TABLE 1

EFFECT OF PRESSURE ON INDUCTION OF MUTATIONS BY NITROGEN MUSTARD IN *Neurospora crassa*
(TEMP = 26° C)

Exp. No.	Treatment	No. isolations	No. morph. mutants	% Mut.	No. biochem. mutants	% Mut.	% Kill
21	0.2% Mustard	357	53	14.9	3	0.8	99.57
	0.2% Mustard + 9000 psi	238	17	7.2	6	2.5	99.94
25	0.2% Mustard	396	45	11.4	4	1.0	99.29
	0.2% Mustard + 9000 psi	435	33	7.6	8	1.8	99.72
48	0.2% Mustard	423	82	19.4	8	1.9	....
	0.2% Mustard + 9000 psi	377	46	12.0	10	2.7	....
53	0.2% Mustard	329	49	15.0	..	..	....
	0.2% Mustard + 9000 psi	595	44	7.4	..	..	....
29	0.2% Mustard	323	27	8.3	..	..	98.27
	0.2% Mustard + 5000 psi	377	20	5.3	..	..	98.50
39	0.2% Mustard	513	63	12.3	4	0.8	....
	0.2% Mustard + 5000 psi	448	36	8.0	5	1.1	....
	None	400	5	1.4	0	0	....
	9000 psi	385	3	0.8	0	0	50.00

concerned, for pressure applied at that time has no appreciable effect. The results therefore indicate that there are temporary delayed effects of nitrogen mustard which can be influenced by application of high hydrostatic pressure.

From the type of temperature and pressure analysis which has been adequately outlined by Johnson, Eyring, and their co-workers, it should be possible to obtain a clearer understanding of the action of chemical agents and various types of radiation in inducing genic changes. The action of pressure on the combined effects of various mutagenic and nonmutagenic agents (N-mustard, x-ray, ultraviolet, and infrared radiation, etc.) may be expected to clarify greatly the process by which these environmental factors can modify the mutation process.

A microconidial strain of *Neurospora crassa*[2] (*2*) was used to study the effect of pressure on the induction of both biochemical and morphological mutants by nitrogen mustard, bis-β-chloroethylmethylamine. Eight-day-old conidia were suspended in 0.1 M phosphate buffer (pH 6.5) and filtered through a sterile pad of cotton in order to remove any mycelial fragments. After the desired treatment, the spores were plated onto a complete medium containing 1.5% L-sorbose (*16*). After 2–3 days, single isolates were transferred to small (10 × 75 mm) complete slants and subsequently scored for morphological mutations. These isolates were then transferred to a liquid minimal medium to determine the presence of any biochemical mutants. Most such mutants found involved deficiencies of single amino acids, vitamins, or purines.

The method used in applying high pressure to the conidial suspension was essentially that which has been described by Johnson *et al.* (*14*). The desired amount of an aqueous solution of nitrogen mustard was mixed with the conidial suspension, and a sample of the mixture was placed in the high pressure bomb. In those cases where pressure was applied simultaneously with the mustard, there was a lapse in time of approximately 30 sec between mixing of the mustard with the conidial suspension and application of the pressure. After treatment under high pressure, a sample of the mixed suspension was removed from the pressure bomb and rapidly plated onto the complete medium.

[2] Kindly supplied by Dr. E. L. Tatum.

References

1. AUERBACH, C. *Biol. Rev.*, 1949, **24**, 355.
2. BARRATT, R. W., GARNJOBST, L., and TATUM, E. L. *Proc. 8th internat. gen. Congr., Suppl. Hereditas*, 1949.
3. BEADLE, G. W. and TATUM, E. L. *Amer. J. Bot.*, 1945, **32**, 678.
4. CAMPBELL, D. H. and JOHNSON, F. H. *J. Amer. chem. Soc.*, 1946, **68**, 725.
5. DE ROBERTIS, E. D. P., NOWINSKI, W. W., and SAEZ, F. A. *General cytology.* Philadelphia: W. B. Saunders, 1948.
6. ELMORE, D. T. *et al. Biochem. J.*, 1948, **42**, 308.
7. EYRING, H. and STEARN, A. E. *Chem. Rev.*, 1939, **24**, 253.
8. EYRING, H. and MAGEE, J. L. *J. cell. comp. Physiol.*, 1942, **20**, 169.
9. EYRING, H., JOHNSON, F. H., and GENSLER, R. L. *J. phys. Chem.*, 1946, **50**, 453.
10. GOLDACRE, R. J., LOVELASS, A., and ROSS, W. C. J. *Nature*, Lond., 1949, **163**, 667.
11. JOHNSON, F. H. and CAMPBELL, D. H. *J. cell. comp. Physiol.*, 1945, **26**, 43.
12. JOHNSON, F. H. and WRIGHT, G. G. *Proc. Nat. Acad. Sci.*, 1946, **32**, 21.
13. JOHNSON, F. H., BAYLOR, M. B., and FRASER, D. *Arch. Biochem.*, 1948, **19**, 237.
14. JOHNSON, F. H. and EYRING, H. *N. Y. Acad. Sci.*, 1948, **XLIX**, 376.
15. SWANSON, C. P., MCELROY, W. D., and MILLER, H. *Proc. nat. Acad. Sci.*, in press.
16. TATUM, E. L., BARRATT, R. W., and CUTTER, V. M. *Amer. J. Bot.*, 1948, **35**, 803.

A Prediction Regarding the Humboldt Current

Lalla R. Boone[1]

University of California, Berkeley

According to a finding of the late E. G. Mears, an unusual ice outbreak was due in the North and South Atlantic during the proper seasons of 1949. The Humboldt Current should begin receiving warm water invasions by the southern summer of 1950, but these invasions should not become serious until 1951–52. Dr. Mears' attention was drawn to the Humboldt Current during the 1941 conference of scientists in Lima. In *Science* (*16*) of April 24, 1942, he pointed out that the 1941 tropical intrusion (*9*) into the normally subtropical Peru, did not correspond to the seven-year cycle (*24*), which had been proposed previously, for only two years had elapsed since the 1939 interruption had occurred. In Dr. Mears' subsequent study of the Humboldt Current, he became con-

[1] Research Assistant to E. G. Mears, 1940–1946.

fident that the disastrous warm water visits to the coast of Peru are occasioned by tides, (*5, 7, 12, 15, 18*, p. 334, *23, 25, 26*). They are connected with moon cycles (*23, 25, 26*) and are related to sunspot activity indirectly as the sunspots affect the moon (*2, 19, 22, 23, 32, 33, 36*).

Pettersson, of the Hydrographic Station of Borneo, has shown that tides at boundaries between deep and bottom waters of deep inlets during certain moon cycles are as much as fifty times greater (*25, 26*) than simultaneous tides at the surface. Therefore, even though polar region tides at the surface are small (*12*), in deep polar inlets tides at boundaries between deep and bottom waters may be very important, for Pettersson has proved (*25, 26*) that it is because of these tides that important ice outbreaks come from such inlets. He suggested in 1929 (*26*) that ice outbreaks from such inlets in the immediate antarctic vicinity of the Humboldt Current might cause the tropical irregularities in the Humboldt Current area. When Gunther (*10*) demonstrated that antarctic water had no part in the Humboldt Current either directly at the surface or from upwelling, and other *Discovery Reports* (*4, 6, 8, 13, 14*) made clear that only the Weddell Sea had an outlet sufficiently deep to emit significantly large quantities of ice (*30, 35*), it became apparent that Pettersson's suggestion needed to be amplified. Dr. Mears, in a manuscript he was preparing for publication when he died, stated that ice from the Weddell Sea seemed to fit known occurrences better than ice from the immediate antarctic vicinity of the Humboldt Current could, because there appeared to be a lag between ice outburst and abnormalities in the Humboldt Current area. If the ice discharge came into the immediate stream from which the Humboldt stems—the West Wind Drift— the lag of approximately a year between unusual ice conditions known in the antarctic and any disturbance in normal phenomena of the Humboldt Current area, and two to three years before serious interruption occurred, would be difficult to explain (*23*). This lag, if the significant ice discharge comes only from the Weddell Sea, would be necessitated by the long circuit which the body of water affected by the discharge from the Weddell Sea must make around the Antarctic Ocean to the American West Coast before it could affect the Humboldt Current environs.

That the ice discharge from the Weddell Sea is important is attested by Mackintosh and Herdman (*14*, p. 292): "The Weddell Sea has an important effect in the distribution of ice in the Atlantic sector . . . the flow of cold water from the Weddell Sea . . . exerts an influence far to the east. . . . The Ross Sea, which is shallow and has a less effective current system, has comparatively little influence on the ice beyond its immediate neighborhood." Deacon (*6*) stated that in the Weddell Sea deep and bottom water could be renewed from the surface. From the oxygen and mineral contents of the deep and bottom waters in the eastern Pacific area, Clowes (*4*) agreed with Deacon that the Weddell Sea appeared to be the only place, or the only significant place as far as the Southern Ocean Drift is concerned, where deep and bottom water can be renewed. Since ice conditions from the Weddell Sea affect the circumpolar drift significantly, and conditions in the Weddell Sea can affect the oceanic water from the surface to the bottom, tides at the boundaries between deep and bottom water layers might affect surface water conditions and force unusual ice discharges from the Weddell Sea, even as Pettersson suggested. Dr. Mears suggested that an unusual discharge of ice and abnormal amounts of deep and bottom water from the Weddell Sea might affect, for the complete circuit of the drift, the portion of the circumpolar drift into which it was emitted. Since most of the deep and bottom water of the great polar drift does not seem to cross the South American submarine ridges, but apparently turns to the northward on approaching the American continent (*1, 4, 6, 8, 14, 29, 34, 41*), the Humboldt Current normally rides to the northward over a huge mass of generally northward-moving water (*10*). If this huge mass had unusual augmentations, such as Pettersson (*25, 26*) described as resulting from certain moon cycle tides in deep inlets, that huge mass might be crowded upward as it made its way northward between Easter Island Ridge (*30, 38*) and the coast of South America, in Thoulet's Easter Island Sea (*38*). As the crowded water pushes upward, everything above, including the Humboldt Current, must make adjustments. The partial loss of equilibrium at such times in the Humboldt Current's more or less steady northward flow would not be surprising. According to Schweigger (*31*), that is exactly what the Humboldt Current appears to do at periodic intervals, which, as Dr. Mears (*18, 23*) pointed out, seem to coincide with moon rather than sun cycles.

Because the significant ice discharge and attendant phenomena take place as far removed as possible in the circumpolar drift from the Humboldt Current area, there must be a distinct lag between interrelated occurrences, if there be interrelationship. The data are far too few for conclusive statements, but those few data seem to point to a lag of about a year after the unusual ice outbreak before the abnormalities in the Humboldt Current area begin to manifest themselves. It is about the third year before serious interruptions of normal conditions occur. An unusual ice outbreak came from the Weddell Sea in 1930 (*14*, p. 292) according to Mackintosh and Herdman, who were in the region at the time. Yet 1930 was a normal year in the Humboldt Current (*31*) according to Schweigger, of the Peruvian Fisheries Department, who was investigating the Humboldt Current over the period from 1928 to 1941. It was not until 1931, the year of Gunther's careful oceanographic examination of the current (*10*), that abnormal conditions tended to arise and not until 1932 that a serious interruption of cool weather conditions in Peru occurred (*31*). In 1938 ice was again exceptionally bad in the Weddell Sea outlet and its approaches (*14*, p. 292); in 1939 there were warm water invasions into the usual path of the Humboldt Current; but conditions along shore and throughout coastal Peru were not affected seriously until 1941 (*9, 17, 19, 20, 21, 31*), the third year after the ice outbreak from the Weddell Sea. Data regarding ice from the Weddell Sea before the disastrous years of 1891 and 1925 in the Humboldt Current region are not available to the writer.

Pettersson (*26*) stated that the tides affected the North Atlantic through the deep passages from the Arctic during the same year they did the South Atlantic from the Antarctic. The U. S. Ice Patrol (*40*) reported in 1922 that "the berg menace existed this year later than during any season since the patrol was taken over by the Coast Guard in 1914. . . . The presence of these [eleven] bergs so far south [around 43 degrees north latitude] is difficult to understand as we have had almost continuous southerly winds for the past month" (*40*, No. 10, p. 41). The third year after the unusual North Atlantic ice conditions in 1922 came the 1925 disaster in Peru. In 1938 the ice outbreak from the Arctic was again unusual (*40*), as it was from the Weddell Sea (*14*). Data fail regarding ice before the Humboldt Current debacle of 1891. But Tebbutt, of the Sydney Observatory, noted a tide during the southern winter of 1889, which was so high for three successive nights that the new gages could not measure it (*37*). The third year after these excessive tides came the notable invasions of tropical conditions and the resultant death to the abundant subtropical life in the Humboldt Current area (*3, 28*).

When ice and sea tide data fail, another suggestion of Dr. Mears' (*22, 23*) appears: there are tides in the air (*2, 23*, p. 101, *33, 36*) and at air layer boundaries, these tides may be as significant as they are at boundaries between sea layers (*22, 23*). Certain it is that at normal times the cold arctic air masses do not seem able to escape over the Rockies (the great cordillera which under various names reaches from the Aleutians to Panama in North America) into the Pacific coastal region (*23*, pp. 29, 114–5). During significant years, 1922, 1937 (winter), 1889 (January and February), such escapes did occur (*41*) with appalling economic results to Californians from freezing. In 1922 and 1937 the air effect came previous to the ice outbreak. If tides cause both, the effect on the air would be immediate; that upon the ice might be delayed. In 1922 and 1937 the California freezes came first; the ice outbreaks came in the following seasons, in the North Atlantic, both during 1937 and 1938 (*40*); in the Humboldt Current, serious abnormalities came the third year following.

During the winter of 1948–49, the arctic air masses made their breaks over the Rockies into California. If events follow as they seem to have followed in 1889, 1922, and 1937, and as Dr. Mears suggested they may continue to follow in accordance with moon cycles, unusual ice outbreaks were due in both the North and South Atlantic in the proper seasons of this year, 1949. The Humboldt Current should begin to have abnormalities during 1950; it should have serious interruptions during the summer of 1951–52.

References

1. BARLOW, E. W. *Marine Observer*, 1938, **15**, 140.
2. BROOKS, CHARLES F. *Amer. meteorol. Soc. Bull.*, 1922, **3**, 167.
3. CARRILLO, CAMILO N. *Soc. geog. Lima Bol.*, 1892–3, **2**, 72.
4. CLOWES, A. J. *Discovery Rep.*, 1934, **9**, 59; 1938, **19**, 105.
5. COLBERT, L. O. *Sci. Mon.*, Wash., 1944, **59**, 435.
6. DEACON, G. E. R. *Discovery Rep.*, 1933, **7**, 233; 1937, **15**, 42, 110.
7. DOODSON, A. T. and WARBURY, H. D. *Admiralty manual of tides.* London: His Maj. Sta. Office, 1941. Pp. 38–39.
8. EARLAND, A. F. *Discovery Rep.*, 1936, **13**, 11.
9. GOODSPEED, T. H. *Plant hunters in the Andes.* New York: Farrar, 1941.
10. GUNTHER, E. R. *Discovery Rep.*, 1936, **13**, 158, 162, 226.
11. HART, T. J. *Discovery Rep.*, 1937, **16**, 445.
12. KANE, E. K. *Smith. Inst. Contrib. Knowledge*, 1863, **13**, 90.
13. MACKINTOSH, N. A. *Discovery Rep.*, 1937, **16**, 410.
14. MACKINTOSH, N. A. and HERDMAN, H. F. P. *Discovery Rep.*, 1940, **19**, 291–292.
15. MARMER, H. A. *Smith. Inst. ann. Rep.*, 1934, 181.
16. MEARS, E. G. *Science*, 1942, **95**, 433.
17. ———. *Amer. geophys. Union Trans.*, 1943, 242.
18. ———. *Sci. Mon.*, Wash., 1943, **57**, 331.
19. ———. *Smith. Inst. ann. Rep.*, 1943, 245, 249, 251.
20. ———. *J. Amer. acad. Sci.*, 1943, **33**, 125.
21. ———. *Nature*, Lond., 1944, **153**, 346.
22. ———. *Pacific Ocean handbook.* San Francisco: Hooper, 1944.
23. ———. Unpublished manuscript.
24. MURPHY, R. C. *Geog. Rev.*, 1939, **29**, 1.
25. PETTERSSON, HANS and KULLENBERG, B. *Göteborgs Kungl. Vetenskaps-ock Vitterhels-Samhälles Handlingar.*, 1933, **5**, 3, 45.
26. PETTERSSON, OTTO. *Geog. Rev.*, 1929, **29**, 19, 121.
27. PETTERSSON, W. J. *Nature*, Lond., 1929, **123**, 796.
28. PEZET, FREDERICO ALFONSO. *Soc. geol. Lima Bol.*, 1895–6, **5**, 457.
29. REVELLE, ROGER R. *Scientific results of the seventh cruise of the "Carnegie."* Washington: Carnegie Inst., 1944. P. 126.
30. ROOS, S. E. *Geog. Rev.*, 1937, **27**, 574.
31. SCHWEIGGER, E. H. *Bol. Compañia Admin. Guano*, 1942. **18**, 27.
32. STETSON, HARLAN T. *Sciences*, 1935, **82**, 595.
33. ———. *Amer. meteorol. Soc. Bull.*, 1936, **17**, 101.
34. SVERDRUP, H. U. *Scripps Inst. oceanog. Contrib.*, 1941, 130.
35. ———. *Oceanography for meteorologists.* New York: Prentice-Hall, 1942. Pp. 62, 219–222.
36. TALMAS, C. F. *Amer. meteorol. Soc. Bull.*, 1932, **13**, 187.
37. TEBBUTT, J. *On the high tide of June 15–17th, 1889.* Sydney: Roy. Soc. N. S. W., 1889. Pp. 1–3.
38. THOULET, J. *Ann. Inst. Oceanog.*, 1928, **5**, 1.
39. WÜST, GEORG. *Berlin Univ. Inst. Meereskunde Veröff.*, 1929.
40. *U. S. Coast Guard Internat. ice observ. and ice patrol service in the No. Atlantic Bull.* 1922, **10**, 14, 23, 40; 1923, **11**, 12, 57; 1924, **12**, 74, 79, 83; 1926, **13**, 7; 1936, **26**, 5; 1937, **27**, 1, 2, 4, 6; 1938, **28**, 1; 1939, **29**, 11; 1940, **30**, v.
41. *U. S. Wea. Bur. mon. wea. Rev.*, 1888, **16**, 8, 18; 1889, **17**, 8, 35; 1922, **50**, 41; 1938, **66**, 12, 215, 312.