line the trend was toward a specialized epidermal pattern in which the long cells are greatly reduced and the short cells (silica and suberized cells or silica-suberized couples) are abundant. This contrasts with the *Berriochloa-Piptochaetium-Stipa* (section *Hesperostipa*) line in which only long cells are present. The reason for the differences in the patterns is unknown, but the fact that these lines have been divergent for a significant period of geologic time is clearly indicated by the patterns of the fossil and living species.

My findings also indicate that species of *Piptochaetium* and North American species of *Stipa* (section *Hesperostipa*) appear to have a common origin in species of the fossil genus *Berriochloa*. However, intermediate forms of Late Pliocene and Pleistocene grasses are not available, and the origin of the characteristic lemma pattern of *Piptochaetium* is unknown. At some time during the late Pliocene or Pleistocene *Stipa* (section *Hesperostipa*) and *Piptochaetium* became generically distinct.

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References and Notes

1. In grasses the flower is normally enclosed by two bracts, the lemma (lower) and palea (upper). In many grasses these floral bracts are indurate at maturity and enclose and protect the caryopsis ("grain"). The lemma and palea devoid of the flower is termed the anthoecium. Only the anthoecia are preserved as fossils.
2. E. W. Berry, *Proc. U.S. Natl. Mus.* **73**, 1 (1929); M. K. Elias, *Univ. Kans. Sci. Bull.* **20**, 333 (1932); A. B. Leonard, *ibid.* **38**, 1393 (1958); E. C. Galbreath, *Trans. Ill. State Acad. Sci.* **67**, 366 (1974).
3. M. K. Elias, *Geol. Soc. Am. Spec. Pap. (Reg. Stud.)* **41**, 1 (1942).
4. M. K. Elias [(*3*); personal communication, 1975] believed that the differences between *Stipidium* and *Berriochloa* were artificial and that these genera would eventually be united. I have recently united the genera (*5*) retaining the genus *Berriochloa* for all fossils previously assigned to *Berriochloa* or *Stipidium*.
5. J. R. Thomasson, thesis, Iowa State University (1976).
6. The tribe Paniceae is a group of predominantly tropical to subtropical grasses. It includes cultivated crops such as millets and sorghums, and weedy grasses known as sandburs, foxtails, and crabgrasses.
7. The tribe Stipeae is a group of grasses widely distributed in temperate, tropical, and subtropical regions of the world. It includes many grasses commonly referred to as needlegrasses, needle-and-thread grasses, and ricegrasses. Many are common constituents of grasslands of North and South America where they are valuable forage grasses.
8. M. V. Brown, *Bot. Gaz.* **119**, 170 (1958); H. Prat, *Ann. Sci. Nat. Bot. Biol. Veg.* **14**, 117 (1932); *ibid.* **18**, 165 (1936); *Bull. Soc. Bot. Fr.* **107**, 32 (1960); ——— and C. Vignal, *Bol. Soc. Argent. Bot.* **12**, 155 (1968); J. R. Reeder, *Am. J. Bot.* **44**, 756 (1957).
9. S. Bjorkman, *Symb. Bot. Ups.* **17**, 1 (1960); C. A. Clark and F. W. Gould, *Am. J. Bot.* **62**, 742 (1975); C. Hsu, *J. Fac. Sci. Univ. Tokyo Sect. 3* **9**, 43 (1965).
10. J. R. Thomasson, *Am. J. Bot.*, in press.
11. A detailed report on the systematics of the fossils is in preparation.
12. Epidermal cells of grass leaves and floral bracts are classified as long cells or short cells, the former generally much longer than wide and frequently having sinuous lateral walls, and the latter as wide as or wider than long, measured on the longitudinal axis of the blade or floral bract. Short cells are usually distinguished as either silica cells if a silica-body fills the lumen, or a suberin cell when the walls are impregnated with suberin. In my experience there seems to be little correlation between the pattern of long and short cells on the leaf epidermis and the pattern of long and short cells on the lemma and palea epidermises.
13. G. L. Stebbins, Jr., *Ecol. Monogr.* **17**, 149 (1947); *Taxon* **24**, 91 (1975).
14. D. L. Williams, *J. Biogeogr.* **2**, 75 (1975).
15. L. R. Parodi, *Rev. Mus. La Plata Secc. Bot.* **6**, 213 (1944); *Darwiniana* **7**, 369 (1947); ——— and F. Freiser, *Cienc. Invest.* **1**, 144 (1947); J. I. Valencia and M. Costas, *Bol. Soc. Argent. Bot.* **12**, 167 (1968).
16. The genera *Stipa* and *Piptochaetium* are distinct on the basis of palea characteristics: the former has a smooth palea, while the latter has a grooved and keeled palea into which the edges of the lemma lock. I have examined thousands of specimens of *Berriochloa* and have never seen one with a distinctly grooved and keeled palea, although I have seen some with slight medial depressions. The origin of the groove in modern *Piptochaetium* is unknown.
17. Supported by grant BMS 74-13324 from the National Science Foundation and by the Bessey Microscopy Facility, Iowa State. I thank R. W. Pohl, P. Elsner, J. L. Horner, J. A. Holman, R. J. Zakrewski, and R. M. Hunt for cooperation and assistance. I also thank M. G. Netting and J. H. McAndrews for personal intervention in support of my field studies.

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Lunar Tidal Acceleration Determined from Laser Range Measures

Abstract. *Lunar laser range measures covering the period 1969 to 1976 have been used to determine the anomalous secular acceleration in the mean longitude of the moon, commonly attributed to the effect of tidal friction in the earth. The acceleration determined is −24.6 ± 1.6 arc seconds per century squared, against an atomic time scale, where the uncertainty is the formal standard deviation of the solution. The realistic uncertainty is surely larger, as evidenced by the ensemble of solutions performed with various models and observation sets. The determined value is in good agreement with the conventional value and with several recent determinations by other methods. An attempt to determine the rate of change of the mean distance, essential for separating the tidal effect from a time variation of the gravitational constant, yielded no significant result, because the observations still span too short a time.*

The longitude of the moon shows an acceleration that is not explained satisfactorily by the techniques of classical celestial mechanics. This fact, well known for more than two centuries, continues to provoke both scientific activity and controversy. The question is not only astronomical but geophysical and cosmological as well, since the cause of the acceleration is now commonly thought to be frictional dissipation in the earth, but it will also contain a contribution due to a time variation of the gravitational constant G, if such exists. As we have discussed elsewhere (*1*, *2*), there are other possible sources of contamination for a purely geophysical interpretation, but this is beyond the scope of this report.

Since the basic observed fact is an acceleration in longitude, the most obvious technique for studying it is by means of measures of angular position of the moon. In the Taylor's series expansion of the mean longitude L

$$L = L_0 + \dot{L}_0(t - t_0) + \tfrac{1}{2}\ddot{L}_0(t - t_0)^2 + \cdots \qquad (1)$$

the parameter of interest is $\ddot{L} = 2\dot{n}$ (*3*), where n is the "sidereal mean motion" (*4*). This parameter, or rather the correction to the adopted value, has been studied by means of observations of lunar and solar eclipses, equinox passages, meridian transits, and stellar occultations. The currently adopted conventional value of the "tidal" contribution of $\ddot{L}$ is −22.44 arc sec/cy^2 (cy = century); the results of recent studies of angular position observations range from −18 to −42 arc seconds (*5*). One must ask why the disparity is still so large.

One of the basic difficulties in this problem has been the lack of explicit partial derivatives with respect to the mean motion of the lunar orbit, which should be regarded as independent of the customary six Keplerian elements of the orbit. In some studies, the lack has been overcome by application of Kepler's third law

$$a^3n^2 = G(E + M) \qquad (2)$$

relating the mean motion with the mean distance a, the universal gravitational constant G, and the mass $E + M$ of the earth-moon system. The assumption that $G(E + M)$ is constant gives, to first order

$$2\delta\dot{n}/n = -3\delta\dot{a}/a \qquad (3)$$

Thus, derivatives for $\ddot{L}$ can be obtained from the readily available derivatives with respect to the mean distance. Van Flandern's attempt (*6*) to estimate $\dot{G}$ was an early warning signal that this is not sufficient. In that work, an attempt was

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made to distinguish between solutions made on the basis of different time scales that would, in principle, behave differently if the gravitational constant were variable. This study points out (implicitly) a second fundamental problem of the usual modes of determining $\ddot{L}$: only angular measures are used, and they are not all well defined (*7*) and none are sensitive to independent changes in a.

In fact, it is necessary to replace Eq. 3 with the relation

$$2\delta\dot{n}/n + 3\delta\dot{a}/a = \delta\dot{G}/G \qquad (4)$$

with the condition that one use independent partial derivatives with respect to n and a, as well as observations that are sensitive to both parameters. We have calculated numerical partial derivatives for both of these quantities independently (using appropriate variations of the earth-moon mass), and we have used these derivatives to perform a differential correction of the lunar orbit to fit 2034 laser range observations obtained at the McDonald Observatory between September 1969 and October 1976 (*8, 9*). The positions of the moon were calculated from the unpublished but widely available numerical ephemeris known as LURE2 (*10*), which was constructed with a tidal acceleration $\ddot{L} = -40$ arc sec/cy^2, following Oesterwinter and Cohen (*11*) and Van Flandern (*6*). A previously reported attempt with fewer data (*9*) gave a result whose quoted uncertainty was as large as the correction, and thus of no practical interest. Our result is a correction $\Delta\ddot{L} = +15.4 \pm 1.6$ arc sec/cy^2, resulting in a value for the tidal acceleration of

$$\ddot{L}_t = -24.6 \pm 1.6 \text{ arc sec/cy}^2$$

The value cited is that which we consider to be the best founded from an ensemble of solutions for which we used two different ephemerides, two different libration models, and data spans of 6 and 7 years. The cited uncertainty is a formal standard deviation from the adopted least-squares solution, and must therefore be regarded with extreme caution. All of the various solutions lay in the range -22 to -26 arc sec/cy^2, which suggests that a more realistic error estimate would be about ± 5 arc sec/cy^2.

In the series of solutions that gave this result, we also solved for other pertinent parameters, including the telescope and reflector coordinates, the other orbital elements, the harmonic coefficients of the lunar gravity field, and several global parameters for the rotation of the earth. All were within reasonable bounds, and the standard deviation of the postfit residuals over 7 years' data was 2.8 nsec, or 42 cm in equivalent one-way distance. We also tried to solve for $\dot{a}$ simultaneously with $\ddot{L}$, but the results were inconclusive. This was not unexpected, because the total change in the mean distance over the observed interval implied by our result given above is only about 15 cm (the level of observational noise) if the gravitational constant is really constant (*11*). These solutions did not perturb the solution for the secular acceleration significantly, but the values implied for the secular variation of G spanned a range including zero and Van Flandern's result. It will require several more years before the cosmological question of $\dot{G}$ can be resolved with any confidence.

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1. J. D. Mulholland, paper presented at the International Astronomical Union 16th General Assembly, Grenoble, 1976.
2. O. Calame and J. D. Mulholland, paper presented at the Symposium on Tidal Friction and Earth Rotation, Bielefeld, West Germany, 1977.
3. We follow the convention that a superior dot represents a time derivative. The relation given is imposed by our procedure, although we realize [and explained in (*2*)] that the literature is confused on this point by an ambiguity in the definition of the perturbed mean motion, which leads to different expressions for its time derivatives, by a factor of 2 in the case of $\dot{n}$.
4. In nearly all discussions, $\dot{n}$ is supposed to be constant, largely because no geophysically plausible mechanism can account for a significant variation over historic time.
5. A complete and readable history of this subject is found in P. M. Muller, "An analysis of the ancient astronomical observations with the implications for geophysics and cosmology," published privately by the author, 1975.
6. T. C. Van Flandern, *Mon. Not. R. Astron. Soc.* **170**, 333 (1975).
7. Some of the angular measures are not well defined with respect to the center of mass (CM), because they are low-precision measures of the edge of the visible disk. Some have unique systematic errors. If there is dissipation in the rotation, or if long-period effects are neglected, then the CM may appear to accelerate relative to the Watts center, used in reducing such data.
8. For discussions of the techniques required, see O. Calame, *Manuscr. Geod.* **1**, 173 (1976).
9. J. D. Mulholland, in *Scientific Applications of Lunar Laser Ranging*, J. D. Mulholland, Ed. (Reidel, Dordrecht, 1977), p. 9.
10. J. G. Williams, in *ibid.*, p. 37.
11. C. Oesterwinter and C. J. Cohen, *Celestial Mech.* **5**, 317 (1972).
12. While it may strike the reader as curious that we seem to say that the range data are more sensitive to angle than to distance, this is not really the case. The linear displacement along the orbit corresponding to our result is about 200 m.

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Alkaloids in Whole Plant Material: Direct Analysis by Kinetic Energy Spectrometry

Abstract. *A new approach to mixture analysis has been applied to the direct detection of various alkaloids in plant materials. The method requires absolutely no sample treatment. Results are presented for cocaine, morphine, papaverine, coniine, and atropine. The signal-to-background characteristics are superior to those of conventional mass spectrometry. Sensitivity is sufficient to detect and identify between 1 and 10 nanograms of alkaloid.*

The analysis of complex mixtures is often complicated by the effort necessary in sample treatment before the components can be actually identified. We report here a new approach to mixture analysis, developed from mass spectrometry, which involves absolutely no sample treatment. We present results on the analysis of alkaloids in plant materials, exemplified by the identification of papaverine in raw opium (Fig. 1). The useful sensitivity of the technique is also shown to be better than that obtained in conventional mass spectrometry.

The basis for the technique has been described elsewhere (*1*). The sample is ionized to produce, among other things, a molecular ion of each component in the mixture. The ion of interest is mass-analyzed and allowed to react with a target gas at high kinetic energy, which causes fragmentation of the ion. By using kinetic energy analysis to identify these fragments, one can deduce the structure of the initial ion (*2*). The spectrum obtained, termed a MIKE (mass-analyzed ion kinetic energy) spectrum, closely resembles the fragmentation pattern observed in the mass spectrum of the pure compound. Thus, the MIKE technique provides a method of obtaining the mass spectrum of a given ion corresponding to a particular component of the mixture.

We have used the MIKE technique in the analysis of simple mixtures (*1, 3*). Success in the analysis of plant extracts for various alkaloids (*4*) prompted us to attempt the analysis of alkaloids from whole plant tissues (*5*).

We analyzed freshly cut poison hemlock (*Conium maculatum* L.) for the purpose of detecting the poisonous alkaloid coniine (*6*). Figure 2 illustrates the signal and background characteristics of the method: the top portion shows the background mass and MIKE spectra, and the