analyses, using reported values for chromites from individual meteorites or group means (*16*). Samples were etched twice, to remove Q as completely as possible. The figures in the last three columns refer to weight losses in the first and second treatments; they have substantial errors for the smaller samples (Krymka and Olivenza). The Cr and Fe data in the last two columns (determined by instrumental neutron activation analysis) refer to first treatment only; the Fe values have errors of ± 20 to 50 percent.

Type	Name	PMD	Residue (%)	Cr (%)	Fe (%)	Chromite (%)	Loss on HNO_3 etching: Weight (%)	Cr (%)	Fe (%)
LL6	St. Séverin		0.63	36.8	22.1	98	7, 4	0.21	2.7
LL5	Olivenza		0.60	34.2	23.7	90	4, 10	0.54	1.3
LL4	Hamlet	3.5	0.54	30.9	17.6	76	11, 11	0.32	2.5
LL3	Parnallee	19	0.37	33.6	18.9	81	11, 22	2.00	3.0
LL3	Krymka	45	0.32	19.1	15.1	47	4, 12	1.22	5.2
C3V	Allende (*5*)	90	0.40	13	9	39	7	0.77	2.67

taining most of its Ne in the etched residue. This trait may be due to two mineralogical peculiarities of the Krymka and Allende residues: high carbon content and high Fe^{3+} content of the chromite (*18*).

A surprising result in Fig. 1 is that planetary Ne is present in all five unetched residues, although it had never been detected in the bulk meteorites or, for that matter, in any equilibrated chondrites. That the neon is planetary and not solar is shown by the low $^{20}Ne/^{22}Ne$ ratios [8.6 to 11, after correction for cosmogenic Ne, compared to 12.5 ± 0.2 for trapped solar-wind Ne (*19*)]. Evidently it had been masked by the large amounts of cosmogenic Ne [3 to 14 × 10^{-8} cm^3/g at standard temperature and pressure (STP)], which are removed in our procedure along with the bulk of the meteoritic matter.

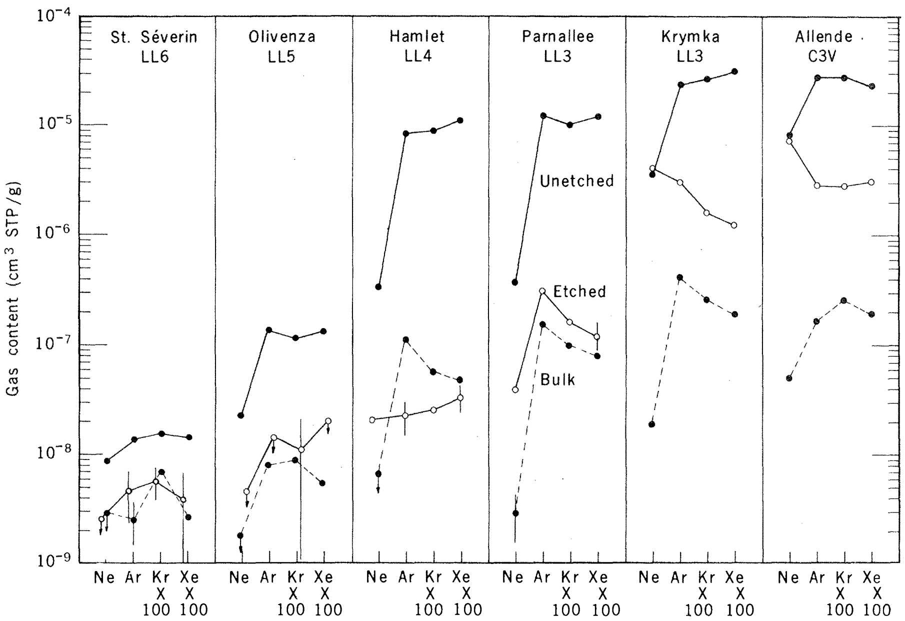

Fig. 1. Acid-resistant residues from chondrites (heavy solid lines) are enriched in primordial noble gases relative to bulk meteorites (dashed lines), especially in the less metamorphosed meteorites (petrologic types 3 and 4). Most of the gases are removed by etching with HNO_3 (open circles), and apparently are located in an oxidizable mineral (phase Q). Errors larger than 25 percent are indicated by error bars; those exceeding 100 percent are expressed as upper limits (downward arrows).

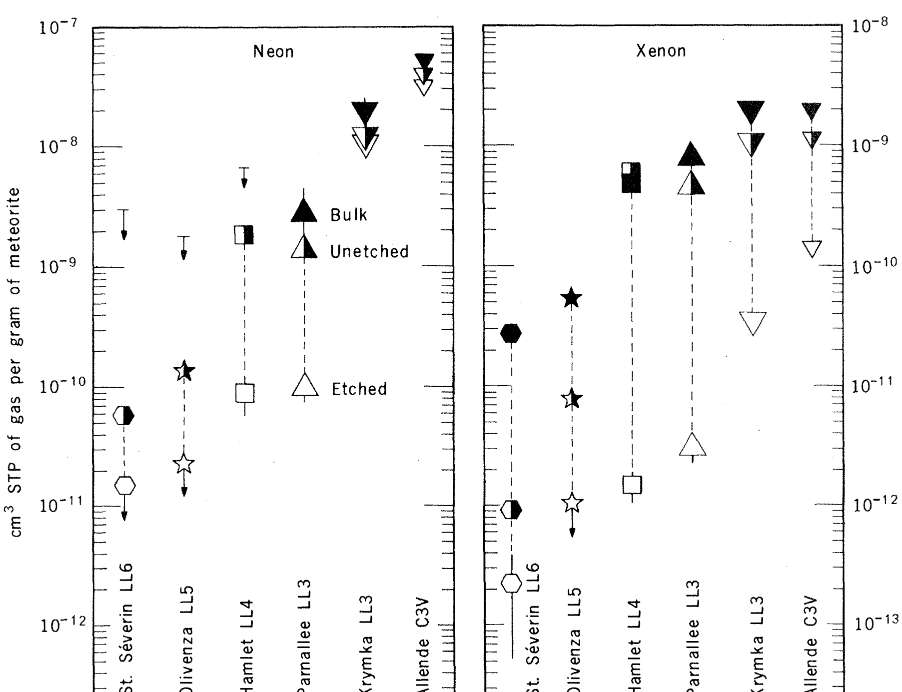

Fig. 2. Material balance plot showing that the HNO_3-soluble phase Q often accounts for the major part of the noble gases in the meteorite. Unetched residues (half-filled symbols) fall only slightly below the bulk meteorites (filled symbols), whereas etched residues (open symbols) are substantially lower.

To determine which host phase accounts for most of the gas, we compare in Fig. 2 their contents of Ne and Xe per gram of meteorite (rather than per gram of sample). In petrologic types 3 and 4, the unetched samples (half-filled symbols) account for 50 to 100 percent of the Xe in the bulk meteorite (filled symbols), and since the etched samples lie one to two orders of magnitude lower, it is clear that most of the Xe is located in the HNO_3-soluble phase, Q. But Q becomes progressively less important for the higher petrologic types, accounting for 13 percent of the Xe in Olivenza and only 3 percent in St. Séverin.

The picture for Ne is less complete, because only upper limits are available for bulk LL4's to LL6's (because of masking by cosmogenic Ne) and for two of the etched samples (because of their small size). But it is clear that Q contains most of the detectable primordial Ne, except in Krymka and Allende, where the etched residues account for a major part.

The two models for primordial noble gases in meteorites make opposite predictions for the ratio of light to heavy noble gases (for instance, Ne/Ar) in a given mineral. In the metamorphic model, the Ne/Ar ratio should *decrease* with falling Ar content, because Ne diffuses considerably faster than Ar (*20*) and will therefore be driven out preferentially during metamorphism. In the condensation model, on the other hand, the Ne/Ar ratio should *increase* with falling Ar content, because Ne, having a smaller heat of solution (*21*), will have a smaller temperature coefficient of solubility, and will therefore become predominant in meteorites condensing at higher temperatures [see figure 9 of (*5*)].

This test has at last become feasible, now that primordial Ne has been found in metamorphosed meteorites (Figs. 1 and 2) and has been traced to a single mineral, Q. Figure 3 compares $^{20}Ne/^{36}Ar$ ratios of Q as a function of ^{36}Ar content (*22*).

The trend in Ne/Ar ratios decisively supports the condensation model over the metamorphic model. As the ^{36}Ar content falls by a factor of 10^3 from Parnallee to St. Séverin, the Ne/Ar ratio rises by a factor of 30, instead of falling as predicted by the metamorphic model. The condensation model, on the other hand, predicts both the rise in the Ne/Ar ratio and the colinearity of the points. [The latter reflects the fact that noble-gas solubilities vary logarithmically with reciprocal temperature (*21*); thus a log-log plot of an abundance ratio against concentration should be a straight line.]

Some caution may be in order, because the correlation in Fig. 3 is based on only four points (unless we count the Krymka point, whose errors are very large because of the large amount of Ne in the etched sample). Many meteorites have lost gases through shock heating at some stage in their histories, and since Ne would be lost more readily than Ar, we cannot be certain that some of the low Ne/Ar ratios in Fig. 3 are not due to shock. Although the high K-Ar and U-He ages and lack of conspicuous shock effects rule out late, postmetamorphic impacts, they do not exclude early, premetamorphic impacts that could have driven out Ne while leaving no lasting shock effects. Low Ne/Ar ratios produced in this way should not correlate with Ar content, and so at least the present, limited data show no evidence for such loss.

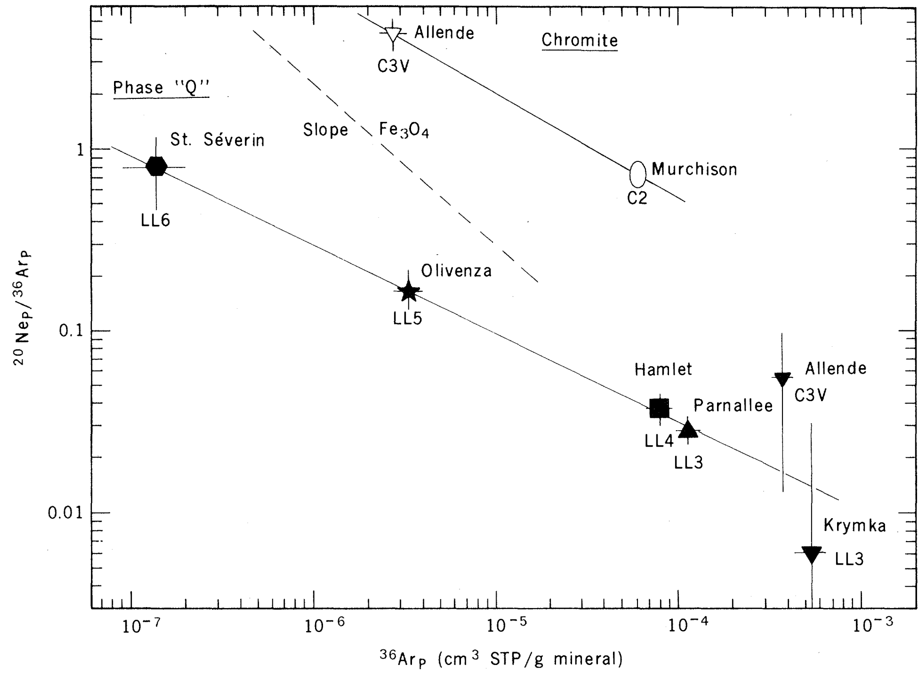

Fig. 3. The Ne/Ar ratio in meteoritic minerals (phase Q and chromite) falls with increasing Ar content. This is the trend expected for equilibrium trapping of noble gases in solids at falling temperatures [compare the dashed line for synthetic Fe_3O_4, from (*21*)]. Diffusion losses during metamorphism would have given the reverse trend, and therefore must have been negligible.

Moreover, the only available data for another single mineral, chromite from Murchison and Allende (*6*), show a similar correlation of Ne/Ar with Ar content. They define a line parallel to the Q line, which, if taken at face value, implies that the difference in heats of solution of Ne and Ar is essentially the same for Q and chromite. The slope of both lines is slightly smaller than that for synthetic magnetite (*21*). This may mean either a smaller difference in heats of solution (~7 instead of 13 kcal/mole) or a systematic decrease in the amount of Q from LL3 to LL6, not reflected in the weight losses (*22*). A tenfold decrease would be needed to eliminate the difference in slope.

Thus it appears that primordial noble gas abundances in chondrites were established during condensation. Metamorphism, while recrystallizing the major silicate and metal phases (*10, 11*), apparently did not measurably disturb the major part of the noble gases, which is located in Q. Within the accuracy and statistical limitations of our data, there is no evidence for gas loss.

It is not quite clear why Q accounts for a smaller share of gas in the LL5's and LL6's (Fig. 2). One possibility is that formation of Q began only at some temperature below 500°K (*7*) and had not progressed very far at the time these meteorites accreted. Alternatively, some part of Q in higher petrologic types may have been resorbed by adjacent phases, transferring its gases to those phases. Once these questions are settled, and the heats of solution of noble gases in Q are measured, it may be possible to use the Ne/Ar ratio as a cosmothermometer for meteorites and planets.

The data in Figs. 1 to 3 do not preclude the possibility that metamorphism caused some modest redistribution of volatile trace elements such as Cs and Br (*23*) or Tl, Bi, and In (*24*). Stepwise heating experiments show that a major part of the trace elements volatilizes at much lower temperatures than do the noble gases in Q [400° to 800°C (*24*) compared to 1200° to 1600°C (*25*)]. However, it is now clear that the ~10^3-fold differences in noble-gas contents of chondrites are intrinsic, and not caused by metamorphism. Thus the fundamental premise of the metamorphic model, that all ordinary chondrites initially had similar contents of volatiles (*13, 14*), is false. And since volatile trace elements correlate rather well with noble gases (*3, 13*), it would seem, by Ockham's razor, that their abundances reflect varying degrees of condensation, not metamorphic redistribution. Any such redistribution seems to have been limited to a purely local, centimeter scale (*4, 23*).

Our data also have a bearing on the origin of noble gases in planets. Apparently temperatures in the solar nebula varied enough with time to cause a 10^3-fold variation in noble gas contents of successive condensates at a single location. Models that build each planet from a single material of a single condensation temperature and composition (*26*) hence are an oversimplification.

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18. Allende chromite has some 30 mole percent Fe^{3+} in the M^{3+} sites [D. Virgo, private communication cited in (*5*)], and the chromite of unequilibrated ordinary chondrites also seems to contain small amounts of Fe^{3+}, judging from the increase of Fe/Cr with PMD (*16*); see also Table 1.
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22. For an estimate for the Q content, we used the weight loss in the first HNO_3 treatment. Unfortunately, HNO_3 does not give a clean separation of Q and chromite; some chromite dissolves in the first treatment, whereas some Q survives. And since some of the samples weighed less than 2 mg, weighing errors are appreciable. However, estimates based on soluble Fe (Table 1) give fairly similar results, and the uncertainties are not large enough to affect our conclusions. The trend in Fig. 3 would have been essentially similar if we had merely plotted the gas contents per gram of residue (that is, assumed constant Q contents).
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Somatostatin: Widespread Abnormality in Tissues of Spontaneously Diabetic Mice

Abstract. *Diabetic mice of the C57BL/6J obob and C57BL/Ks dbdb strains show a reduction in pancreatic somatostatin concentration accompanied in the obob strain by a striking decrease in the number of somatostatin-containing cells in the islets. Somatostatin concentration is also decreased in the stomach but increased in the hypothalamus. These findings suggest different control mechanisms for somatostatin in the hypothalamus compared to the gut and pancreas and exclude a primary genetic abnormality of somatostatin cells in the mutants.*

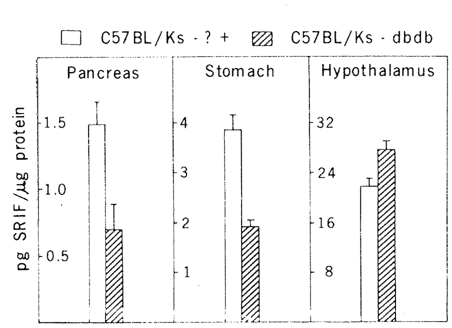
The obob and dbdb mice are single gene mutants characterized by obesity and hyperphagia. Mice of both strains develop spontaneous diabetes with different clinical features depending on the genetic background (*1*). Although the primary defect in the mutant mice has not been elucidated, substantial evidence exists for an underlying hypothalamic abnormality. Thus, apart from the abnormal appetite control which in the dbdb mouse is presumed to be secondary to a defect in the hypothalamic satiety center (*2*), the obob mouse in particular exhibits a variety of other dysfunctions suspected of being hypothalamic in origin, such as impaired thermoregulation, thyroid function, reproductive function, and growth hormone (GH) secretion (*3*).

Recent studies have revealed a striking reduction in the pancreatic concentration of immunoreactive somatostatin in 3-month-old obob and dbdb mice (*4*). Since somatostatin is widely distributed throughout the brain and gastrointestinal tract (*5, 6*), our study was undertaken to examine somatostatin in other organs. It demonstrates striking changes in the concentration of the peptide in the stomach and hypothalamus in addition to those of the pancreas of the obob and dbdb mice.

Male C57BL/6J obob and lean littermate controls C57BL/6J?+ were purchased from the Centre de Sélection et Élevage d'Animaux de Laboratoires, Orléans, France, and studied at 8 weeks of age. Male C57BL/Ks dbdb and lean controls C57BL/Ks?+ were obtained from the Jackson Laboratory, Bar Harbor, Maine, and studied at 11 to 12 weeks of age. Animals in the fed state were killed by decapitation, and trunk blood was collected for glucose and insulin estimations (*7*). The following tissues were extracted for somatostatin: whole hypothalamus and pyloric antrum from all mice (*8*), whole pancreas from the dbdb and control mice, and pancreatic islets from the obob and control mice. From a second group of obob and control mice, the whole pancreas was removed, divided longitudinally into two halves, one of which was extracted; the other half was fixed in Bouin's solution, sectioned, stained by immunofluorescence for somatostatin, and subjected to morphometric analysis.

Somatostatin was extracted from tissues by sonification in 1*N* acetic acid at 0°C and measured by specific radioimmunoassay (*4, 6*). The total protein concentration of the extracts was determined by the method of Lowry *et al.* (*9*).

For morphometric analysis, the somatostatin-containing cells were identified by indirect immunofluoresence and quantified in the first 20 islets encountered in sections of each pancreas. The volume density per islet of the somatostatin cells was determined by the point counting method of Weibel (*10*). In addi-



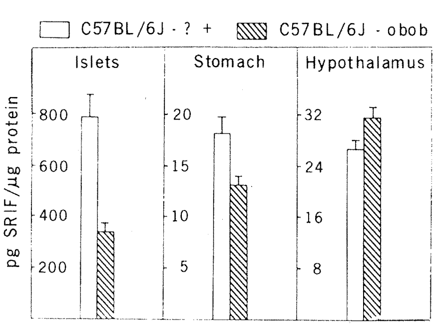


Fig. 1 (left). Comparison of somatostatin concentration in whole pancreas, stomach, and hypothalamus of dbdb (N = 10) and control (N = 10) mice. Means ± standard errors are plotted. Fig. 2 (right). Comparison of somatostatin concentration in islet, stomach, and hypothalamus of obob (N = 10) and control (N = 10) mice. The points represent means ± the standard errors.