PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

NEW SERIES.
Vol. III.

WHOLE SERIES.
Vol. XI.

FROM MAY, 1875, TO MAY, 1876.

SELECTED FROM THE RECORDS.

BOSTON:
PRESS OF JOHN WILSON AND SON.
1876.

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PROCEEDINGS

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ARTS AND SCIENCES.

VOL. XI.

PAPERS READ BEFORE THE ACADEMY.

RESEARCHES ON THE HEXATOMIC COMPOUNDS OF COBALT.

By Wolcott Gibbs, M.D.

Presented, June 8th, 1875.

(*Continued from Vol. X. p.* 38.)

Nitrates of Purpureocobalt. — In our joint memoir, Genth and I assigned the anhydrous nitrate, $Co_2(NH_3)_{10}(NO_3)_6$, to the roseocobalt series, upon the ground that with certain reagents it forms salts identical with those which the hydrous nitrate, $Co_2(NH_3)_{10}(NO_3)_6+2OH_2$, yields under the same circumstances. I am now satisfied that this salt belongs in reality to the purpureocobalt series, partly because it exhibits toward the hydrous nitrate relations precisely analogous to those which exist between $Co_2(NH_3)_{10}Cl_6$ and $Co_2(NH_3)_{10}Cl_6+2OH_2$, and partly because, while a few of its reactions correspond with those of the hydrous salt, the greater number agree with those of the anhydrous chloride. By dissolving the normal nitrate of purpureocobalt in water containing ammonic nitrate in large quantity, with a little free ammonia, Genth and I obtained a new salt in beautiful violet-red talcose scales, readily decomposed by solution in water. The formula of this salt is most probably

$$Co_2(NH_3)_{10}.O.(NO_3)_4+6OH_2,$$

as the following analyses appear to show: —

0·0675 gr. gave 0·0303 gr. SO_4Co = 17·08% cobalt.
0·0729 gr. gave 0·0333 gr. SO_4Co = 17·18% cobalt.
0·0769 gr. gave 0·0343 gr. SO_4Co = 17·16% cobalt.

0·5480 gr. gave 161·75 c.c. nitrogen (moist) at 10°·3 C and 755·4^{mm} (h = 118·8^{mm}) = 29·82%.
0·5171 gr. gave 0·2955 gr. water = 6·36% hydrogen.
0·4590 gr. gave 0·2699 gr. water = 6·54% hydrogen.

		Calculated.	Found.		
Cobalt,	2	17·87	17·08	17·18	17·16
Nitrogen,	14	29·69		29·82	
Hydrogen,	42	6·36	6·36	6·54	
Oxygen,	19	46·06	—	—	

The analyses are those made with the salt originally prepared by Genth and myself, as I have not succeeded in obtaining it a second time. The deficiency in the cobalt is perhaps to be attributed to the small quantity of salt at my disposal for analysis. Admitting the correctness of the formula, the scaly nitrate belongs to the basic series of purpureo-salts, of which the chromate already described, $Co_2(NH_3)_{10}.O.(CrO_4)_2$, furnishes an example. Its structural formula will then be, as compared with that of the normal nitrate: —

$$Co_2\begin{cases} NH_3—NO_3 \\ NH_3—NH_3—NO_3 \\ NH_3—NH_3 \\ NH_3—NH_3 \end{cases}\!\!\!>O \quad \begin{matrix} \\ NH_3—NH_3—NO_3 \\ NH_3—NO_3 \end{matrix} \qquad Co_2\begin{cases} NH_3—NO_3 \\ NH_3—NH_3—NO_3 \\ NH_3—NH_3—NO_3 \\ NH_3—NH_3—NO_3 \\ NH_3—NH_3—NO_3 \\ NH_3—NO_3 \end{cases}$$

The formation of the basic nitrate may be expressed by the equation: —

$$Co_2(NH_3)_{10}(NO_3)_6 + 2NH_3 + OH_2 = Co_2(NH_3)_{10}.O.(NO_3)_4 + 2NH_4.NO_3.$$

The readiness with which it is decomposed by water renders it impossible to determine the reactions of the salt; but, as I find that chloride of purpureocobalt is formed with evolution of chlorine when it is boiled with chlorhydric acid, we have at least some positive evidence in favor of the view which I have taken. The marked effervescence which occurs on boiling the nitrate with chlorhydric acid is precisely similar in character to that which takes place when ammonic nitrate is heated with the same acid. The normal nitrate of purpureocobalt furnishes by far the most convenient method of passing from the purpureo-series to the roseo-series. It is only necessary to dissolve the salt in a solution of ammonia, and then to allow this solution to flow slowly into moderately strong nitric acid, surrounded with ice or snow so as to prevent any sensible rise of temperature. The nitrate of roseocobalt separates immediately as a red crystalline precipitate, nearly insoluble in the excess of nitric acid. From this salt many other salts of the roseo-series may be prepared with facility.

Chloro-nitrate of Purpureocobalt. — Acid sulphate of roseocobalt not free from chloride of purpureocobalt was treated in the cold with a solution of potassic nitrite and nitrate. After standing some days a red mother liquor was formed, together with a mixture of a red crystalline salt, and a bright yellow powder. On filtering and washing with hot water, a fine violet liquid was obtained, which, on standing, gave very well-defined large octahedral crystals of a deep cherry-red color. The crystals were easily soluble in hot water, and contained only a trace of sulphuric acid. Qualitative analysis showed the presence of chlorine, nitric teroxide, cobalt, and ammonia. The salt gave the reactions of nitrate or chloride of purpureocobalt with more or less distinctness. Of this salt,

0·4515 gr. gave 0·1516 gr. silver = 8·30% chlorine.
0·4000 gr. gave 0·1332 gr. silver = 8·23% chlorine.
0·4809 gr. gave 0·2397 gr. SO_4Co = 18·98% cobalt.
0·4448 gr. gave 0·2228 gr. SO_4Co = 19·07% cobalt.
1·0770 gr. gave 0·4650 gr. water = 4·79% hydrogen.

The formula $Co_2(NH_3)_{10}Cl_3(NO_3)_3+Co_2(NH_3)_{10}(NO_3)_6$ requires

		Calculated.	Found.	
Cobalt,	4	19·28	18·98	19·07
Chlorine,	3	8·55	8·30	8·23
Hydrogen,	60	4·80	4·79	

I can assign no plausible explanation of the formation of the chloro-nitrate under the circumstances, and did not succeed in obtaining the salt by mixing the chloride and nitrate of purpureocobalt in the proper proportions, and allowing the mixed solutions to stand. The crystals formed always consisted principally of the chloride. I was not more successful in the attempt to form a chloro-nitrate with the formula, $Co_2(NH_3)_{10}(NO_3)_3Cl_3$, by mixing solutions of the chloride and nitrate, the chloride crystallizing from the mixture unchanged. I remark, however, that as the acid sulphate employed contained chlorine, probably as undecomposed chloride of purpureocobalt, and as the potassic nitrite contained also nitrate, the reaction must have been between the chloride and nitrate. Two chloro-nitrates of roseocobalt have been observed by Krok, in combination with mercuric and platinic chlorides, the salts having respectively the formulas $Co_2(NH_8)_{10}(NO_3)_3Cl_3+3HgCl_2$ and $Co_2(NH_3)_{10}(NO_3)_2Cl_4+2PtCl_4$.

Tungstate. — When chloride of purpureocobalt is boiled with sodic tungstate, WO_4Na_2, it is quickly converted into a violet granular crystalline mass, which, after washing with cold water, is perfectly free from chlorine. When dried *in vacuo* over sulphuric acid, the crystals have a fine deep violet color. The salt is but slightly soluble in either cold or boiling water, even in presence of free nitric acid. It dissolves readily in a solution of sodic or ammonic carbonate; the solutions have a fine violet color. Of this salt,

1·0294 gr. gave 0·5418 gr. WO_3 (by mercurous nitrate) = 56·26% WO_4.

2·3912 gr. gave 1·7163 gr. WO_4Co (by careful ignition) = 75·96%.

The formula $Co_2(NH_3)_{10}.O.(WO_4)_2$ requires 55·11% WO_4 and 76·75% WO_4Co.

The salt cannot be recrystallized, and was therefore probably not absolutely pure.

Oxalo-chloride. — When a solution of ammonic oxalate is added to one of chloride of purpureocobalt, violet needles are soon deposited, which Genth and I considered as the normal oxalate of this series, and to which we gave the formula, as we should now write it: —

$$Co_2(NH_3)_{10}.O.(C_2O_4)_2+3OH_2.$$

Two determinations of cobalt and one of oxalic acid agreed very closely with this formula. Krok * subsequently discovered that this salt contains chlorine, and he assigns to it the formula: —

$$Co_2(NH_3)_{10}Cl_2(C_2O_4)_2.$$

On carefully re-examining this salt, I find that the percentage of chlorine varies considerably in different preparations. Thus: —

{ 0·7108 gr. gave 0·2512 gr. silver = 11·61% chlorine.
{ 0·3627 gr. gave 0·2186 gr. SO_4Co = 22·95% cobalt.

{ 0·5093 gr. gave 0·2930 gr. SO_4Co = 21·90% cobalt.
{ 0·5768 gr. gave 0·2241 gr. silver = 12·78% chlorine.

It is therefore probable that the chloro-oxalate contains as an admixture a greater or less percentage of another oxalate, possibly $Co_2(NH_3)_{10}.O.(C_2O_4)_2$. I did not succeed in obtaining this salt from nitrate of purpureocobalt and ammonic oxalate, the reaction resulting only in

* Acta Univ. Lund. 1840. I believe that this is the only error which has been detected in the first part of this paper.

the formation of oxalate of roseocobalt, — a result possibly due to the presence of a little free ammonia. The chloro-oxalate does not appear to unite with metallic chlorides. It reduces gold from auro-chloride of sodium, $AuCl_4Na$, while with platinic chloride it forms only the ordinary chlorplatinate, $Co_2(NH_3)_{10}Cl_6+2PtCl_4$, and with mercuric chloride the anhydrous 6-atom salt, $Co_2(NH_3)_{10}Cl_6+6HgCl_2$. In this respect it differs remarkably from the oxalate of roseocobalt, which, as I shall show, forms a well-defined salt with platinic chloride. The chloro-oxalate dissolves readily in a hot solution of oxalic acid, and crystallizes in violet needles which contain chlorine, and which appear to be an acid chloro-oxalate.

Neutral Sulphate. — Schiff has described a violet-colored very slightly soluble sulphate which he obtained, together with sulphate of luteocobalt, by the action of an alcholic solution of ammonia upon Frémy's sulphate of fusco-cobalt. To this salt Schiff gives a formula corresponding with

$$Co_2(NH_3)_{10}.O.(SO_4)_2+3OH_2.$$

This would be the basic sulphate corresponding to the chromate which I have described, and which has the formula $Co_2(NH_3)_{10}.O.(CrO_4)_2$. By the action of baric chloride upon this sulphate, Schiff obtained, as he asserts, a new chloride with the formula : —

$$Co_2(NH_3)_{10}.O.Cl_4+3OH_2,$$

which he regards as the true chloride of the purpureocobalt series. From what I have already said, the existence of such a basic sulphate and chloride may be regarded as not merely possible but probable. On the other hand, Braun, on repeating Schiff's experiments, obtained wholly different results. The action of ammonia upon salts of fusco-cobalt yielded him only the ordinary salts of purpureocobalt, together with salts of luteocobalt. Further researches are therefore needed to establish the existence of Schiff's salts. In a single experiment I obtained a small quantity of a salt which appears to be the neutral sulphate of purpureocobalt. A mixture of cobaltic sulphate with excess of ammonia water was allowed to stand some weeks with frequent agitation. The deep-red solution was filtered and precipitated by alcohol. The heavy red liquid thrown down became solid after a time. Cold water dissolved the larger portion of this mass, but left a beautiful violet crystalline powder, which was washed on a filter till the washings had a fine clear violet tint, and dried *in vacuo* over SO_4H_2 for some days. Of this salt,

0·4392 gr. gave 0·2332 gr. SO_4Co = 20·21% cobalt.
0·7952 gr. gave 0.9208 gr. SO_4Ba = 47·71% SO_4.

These analyses lead to the formula : —

$$Co_2(NH_3)_{10}(SO_4)_3+OH_2.$$

		Calculated.	Found.
Cobalt,	2	20·27	20·21
SO_4,	3	47·42	47·71

The results of the analyses agree well with the formula given ; but it is possible that the salt, which was not recrystallized, contained some small impurity, and that it is really anhydrous, like the normal chloride and sulphate. The sulphate is but slightly soluble in cold water, but dissolves rather easily in hot water, forming a beautiful violet solution. Auro-chloride of sodium gives a beautiful crystalline orange-red precipitate with a solution of the sulphate, differing apparently from the corresponding salt of roseocobalt. In this salt,

0·2698 gr. gave 0·0924 gr. gold = 34·24%.

This percentage of gold corresponds very closely to that required by the formula, $Co_2(NH_3)_{10}(SO_4)_2Cl_2+2AuCl_3$, which is 34·02. The sulphato-chloro-aurate of roseocobalt has, as I shall show, the formula $Co_2(NH_3)_{10}(SO_4)_2Cl_2+2AuCl_3+4OH_2$, the purpureo-salt showing, as usual, a less disposition to unite with water of crystallization. The above results were obtained with only three grammes of material ; but they are sufficient, I think, to make it at least probable that the violet salt in question is the true sulphate of purpureocobalt.

Pyrophosphate. — Sodic pyrophosphate gives a lilac or rose colored precipitate with a solution of chloride or nitrate of purpureocobalt, readily soluble in an excess of the precipitant, and crystallizing from the solution in beautiful rose-red efflorescent crystalline scales. The salt is readily soluble in ammonia, and the solution yields beautiful garnet-red measurable crystals, which are free from sodium. The pyrophosphate was first carefully studied and analyzed by C. D. Braun, whose analyses agree closely with a formula which he writes,

$$5NH_3.Co_2O_3.2PO_5+21HO$$

(old style). This formula must now be written

$$Co_2(NH_3)_{10}(P_4O_{13})+21OH_2$$

in the new notation, P_4O_{13}, being hexatomic. In the salt crystallized from ammonia : —

1·2456 gr. gave 0·5387 gr. $Co_2P_4O_{12}$ by ignition = 43·24% and 56·76% water, ammonia, and oxygen.
1·4184 gr. gave 0·9415 gr. water (burnt with CuO) = 7.22% hy'gen.
1·0964 gr. gave 0·3911 gr. water = 35·67% water of crystallization.

The formula $Co_2(NH_3)_{10}P_4O_{13}+21OH_2$ requires 43·48% $Co_2P_4O_{12}$, and 56·52% water, ammonia, and oxygen; also 7·21% hydrogen, and 37·87% water of crystallization. These analyses fully confirm Braun's results. The formation of the salt from sodic pyrophosphate and chloride of purpureocobalt may be represented by the equation:—

$$Co_2(NH_3)_{10}Cl_6+2P_2O_7Na_4+OH_2 = Co_2(NH_3)_{10}P_4O_{13}+6NaCl+2ONaH.$$

The mother liquor from which the pyrophosphate has crystallized has a strong alkaline reaction. The decomposition of the salt by heat may be expressed by the equation: —

$$Co_2(NH_3)_{10}.P_4O_{13} = Co_2P_4O_{12}+O+10NH_3,$$

though it is of course most probable that a part of the ammonia is oxidized to water and nitrogen.

The pyrophosphate of purpureocobalt furnishes, if the formula given be adopted, an instance of a true *dipyrophosphate* bearing the same relation to the ordinary salts of the acid which the disulphates, dichromates, &c., bear to the normal sulphates and chromates. In other words, two molecules of $P_2O_7H_4$, or $P_2O_3.(OH)_4$ are fused together, so as to form a single molecule of $P_4O_{13}H_6$, or $P_4O_7(OH)_6$, an atom of water being given off. Thus we have in symbols: —

$$2.P_2O_3.(OH)_4 = P_4O_7.(OH)_6+OH_2.$$

The structure of dipyrophosphoric acid may be briefly represented by the expression: —

$$3(OH) \equiv (P_2O_3)—O—(P_2O_3) \equiv (OH)_3.$$

The corresponding salt of luteocobalt presents a similar instance. According to Braun, the whole of the water of crystallization is given off at 100°C.; but I found that one atom was retained at that temperature, the loss in my analysis being 35.67°, while the formula for 20 atoms requires 36.07%.

Ammonia-cobalt-nitrite. — A solution of the potassium salt of Erdmann's series, $Co_2(NH_3)_4(NO_2)_8K_2$, gives with nitrate of purpureocobalt a beautiful very dark orange-red precipitate in crystals, which are sometimes acicular, and sometimes granular. The crystals are not very soluble in cold, but dissolve quite easily in hot water. The solution gives the characteristic reaction with argentic nitrate. Of this salt: —

0·4583 gr. gave 0·2466 gr. SO_4Co = 24·11% cobalt.

The formula $\{Co_2(NH_3)_{10}\}\ \{Co_2(NH_3)_4(NO_2)_8\}_3$ requires 24·20%.

The solution of this salt does not give the reactions of xanthocobalt at first, but after some days ammonic oxalate throws down the characteristic wine-yellow oxalate. The solution is decomposed by long standing, large crystals of cobaltic nitrate, $Co(NO_3)_2$, being formed together with crystalline scales of the corresponding salt of xanthocobalt already described.

Cobalto-nitrite. — The sodium salt of Fischer's series,

$$Co_2(NO_2)_{12}Na_6,$$

is soluble at the instant of formation in an excess of sodic nitrite. Alcohol precipitates, after a time, some of the yellow insoluble sodic salt, and gives a very deep orange-red solution, from which the alcohol may be expelled by evaporation. This solution gives with one of nitrate of purpureocobalt, after a short time, fine deep orange-red to ruby-red octahedral crystals, which are very slightly soluble in water even on boiling. This salt gave by digestion with a solution of thallous nitrate the characteristic scarlet crystalline salt, $Co_2(NO_2)_{12}Tl_6$, which I shall describe further on. On analysis: —

0·5598 gr. gave 0·3290 gr. SO_4Co = 22.38% cobalt.
0·7324 gr. gave 188.5 c.c. nitrogen (moist) at 6°C and 773·4^{mm} = 31·87% nitrogen.

The ratio is here exactly that of one atom of cobalt to six atoms of nitrogen; and the analyses lead to the formula: —

$$\{Co_2(NH_3)_{10}(NO_2)_2\}_3\ \{Co_2(NO_2)_{12}\}_2 + 9OH_2,$$

which requires 22·33% cobalt, and 31·79% nitrogen. The constitution of the salt is fully established by these analyses, and by the reaction with the thallium salt given above, since we have: —

$$\{Co_2(NH_3)_{10}(NO_2)_2\}_3\ \{Co_2(NO_2)_{12}\}_2 + 12TlNO_3 = 3.Co_2(NH_3)_{10}(NO_2)_2(NO_3)_4 + 2.Co_2(NO_2)_{12}Tl_6.$$

The compound therefore belongs in reality to the xanthocobalt series; it gives the reactions of the ordinary salts of that series distinctly. The formation of this remarkable salt may very probably be expressed by the equation: —

$$3.Co_2(NH_3)_{10}(NO_3)_6+3Co_2(NO_2)_{12}Na_6=\{Co_2(NH_3)_{10}(NO_2)_2\}_3$$
$$\{Co_2(NO_2)_{12}\}_2+18NaNO_3+2Co(NO_2)_2+2NO_2.$$

I shall allude to its composition again, when speaking of the metameric compounds of the cobaltamines.

The salt described is not the only one which is formed by the action of a solution of $Co_2(NO_2)_{12}Na_6$ on nitrate of purpureocobalt. In several experiments I obtained an orange-red granular salt readily soluble in cold water. The solution of this salt gave with nitrate of luteocobalt a beautiful crystalline precipitate of

$$\{Co_2(NH_3)_{12}\}\{Co_2(NO_2)_{12}\}.$$

With thallous nitrate it gave the characteristic scarlet salt $Co_2(NO_2)_{12}Tl_6$. On the other hand, it gave all the reactions of the salts of xanthocobalt with great distinctness, including the highly characteristic crystalline ferrocyanide. This salt could in no way be distinguished from one obtained by the action of $Co_2(NO_2)_{12}Na_6$ upon sulphate of roseocobalt which, as I shall show, has the formula :—

$$\{Co_2(NH_3)_{10}\}\{Co_2(NO_2)_{12}\} \text{ or } Co_2(NH_3)_{10}(NO_2)_6+Co_2(NO_2)_6.$$

In acting upon solutions of purpureocobalt with solutions of cobalto-nitrite of sodium in excess of sodic nitrite, it often happens that neither of the salts above described is obtained in appreciable quantity, but only nitrate of xanthocobalt and cobaltic salts formed by a total reduction of the cobaltamines. It is therefore important to avoid an excess of sodic nitrite as much as possible.

Chloro-fluosilicate. — When a hot solution of chloride of purpureocobalt containing a few drops of free chlorhydric acid is poured into a hot solution of fluosilicate of zinc, no precipitate is produced at first, but after a time a beautiful violet-red crystalline salt separates. This salt is very slightly soluble in cold water, but dissolves with a violet tint in a large quantity of boiling water; it is readily soluble in a hot solution of sodic carbonate. It is decomposed very quietly by heat, giving off white condensible vapors, and leaving a dull violet residue. Of this salt : —

0·6379 gr. gave 0·2861 gr. SO_4Co = 17·10% cobalt.
0·8221 gr. gave 0·2479 gr. silver = 9·91% chlorine.

The formula $Co_2(NH_3)_{10}(SiF_6)_2Cl_2+3OH_2$ requires 16·93% cobalt, and 10·18% chlorine.

The determination of the chlorine was made by dissolving the salt in sodic carbonate, adding an excess of argentic nitrate, and afterward a small excess of nitric acid. The chloro-fluosilicate appears to combine with auric and platinic chlorides to form crystalline salts containing silicic fluoride. Nitrate of purpureocobalt gives with a solution of fluosilicic acid, SiF_6H_2, a beautiful violet-red granular crystalline precipitate, but slightly soluble in cold water. I have not examined this salt; it is probably the normal fluosilicate $Co_2(NH_3)_{10}(SiF_6)_3$.

It occurred to me that the fluorine compounds of the cobaltamines might offer means of separating certain metallic elements which have hitherto proved intractable by ordinary methods. The numerous experiments made with this end in view have not, however, led to really valuable results. I shall therefore content myself by briefly describing in this place a few reactions which will serve as starting-points to those who may be disposed to enter upon this field of investigation.

Nitrate of croceocobalt gives a fine granular crystalline salt with fluosilicic acid, and a beautiful salt in large granular crystals with potassic fluo-titanate, TiF_6K_2. Both salts are soluble in much hot water, the solutions yielding large and perhaps measurable crystals.

Nitrate of xanthocobalt gives very fine granular crystalline salts with fluosilicic acid and potassic fluotitanate. Both salts may be dissolved in a large quantity of hot water, and recrystallized without decomposition.

Sulphate of roseocobalt gave no precipitate with fluosilicic acid or potassic fluosilicate even after long standing; but a solution of the iodo-sulphate of roseocobalt, $Co_2(NH_3)_{10}(SO_4)_2I_2$, gave with fluosilicic acid a dull violet-red crystalline precipitate very slightly soluble in water.

Nitrate of luteocobalt gives beautiful granular orange-yellow crystalline precipitates with fluosilicic acid and solution of potassic fluotitanate. The fluotitanate is somewhat lighter in color than the fluosilicate. Both salts are almost insoluble even in boiling water. Krok * observed that iodo-sulphate of luteocobalt gives a very insoluble crystalline precipitate with fluosilicic acid. I find that this salt contains iodine, and it will probably prove to have the formula $Co_2(NH_3)_{12}(SiF_6)_2I_2$. Iodide of luteocobalt gives a beautiful orange crystalline precipitate with potassic fluozirconate, which requires a large quantity of boiling water for solution, and may be recrystallized without decomposition. Iodide of luteocobalt gives also crystalline very slightly soluble precipitates with potassic fluotantalate, fluoniobate, and oxyfluoniobate, not differing from each other, so far as I

* Acta Universit. Lund. 1870.

have been able to determine, sufficiently to be made available in analysis, and probably isomorphous. Nitrate of luteocobalt gives fine orange crystalline, slightly soluble precipitates with potassic oxyfluotungstate, oxyfluomolybdate, and fluoborate.

For convenience of reference I give here a list of the salts which, in my judgment, belong to the purpureocobalt series, and which have been more or less completely described.

NORMAL SERIES.

Chloride,	$Co_2(NH_3)_{10}Cl_6$
Bromide (Claudet),	$Co_2(NH_3)_{10}Br_6$
Iodide (Claudet),	$Co_2(NH_3)_{10}I_6$
Sulphate,	$Co_2(NH_3)_{10}(SO_4)_3+OH_2$
Nitrate,	$Co_2(NH_3)_{10}(NO_3)_6$
Chloro-nitrate,	$Co_2(NH_3)_{10}Cl_3(NO_3)_3+Co_2(NH_3)_{10}(NO_3)_6$
Chloro-oxalate,	$Co_2(NH_3)_{10}(C_2O_4)_2Cl_2$
Pyrophosphate (Braun),	$Co_2(NH_3)_{10}P_4O_{13}+21OH_2$
Chromate (Braun),	$Co_2(NH_3)_{10}(CrO_4)_3$
Dichromate,	$Co_2(NH_3)_{10}(Cr_2O_7)_3+OH_2$
Ammonia-cobalt-nitrite,	$\{Co_2(NH_3)_{10}\}\{Co_2(NH_3)_4(NO_2)_8\}_3$
Cobalto-nitrite,	$\{Co_2(NH_3)_{10}(NO_2)_2\}_3\{Co_2(NO_2)_{12}\}_2+9OH_2$
Chloro-fluosilicate,	$Co_2(NH_3)_{10}(SiF_6)_2Cl_2$
Platino-chloride,	$Co_2(NH_3)_{10}Cl_6+2PtCl_4$
Auro-chloride,	$Co_2(NH_3)_{10}Cl_6+2AuCl_3$
Antimonio-chloride,	$Co_2(NH_3)_{10}Cl_6+SbCl_3$
Hydrargo-chloride α,	$Co_2(NH_3)_{10}Cl_6+4HgCl_2$
Hydrargo-chloride β,	$Co_2(NH_3)_{10}Cl_6+6HgCl_2$

BASIC SERIES.

Chromate,	$Co_2(NH_3)_{10}.O.(CrO_4)_2+6OH_2$
Hyposulphate (Rammelsberg),	$Co_2(NH_3)_{10}.O.(S_2O_6)_2$
Nitrate,	$Co_2(NH_3)_{10}.O.(NO_3)_2+6OH_2$
Chloride ? (Schiff),	$Co_2(NH_3)_{10}.O.Cl_4$
Sulphate ? (Schiff),	$Co_2(NH_3)_{10}.O.(SO_4)_2$
Tungstate,	$Co_2(NH_3)_{10}.O.(WO_4)_2$

ROSEOCOBALT.

Sulphates of Roseocobalt. — In our joint memoir Genth and I have stated that when a mixture of cobaltic sulphate and ammonia is exposed to the air for some time three different salts are sometimes formed, one of which is readily soluble in water, giving characteristic reactions different from those of the normal sulphate, while a second salt dissolves in warm water, and gives orange-red crystals. I propose now to give the results of my further study of these salts.

Soluble Sulphate of Roseocobalt. — Since the publication of the memoir above mentioned, this salt has been studied by Braun, who appears not to have been aware of its previous discovery by Genth and myself. Braun prepared it by adding sulphuric acid to an oxidized solution of ammonia and cobaltic sulphate and precipitating the solution with alcohol. In this manner he obtained a rose-red crystalline powder, which on analysis gave the formula of the ordinary sulphate, first correctly analyzed by Genth and myself, $Co_2(NH_3)_{10}(SO_4)_3+5OH_2$, but which was readily soluble in water, with a cherry-red color. My more recent investigations fully confirm Braun's results as regards the solubility of this salt, which I have, however, obtained by simply washing the oxidized dry mass of sulphates with cold water in repeated small quantities. To fully establish the difference between this salt and the ordinary sulphate, I determined the solubility of the last-named quantitatively. Of the ordinary sulphate, 11·6205 gr. of a neutral solution saturated at 27°C gave on evaporation 0·1967 gr. of the crystalline sulphate = 1·69%.

The soluble sulphate requires between one and two parts of cold water for solution, as nearly as I could judge, my salt containing small portions of ammonic and cobaltic sulphates. The reactions of the soluble sulphate differ so slightly from those of the ordinary sulphate, that I do not regard the statement made by Genth and myself as fully confirmed by further experience, and believe that the salt with which our experiments were made contained small portions of the yellow sulphate presently to be described. On the other hand, the derivatives of the soluble sulphate appeared in many cases to be more soluble than the corresponding salts prepared from the ordinary sulphate.

Want of material and of proper facilities for work have prevented me from examining the subject with the requisite care and thoroughness. In what follows, however, I have in each case specified which of the two red sulphates was employed.

Iodo-sulphate of Roseocobalt. — When a solution of potassic iodide is added to one of the soluble sulphate of roseocobalt a beautiful cinnabar-red crystalline salt is thrown down, which may be dissolved without much difficulty in hot water, and crystallizes from the solution in granular crystals of an intense orange-red color. This salt has essentially the formula $Co_2(NH_3)_{10}(SO_4)_2I_2+2OH_2$, which is that of the iodo-sulphate described by Krok, and obtained by the action of iodine upon a boiling solution of ammonia and cobaltic sulphate. Krok's analyses agree fairly well with the requirements of the formula. I found, however, that the salt precipitated as above varied in different preparations not inconsiderably. I prepared the salt also from the ordinary sulphate of roseocobalt for the sake of comparison, but could detect no really essential difference between the two. The following are the results of my analyses : —

Of the iodo-sulphate from the ordinary red sulphate of roseocobalt : —

I. 0·6300 gr. gave 0·2673 gr. SO_4Co = 16·15% cobalt.
0·4284 gr. gave 0·1170 gr. silver = 32·12% iodine.
0·5689 gr. gave 0·3516 gr. SO_4Ba = 25·46% So_4.

Of the iodo-sulphate from the soluble sulphate : —

II. 0·4045 gr. gave 0·1776 gr. SO_4Co = 16·72% cobalt.
0·4045 gr. gave 0·1763 gr. SO_4Co = 16·60% cobalt.
0·4647 gr. gave 0·1096 gr. silver = 27·76% iodine.
0·4935 gr. gave 0·3027 gr. SO_4Ba = 25·27% SO_4.
III. 0·3579 gr. gave 0·1442 gr. SO_4Co = 15·33% cobalt.
0·7586 gr. gave 0·3816 gr. silver = 27·18% iodine.
0·7099 gr. gave 0·4308 gr. So_4Ba = 25·32% SO_4.

The formula $Co_2(NH_3)_{10}(SO_4)_2I_2+2OH_2$ requires : —

	Calculated.	I.	II.	III.
Cobalt,	15·33	16·15	16·66 (mean)	15·33
Iodine,	32·99	32·12	27·76	27·18
SO_4,	24·93	25·46	25·27	25·32

These analyses show at least that the reaction between potassic iodide and the soluble sulphate is less definite than in the case of the iodide and the ordinary sulphate. Krok states that he did not obtain sulphate of xanthocobalt by the action of argentic nitrite upon iodo-sulphate of roseocobalt, but only a rose-red solution, giving off nitrous acid with the stronger acids. I found, however, that the iodo-sulphate obtained from the soluble sulphate of roseocobalt, when digested with argentic nitrite and a little free acetic acid, gave argentic iodide and a clear sherry-wine-colored filtrate giving with ammonic oxalate a salt which I could not distinguish from the ordinary oxalate of xanthocobalt. Treated with nitric acid this oxalate gave an octahedral nitrate showing all the reactions of nitrate of xanthocobalt. The rose-red solution which Krok obtained as above, may prove to contain a red modification of xanthocobalt, and deserves further study.

Acid Sulphate. — The acid sulphate described by Genth and myself, and to which we gave the formula (old style) $5NH_3.Co_2O_3.4SO_3+5HO$, may be formulated in various ways. We may regard it as a basic disulphate with the formula,

$$Co_2(NH_3)_{10}.O.(S_2O_7)_2+5OH_2.$$

It is difficult to see how such a basic salt could be formed in a solution, and in presence of an excess of free sulphuric acid. The fact that the salt does not exhibit a strong acid taste and reaction does not in itself furnish a very strong argument. Schultz-Sellack has shown that disulphates of the type $S_2O_7R_2$ are formed by dissolving normal sulphates in warm fuming sulphuric acid; but it has not been shown in any case that a normal sulphate by digestion with sulphuric acid can form a pyrosulphate, — an atom of water being given off. It seems, therefore, more probable that the acid sulphate has the formula,

$$Co_2(NH_3)_{10}(SO_4)_3+SO_4H_2+4OH_2;$$

but it is worthy of notice that the salt is not formed when normal sulphate of roseocobalt is boiled with dilute sulphuric acid. In this case the normal sulphate crystallizes without change. The type of the acid sulphate of roseocobalt is the same as that of the acid carbonate of luteocobalt described by Genth and myself: —

$$Co_2(NH_3)_{12}(CO_3)_3+CO_3H_2+5OH_2,$$

and with that of the acid oxalo-bisulphate, which in my view has the formula,

$$Co_2(NH_3)_{10}(C_2O_4)(SO_4)_2+C_2H_2O_4+2OH_2.$$

On the other hand, the acid oxalate of roseocobalt, which I shall describe, has the formula,

$$Co_2(NH_3)_{10}(C_2O_4)_3+4C_2H_2O_4,$$

the type not being that of the ordinary double oxalates containing a hexatomic metallic element.

Yellow Sulphate of Roseocobalt. — A small quantity of crude sulphate of roseocobalt, which had stood for some years in my laboratory, presented orange-red crusts of indistinct octahedral crystals. These were rubbed to powder, washed with a little cold water, and dissolved in hot water with a little free sulphuric acid. Fine yellow crystals separated, which could not be distinguished in appearance from sulphate of luteocobalt, but appeared to be less soluble in water. Of these crystals, —

0·5018 gr. gave 0·2341 gr. $SO_4Co = 17·76\%$ cobalt.
0·7614 gr. gave 0·7992 gr. $SO_4Ba = 43·25\%$ So_4.
1·1618 gr. gave 213 c.c. nitrogen at 13°C and $760·47^{mm} = 21·62\%$.

The formula $Co_2(NH_3)_{10}(SO_4)_3+5OH_2$, which is also that of the ordinary and of the soluble modification of sulphate of roseocobalt, requires: —

	Calculated.	Found.
Cobalt,	17·71	17·76
SO_4,	43·24	43·25
Nitrogen,	21·02	21·62

The formula $Co_2(NH_3)_{12}(SO_4)_3+5OH_2$ — sulphate of luteocobalt — requires 16.85% cobalt, 41·14% SO_4, and 24·00% nitrogen. The analyses show clearly that the salt was not sulphate of luteocobalt. The solution of the new sulphate gave beautiful yellow or orange-yellow crystalline precipitates with various reagents closely resembling in color the corresponding salts of luteocobalt. Thus with potassic bromide it gave a buff yellow, and with potassic iodide a fine orange-yellow crystalline precipitate. With the platino-chloride and auro-chloride of sodium it gave beautiful yellow salts, the analyses of which will be given in connection with those of the ordinary salts of roseocobalt. By double decomposition with baric nitrate the yellow sulphate gave a fine yellow solution, which on standing yielded crystals of the nitrate of this series readily soluble in hot water. In these crystals, —

0 2517 gr. gave 0·1092 gr. $SO_4Co = 16·50\%$ cobalt.

This percentage of cobalt would indicate the formula $Co_2(NH_3)_{10}(NO_3)_6+3OH_2$, which requires 16·52%. Nitrate of luteocobalt contains 17·00% cobalt.

The sulphate gave also with baric chloride a fine yellow solution and baric sulphate. The solution of the chloride gave beautiful yellow salts, with the chlorides of gold and of platinum. Unlike the ordinary and soluble modifications of chloride of roseocobalt, it did not give chloride of purpureocobalt by boiling with chlorhydric acid. The yellow nitrate gave a beautiful orange-yellow crystalline precipitate with excess of potassic iodide.

Of the yellow chloride, —

$$0{\cdot}4187 \text{ gr. gave } 0{\cdot}2430 \text{ gr. } SO_4Co = 22{\cdot}09\% \text{ cobalt.}$$

The formula $Co_2(NH_3)_{10}Cl_6+2OH_2$, which is that of the ordinary red modification, requires $21{\cdot}97\%$ cobalt.

The results above mentioned, together with the analyses of the gold and platinum salts to be described, are confessedly incomplete, but are all which I could obtain with the very small amount of material — less than five grammes of the sulphate — at my disposal. I regard them as rendering it extremely probable that there is an extensive series of yellow salts isomeric with the ordinary salts of roseocobalt, but differing from them in color, solubility, and perhaps other particulars. It seems not impossible that the so-called xanthocobalt salts belong to this series, as I find that when the beautiful scarlet crystalline iodo-sulphate of roseocobalt is treated with argentic nitrite, a cherry-red solution is obtained, which must contain a salt having the formula, $Co_2(NH_3)_{10}(NO_2)_2(SO_4)_2$, since we have the reaction expressed by the equation

$$Co_2(NH_3)_{10}(SO_4)_2I_2+2AgNO_2 = Co_2(NH_3)_{10}(NO_2)_2(SO_4)_2+2AgI,$$

and since the red solution on boiling with a few drops of acetic acid readily passes into the ordinary sulphate of xanthocobalt.

The salts of the yellow modification of roseocobalt at present more or less perfectly analyzed and described are as follows : —

Chloride,	$Co_2(NH_3)_{10}Cl_6+2OH_2$
Nitrate,	$Co_2(NH_3)_{10}(NO_3)_6+3OH_2$
Sulphate,	$Co_2(NH_3)_{10}(SO_4)_3+5OH_2$
Sulphato-chlorplatinate,	$Co_2(NH_3)_{10}(SO_4)_2Cl_2+PtCl_4$
Sulphato-chloro-aurate,	$Co_2(NH_3)_{10}(SO_4)_2Cl_2+2AuCl_3+4OH_2$.

I may remark in this connection, that rhodium forms two series of salts, one of which is red, and the other yellow, and that the chloride of Claus's base, $Rh_2(NH_3)_{10}Cl_6$, which is yellow, unlike the well-defined double chlorides containing Rh_2Cl_6, may be the true analogue of the yellow modification of $Co_2(NH_3)_{10}Cl_6+2OH_2$.

Chlorplatinate. — When the soluble sulphate of roseocobalt is converted into nitrate by double decomposition with baric nitrate, and chlorplatinate of sodium is added, a salt separates in dark-red mamillary crystalline crusts, which may be regarded as the normal platinum salt of this series. The salt, like most of its congeners, is much more soluble in hot than in cold water, and crystallizes as the solution cools, though not in well-defined forms. Its formula is —

$$Co_2(NH_3)_{10}Cl_6+2PtCl_4+5OH_2,$$

as the following analyses show: —

0·9318 gr. gave 0·2899 gr. platinum, and 0·0868 gr. cobalt (by difference) = 31·12% platinum, and 9·39% cobalt = 40·51% Pt+Co.
0·3040 gr. gave 0·1241 gr. platinum and cobalt = 40·79%.

Heated to 140°C the salt lost 5·41% water, and was then decomposed with a slight explosion, so that the whole of the water is not given off below the temperature of decomposition. The formula requires: —

	Calculated.	Found.
Platinum,	31·15	31·12
Cobalt,	9·28	9·39
Water,	7·08	5·41

When platinic chloride is added to a solution of chloride of roseocobalt, a dull-red crystalline salt in fine needles is formed, readily soluble in hot water, and crystallizing from the solution unchanged. Of this salt, —

0·3766 gr. (reduced by zinc and SO_4H_2) gave 0·1087 gr. platinum and 0·3981 gr. silver = 28·86% platinum and 35·55% chlorine.

These results correspond to the formula $Co_2(NH_3)_{10}Cl_6+2PtCl_4+12OH_2$, which requires 28·72% platinum, and 36·04% chlorine. Braun states that by adding platinic chloride to a solution of a salt of roseocobalt and free chlorhydric acid, he obtained a dark orange-red crystalline precipitate, having the formula, as we should now write it, $3.Co_2(NH_3)_{10}Cl_6+4.PtCl_4$. I have never obtained any such salt; and as Braun's formula is based upon a determination of the sum of the percentages of platinum and cobalt only, it cannot be regarded as even probable. Genth and I have stated in the first part of this paper, that chloride of roseocobalt forms with platinic chloride a salt which we had not completely examined, but which appeared to have the formula $Co_2(NH_3)_{10}Cl_6+3PtCl_4+8OH_2$. I have not obtained this salt again; but the following analyses will serve to show that we had some reason for believing in its existence: —

0·7593 gr. gave 0·3256 gr. platinum and cobalt = 42·88%.
0·6155 gr. gave 0·3326 gr. platinum and SO_4Co = 0·2182 gr. platinum and 0·1144 gr. SO_4Co = 35·45% platinum and 7·07% cobalt.
0·4809 gr. gave 0·7491 gr. AgCl = 38·50% chlorine.

The formula $Co_2(NH_3)_{10}Cl_6+3PtCl_4+8OH_2$ requires : —

	Calculated.	Found.
Cobalt,	7·08	7·07
Platinum,	35·56	35·45
Chlorine,	38·36	38·50

These analyses were not published in the first part of this paper, because Genth and I did not succeed in preparing the salt a second time. I do not myself consider them — in spite of their close agreement with the formula given — sufficient to establish the existence of the salt in question. Further researches may be more successful in this respect.

Sulphato-chlorplatinate. — When chlorplatinate of sodium is added to a solution of the soluble sulphate of roseocobalt, a beautiful bright-red crystalline salt is precipitated, which is but slightly soluble in cold water, but which may be dissolved in a very large excess of boiling water with a few drops of free acid, and crystallizes from the solution without decomposition. This salt has the formula, —

$$Co_2(NH_3)_{10}(SO_4)_2Cl_2+PtCl_4,$$

as the following analyses show : —

0·4806 gr. gave 0·3476 gr. silver = 23·78% chlorine.
0·4221 gr. gave 0·1505 gr. platinum and cobalt = 35·65%.
0·1428 gr. of the mixed metals gave 0·0898 gr. platinum = 22·43% (of the salt), and 13·22% cobalt (by difference).
0·5219 gr. gave 0·2618 gr. SO_4Ba = 20·66% SO_4. Salt fused with CO_3KNa.

The salt lost no water on being heated to 150°C. The formula requires : —

	Calculated.	Found.
Cobalt,	13·24	13·22
Platinum,	22·21	22·43
Chlorine,	23·90	23·78
SO_4,	21·55	20·66

A solution of the yellow modification of the sulphate of roseocobalt already described, gave with chlorplatinate of sodium a beautiful yellow crystalline precipitate remarkably insoluble even in hot water. This salt, after washing and drying *in pleno* over sulphuric acid, was analyzed : —

0·4202 gr. gave 0·1488 gr. platinum and cobalt = 35·41%.

The formula $Co_2(NH_3)_{10}(SO_4)_2Cl_2+PtCl_4$ requires 35·45%. The very small quantity of the sulphate at my disposal prevented me from making a more complete analysis; but there can scarcely be a doubt as to the constitution of the salt.

Chloro-aurate of Roseocobalt. — Chloro-aurate of sodium produces in a cold solution of the chloride of roseocobalt a beautiful bright orange-red crystalline salt, which may be redissolved in hot water, and recrystallized without sensible decomposition. This salt has the formula, —

$$Co_2(NH_3)_{10}Cl_6+2AuCl_3+2OH_2,$$

as appears from the following analyses: —

0·5996 gr. gave 0·3674 gr. gold and SO_4Co containing 0·2047 gr. gold = 10·33% cobalt and 34·14% gold.
0·8900 gr. gave 0·3080 gr. gold = 34·59%, and 1·0013 gr. silver = 36·98% chlorine.

The salt is soluble even in cold water; the solution has a fine orange-red color. The formula requires: —

	Calculated.	Found.
Cobalt,	10·31	10·33
Gold,	34·44	34·37 (mean)
Chlorine,	37·23	36·98

The salt contains two atoms of water, which are not found in the corresponding salt of purpureocobalt. It is one of the most beautiful of the whole series.

Sulphato-chloro-aurate. — Chloro-aurate of sodium gives a beautiful orange-red crystalline precipitate with soluble sulphate of roseocobalt. The salt is but slightly soluble in cold water, and may be washed without sensible loss. It requires much hot water for solution, but dissolves without decomposition, and separates from the solution on cooling in fine bright-red crystals. The formula of this salt is, —

$$Co_2(NH_3)_{10}(SO_4)_2Cl_2+2AuCl_3+4OH_2,$$

as the following analyses show: —

0·4331 gr. gave 0·1389 gr. gold = 32·07%.
0·3542 gr. gave 0·1473 gr. SO_4Ba = 0·1363 gr. SO_4Ba.

	Calculated.	Found.
Gold,	32·04	32·07
SO_4,	15·62	15·86

The yellow modification of sulphate of roseocobalt gives with chloro-aurate of sodium a precipitate in yellow needles, soluble without decomposition in boiling water, and crystallizing from the solution unchanged. In this salt, —

0·1952 gr. gave 0·0494 gr. SO_4Co = 9·63%.

0·2657 gr. gave 0·0856 gr. gold and 0.1866 gr. silver = 32·25% gold and 23·11% chlorine.

The formula, $Co_2(NH_3)_{10}(SO_4)_2Cl_2+2AuCl_3+4OH_4$, requires : —

	Calculated.	Found.
Cobalt,	9·59	9·63
Gold,	32·04	32·25
Chlorine,	23·09	23·11

Chloro-hydrargyrate of Roseocobalt. — Under the head of purpureocobalt I have described two salts having respectively the formulas $Co_2(NH_3)_{10}Cl_6+6HgCl_2$, and $Co_2(NH_3)_{10}Cl_6+4HgCl_2$. The six-atom salt was first described and analyzed by Claudet,* and afterward by Carstanjen,† who also first described the six-atom salts with four and twelve molecules of water of crystallization. I find that the six-atom salts are always formed when chloride of mercury and sodium, $HgCl_4Na_2$, is added to a solution of chloride or of sulphate of roseocobalt, but that the resulting salt always contains four atoms of water of crystallization, while the anhydrous salt, $Co_2(NH_3)_{10}Cl_6+6HgCl_2$, is formed when an excess of the mercuric salt is added to a solution of chloride of purpureocobalt. On re-solution and recrystallization, each salt separates unchanged, so that the hydrous salt does not appear to be merely a hydrated form of the other. The salt $Co_2(NH_3)_{10}Cl_6+6HgCl_2+4OH_2$ crystallizes in lilac-red prismatic forms, which are much more soluble than the anhydrous salt. Of this compound (from $Co_2(NH_3)_{10}Cl_6+2OH_2$), —

1·7840 gr. gave 1·1522 gr. H_gCl_2 = 54·86% mercury.

1·4373 gr. gave 1·2721 gr. silver = 29·09% chlorine.

0·8430 gr. gave 0·1205 gr. SO_4Co = 5·43% cobalt.

0·3731 gr. (from $Co_2(NH_3)_{10}(SO_4)_3+5aq$) gave 0·2373 gr. HgS = 54·84% mercury.

The formula requires : —

	Calculated.	Found.	
Cobalt,	5·37	5·43	
Mercury,	54·57	54·86	54·84
Chlorine,	29·05	29·09	

* Phil. Mag. II. p. 253.

† De Connubiis ammoniaco-cobalticis. Berlin, 1861.

Basic Oxalo-sulphate. — This salt, which in the first part of this paper was assigned to the purpureocobalt series, belongs, as I think, more probably with the salts of roseocobalt, being formed directly from the sulphate of that base. This view compels us to admit the existence of a basic series of roseo-salts, to which, however, I can see no reasonable objection. The formula of the oxalo-sulphate may now be written,

$$Co_2(NH_3)_{10}.O.(C_2O_4).(SO_4)+7OH_2.$$

Acid Oxalo-sulphate. — The acid oxalo-sulphate, described in the same paper, may be written,

$$Co_2(NH_3)_{10}(C_2O_4)_2(S_2O_7)+3OH_2,$$

and would then be a dioxalo-disulphate. Its structural formula upon this view would be

$$Co_2\left\{\begin{array}{l} \left.\begin{array}{l} O\text{———————} \\ NH_3-NH_3-O \end{array}\right> C_2O_2 \\ \left.\begin{array}{l} NH_3-NH_3-NH_3 \\ NH_3-NH_3-NH_3 \end{array}\right> S_2O_7 \\ \left.\begin{array}{l} NH_3-NH_3-O \\ O\text{———————} \end{array}\right> C_2O_2 \end{array}\right.$$

This formula agrees satisfactorily with the results of the analyses, and with the fact that the acid reaction is not very strong. On the other hand, it is at least possible that the salt may contain two atoms less of hydrogen. In this case the formula would be

$$Co_2(NH_3)_{10}(C_2O_4)(SO_4)_2+C_2H_2O_4+2OH_2.$$

If the first view be adopted, the formation of the salt by boiling normal sulphate of roseocobalt with oxalic acid may be expressed by the equation: —

$$Co_2(NH_3)_{10}(SO_4)_3+3C_2H_2O_4=\{Co_2(NH_3)_{10}(C_2O_4)_2(S_2O_7)+ C_2H_2O_4\}+OH_2+SO_4H_2.$$

Upon the second view we should have: —

$$Co_2(NH_3)_{10}(SO_4)_3+3C_2H_2O_4=\{Co_2(NH_3)_{10}(C_2O_4)(SO_4)_2+ C_2H_2O_4\}+2OH_2+SO_4H_2.$$

The second view appears to me preferable, since we have no independent evidence to show that ordinary sulphates ever lose water to form disulphates, except by the action of heat.

Oxalates. — Genth and I have shown that the neutral oxalate of roseocobalt has the formula $Co_2(NH_3)_{10}(C_2O_4)_3+OH_2$. I find now that, as already stated, this salt is sometimes formed as one of the products of the action of ammonic oxalate upon chloride of purpureocobalt, and also by the action of the alkaline oxalate upon the nitrate of the same base. When the neutral oxalate is boiled with an excess of oxalic acid, the solution deposits, on cooling, fine garnet-red crusts of crystals resembling prehnite in appearance. This salt is the acid oxalate of roseocobalt, and has the formula, —

$$Co_2(NH_3)_{10}(C_2O_4)_3+4C_2H_2O_4,$$

as the following analyses show: * —

1. 0·4897 gr. gave 0·1673 gr. SO_4Co = 13·00% cobalt.
2. 0·3421 gr. gave 0·0447 gr. cobalt = 13·06% cobalt.
3. 0·8908 gr. gave 0·5913 gr. Co_2 and 0·3389 gr. water = 18·10% carbon and 4·22% hydrogen.
4. 1·1337 gr. gave 0·7460 gr. Co_2 and 0·4439 gr. water = 18·03% carbon and 4·35% hydrogen.
5. 0·7397 gr. gave 0·4872 gr. Co_2 and 0·2922 gr. water = 17·96% carbon and 4·19% hydrogen.

	Calculated.	Mean.	Found.		
Cobalt,	12·94	13·03	13·00	13·06	
Carbon,	18·42	18·03	18·10	18·03	17·96
Hydrogen,	4·16	4·25	4·22	4·35	4·19

The formula appears, when compared with those of the ordinary double oxalates containing metallic sesquioxides, to be abnormal; but the analyses made with carefully recrystallized, pure, and homogeneous salt seem to leave no reasonable doubt as to the true constitution.

Oxalo-platino-chloride. — When a solution of chlorplatinate of sodium, $PtCl_6Na_2$, is added to one of the neutral oxalate of roseocobalt, a fine red crystalline precipitate forms after a short time, which may be purified by a second crystallization. The salt forms small grouped acicular crystals, which have a rather pale-red color. It is somewhat easily soluble in cold water. Boiling water dissolves it readily, forming a clear red solution, from which the salt crystallizes without decomposition. The formula of this salt is,

$$Co_2(NH_3)_{10}(C_2O_4)_2Cl_2+PtCl_4,$$

as the following analyses show: —

0·5389 gr. gave 0·1210 gr. platinum and 0·4002 gr. silver = 22·45% platinum and 24·41% chlorine.

The formula requires 22·62% platinum and 24·34% chlorine.

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* My friend and former pupil, Prof. Sadtler, had the kindness to make analyses 4 and 5 for me after my own laboratory had been closed. I deemed them necessary to verify the unexpected formula.

Cobalto-nitrite of Roseocobalt. — When a solution of cobalto-nitrite of sodium, $Co_2(NO_2)_{12}Na_6$, in excess of sodic nitrite is added to one of the soluble sulphate of roseocobalt, beautiful brown-orange prismatic crystals are thrown down, which are readily soluble in hot water without decomposition. Of these crystals dried *in pleno* over sulphuric acid, —

0·2820 gr. gave 0·1822 gr. $SO_4Co = 24·60\%$ cobalt.

The formula of the anhydrous salt, $Co_2(NH_3)_{10}(NO_2)_6+Co_2(NO_2)_6$, requires exactly the percentage found. The solution of this salt gives with salts of luteocobalt a beautiful crystalline precipitate of the cobalto-nitrite of that base, $Co_2(NH_3)_{12}(NO_2)_6+Co_2(NO_2)_6$. With salts of strychnia and brucia, it gives the cobalto-nitrites of those alkaloids. The preparation of this salt, like that of all similar compounds, is somewhat uncertain, and often fails entirely in consequence of the formation of salts of xanthocobalt by the action of the excess of sodic nitrite on the sulphate of roseocobalt. By the action of a solution of cobalto-nitrite of sodium upon chloride of purpureocobalt, Sadtler obtained a yellow crystalline salt much more soluble than the luteocobalt salt, $Co_2(NH_3)_{12}(NO_2)_6+Co_2(NO_2)_6$, and to which he assigns the probable formula $Co_2(NH_3)_{10}(NO_2)_6+Co_2(NO_2)_6+OH_2$. Farther study is needed, however, in the case of this salt. It may be identical with that described above.

Dichromate of Roseocobalt. — When a solution of potassic dichromate is added to one of nitrate of roseocobalt, a dark red precipitate is formed, which, after re-solution in water with a few drops of acetic acid, separates in beautiful red scales with bronze-yellow reflections. This salt is identical with that formed in Mr. Mills's process for preparing salts of roseocobalt, to which I have already alluded, and in which I found five atoms of water of crystallization. When digested at a gentle heat with a solution of baric nitrate, the salt yields baric chromate and nitrate of roseocobalt only, so that it certainly belongs to this series, and not to that of purpureocobalt.

Sulphite of Roseocobalt. — I obtained the specimen of this salt which I examined from Dr. Genth who prepared it by boiling chloride of purpureocobalt with a solution of neutral ammonic sulphite.

The salt was recrystallized from its solution in ammonic carbonate, and contained only a trace of chlorine. It forms granular brownish-orange crystals, slightly soluble in cold, and readily decomposed by hot water. Heated in a tube, it gave off water, ammonia, and ammonic sulphite. When sulphuric acid is poured upon the sulphite, some sulphurous oxide is given off, but it is only by strong heating that the whole of the oxide can be expelled. Of this salt: —

0·7132 gr. gave 0·3800 gr. SO_4Co = 20·27% cobalt.
1·7094 gr. gave 2·0505 gr. SO_4Ba = 32·94% SO_2.
1·5422 gr. gave 0·9228 gr. water = 6·64% hydrogen.
0·8927 gr. gave 183 c.c. nitrogen at 15°·5 C. and 765·14^{mm} = 24·07%.

The formula $Co_2\,(NH_3)_{10}(SO_3)_3 + 3OH_2$ requires: —

		Calculated.	Found.
Cobalt,	2	20·27	20·27
Sulphurous Oxide,	3	32·98	32·94
Nitrogen,	10	24·05	24·07
Hydrogen,	36	6·18	6·64

I have assigned this salt somewhat arbitrarily to the roseocobalt series. In the absence of any direct evidence on either side, it is of course equally probable that it belongs to the series of purpureocobalt. Künzel's salt,

$$Co_2(NH_3)_{10}(SO_3)_3 + Co_2(SO_3)_3 + 9OH_2,$$

bears the same relation to the neutral sulphite which I have described which the cobalto-nitrite, $Co_2(NH_3)_{10}(NO_2)_6 + Co_2(NO_2)_6$, bears to the normal nitrite $Co_2(NH_3)_{10}(NO_2)_6$.

The salts known with most certainty to belong to the roseocobalt series are the following: —

Chloride,	$Co_2(NH_3)_{10}Cl_6 + 2OH_2$
Nitrate,	$Co_2(NH_3)_{10}(NO_3)_6 + 2OH_2$
Sulphates α, β, γ,	$Co_2(NH_3)_{10}(SO_4)_3 + 5OH_2$
Acid sulphate,	$Co_2(NH_3)_{10}(SO_4)_3 + SO_4H_2 + 4OH_2$
Iodo-sulphates α, β, γ,*	$Co_2(NH_3)_{10}(SO_4)_2I_2 + 2OH_2$
Bromo-sulphate,*	$Co_2(NH_3)_{10}(SO_4)_2Br_2 + 2OH_2$
Dichromate,	$Co_2(NH_3)_{10}(Cr_2O_7)_3 + 5OH_2$
Basic oxalo-sulphate,	$Co_2(NH_3)_{10}.O.(C_2O_4)(SO_4) + 7OH_2$
Oxalate,	$Co_2(NH_3)_{10}(C_2O_4)_3 + 6OH_2$
Acid oxalo-bisulphate,	$Co_2(NH_3)_{10}(C_2O_4)(SO_4)_2 + C_2H_2O_4 + 2OH_2$
Acid oxalate,	$Co_2(NH_3)_{10}(C_2O_4)_3 + 4C_2H_2O_4$
Ferricyanide,	$Co_2(NH_3)_{10}Cy_6 + Fe_2Cy_6 + 3OH_2$

* Krok, loc. cit.

Cobalticyanide,	$Co_2(NH_3)_{10}Cy_6+Co_2Cy_6+3OH_2$
Platino-chloride,	$Co_2(NH_3)_{10}Cl_6+2PtCl_4+5OH_2$
Auro-chloride,	$Co_2(NH_3)_{10}Cl_6+2AuCl_3+2OH_2$
Hydrargo-chloride,	$Co_2(NH_3)_{10}Cl_6+6HgCl_2+4OH_2$
Sulphato-hydrargo-chloride,*	$Co_2(NH_3)_{10}(SO_4)_2Cl_2+2HgCl_2$
Sulphato-chloro-platinate β, γ,	$Co_2(NH_3)_{10}(SO_4)_2Cl_2+PtCl_4$
Sulphato-chloro-aurate β, γ,	$Co_2(NH_3)_{10}(SO_4)_2Cl_2+4OH_2$
Oxalo-chlorplatinate,	$Co_2(NH_3)_{10}(C_2O_4)_2Cl_2+PtCl_4$
Cerous double sulphate (Wing),	$Co_2(NH_3)_{10}(SO_4)_3+3CeSO_4+OH_2$
Ceric double sulphate (Wing),	$Co_2(NH_3)_{10}(SO_4)_3+Ce_2(SO_4)_3+OH_2$
Chloro-nitro-platino-chloride,*	$Co_2(NH_3)_{10}(NO_3)_2Cl_4+2PtCl_4$
Chloro-nitro-hydrargo-chloride,*	$Co_2(NH_3)_{10}(NO_3)_3Cl_3+3HgCl_2$.

With the data given above before us, we may now compare the purpureo- and roseo- series more advantageously than has hitherto been possible. Genth and I at an early period in our investigation recognized the distinction between these two classes of salts, — a distinction which has been admitted by some chemists, strongly supported by Mills † and F. Rose, and summarily rejected by Blomstrand ‡ and others. I shall omit from the discussion those salts which in the present state of our knowledge might be classed with either series. As a basis for the distinction which I uphold, I present the following facts: —

1. Chloride of purpureocobalt, $Co_2(NH_3)_{10}Cl_6$, cannot be converted into chloride of roseocobalt, $Co_2(NH_3)_{10}Cl_6+2OH_2$, by recrystallization from water. In other words, it does not unite *directly* with water to form a hydrate, the combination always taking place *indirectly*, as, for instance, when chloride of purpureocobalt is dissolved in ammonia water, and the solution poured into strong cold chlorhydric acid. The same argument applies in the case of the nitrate of purpureocobalt, which behaves in a precisely similar manner. Chemistry presents, so far as I have been able to discover, no single case in which similar relations exist between a salt and its hydrate.
2. Chloride of roseocobalt, in either concentrated or dilute solution, loses two atoms of water, and is converted into chloride of pur-

* Krok, loc. cit.

† L. & E. Phil. Mag. (4) xxxv. 245.

‡ Chemie der Jetztzeit. p. 294, note.

pureocobalt by simple heating. I can recall no single instance in which a true hydrate behaves in a similar manner. Nitrate of roseocobalt, when heated in solution with a little free nitric acid, undergoes a similar conversion into nitrate of purpureocobalt.

3. Sulphate, chromate, oxalate, &c., of roseocobalt in solution yield, by double decomposition in the cold with baric chloride and nitrate, salts of roseocobalt only. Is a mere state of hydration transmitted from salt to salt?

4. According to the determinations of F. Rose,* one part by weight of chloride of roseocobalt requires at 10° C. 4·8 parts of water for solution. At the same temperature, one part of chloride of purpureocobalt requires 287 parts of water for solution. Rose remarks that the identity of chloride of roseocobalt and chloride of purpureocobalt can only be maintained by admitting that the same salt can exist both in the hydrous and anhydrous condition in a solution at the same temperature, an assumption directly opposed to the numerous observations of Rüdorff and Wüllner on the tension of the vapor of aqueous solutions.

5. Solutions of the two chlorides form with the same reagents in many cases different salts. Thus, chloride of roseocobalt forms

$Co_2(NH_3)_{10}Cl_6+2PtCl_4+5OH_2$ with platinic chloride,

$Co_2(NH_3)_{10}Cl_6+2AuCl_3+2OH_2$ with auro-chloride of sodium,

$Co_2(NH_3)_{10}(C_2O_4)_3+6OH_2$ with ammonic oxalate.

With the same reagents respectively, chloride of purpureocobalt gives,

$$Co_2(NH_3)_{10}Cl_6+2PtCl_4,$$

$$Co_2(NH_3)_{10}Cl_6+2AuCl_3,$$

$$Co_2(NH_3)_{10}Cl_2(C_2O_4)_2.$$

6. The greater number of the salts of the roseocobalt series contain water of crystallization. The greater number of the salts of purpureocobalt are anhydrous. If it be replied that this statement involves a *petitio principii*, I reply that the presence or absence of water of crystallization is, in most cases at least, coexistent with other properties tending to establish a clear distinction between the two classes of salts.

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* Untersuchungen über ammoniakalische Kobalt-Verbindungen. Heidelberg, 1871, p. 47.

7. I have rendered it, to say the least, extremely probable that there are three distinct modifications of roseocobalt, yielding salts with similar or identical empirical formulas, but differing in color and solubility. Is it unreasonable to suppose that there may be a fourth modification or possible variation in the arrangement of the atoms constituting the molecule $Co_2(NH_3)_{10}$?

With respect to the few known cases in which salts of roseocobalt and purpureocobalt yield the same salts by double decomposition with the same reagents, I have to say that there appears to be no reason for doubting that in such cases there is a transformation of one modification of the molecule $Co_2(NH_3)_{10}$ to another, since we already know that such transformation may be effected by heat alone. The best instances of this transformation occur in the case of the reactions of the two chlorides with potassic ferricyanide and cobalticyanide mentioned by Genth and myself.

LUTEOCOBALT.

Rogojski * first noticed the existence of a salt of luteocobalt containing both chlorine and sulphuric oxide, and having a formula which we should now write $Co_2(NH_3)_{12}Cl_6+Co_2(NH_3)_{12}(SO_4)_3$, but which might also be written $Co_2(NH_3)_{12}(SO_4)_2Cl_2+Co_2(NH_3)_{12}(SO_4)Cl_4$. In examining this salt, Genth and I found that the chloride and sulphate are capable of crystallizing together in all proportions. Dana then showed that the two salts are isomorphous. Genth and I observed further that mixtures of the chloride and sulphate gave peculiar crystalline salts with the chlorides of platinum and mercury. These we naturally regarded simply as mixtures. Braun afterward obtained a chloro-chromate which he regarded as a double salt, and which we should now write $Co_2(NH_3)_{12}(CrO_4)_4Cl_2$. The salt is easily formed by mixing solutions of one molecule of the chloride and two of the neutral chromate. As in the case of the corresponding salts of roseocobalt, Krok † first showed that definite compounds are formed when ammoniacal solutions of sulphate of luteocobalt are heated with iodine. The resulting iodo-sulphate has the formula $Co_2(NH_3)_{12}(SO_4)_2I_2$. By the action of chlorine upon this salt the corresponding chloride is formed, and this gives well-defined crystalline salts with platinic and

* Compt. Rendus, xxxiv. 186. † Acta Univ. Lund. 1840.

mercuric chlorides, which have respectively the formulas $Co_2(NH_3)_{12}(SO_4)_2(HgCl_2)_2$ and $Co_2(NH_3)_{12}(SO_4)_2(PtCl_6)$.

Chloro-platino-chromate of Luteocobalt. — When neutral chromate of luteocobalt is dissolved, and a solution of platinic chloride added, brown-yellow crystals are obtained, which require a large quantity of boiling water for solution, and are difficult to purify by recrystallization. Of this salt: —

0·6567 gr. gave 0·1920 gr. platinum, and 0·6026 gr. silver = 29·23% platinum, and 30·16% chlorine.

These numbers indicate the formula $Co_2(NH_3)_{12}(CrO_4)Cl_4 + 2PtCl_4 + 5$ aq., which requires 29·33% platinum, and 31·55% chlorine. I do not consider the constitution of this salt to be sufficiently established by my analyses, though there is no *a priori* improbability in the formula itself.

Oxalo-auro-chloride of Luteocobalt. — When neutral oxalate of luteocobalt is digested with a solution of auro-chloride of sodium, the salt quickly changes its appearance as regards form and color, and a new salt is formed, which is readily soluble in boiling water, and crystallizes from the solution in long orange-yellow needles. The formula of this salt is, —

$$Co_2(NH_3)_{12}(C_2O_4)_2Cl_2 + 2AuCl_3 + 4OH_2,$$

as appears from the following analyses: —

0·5109 gr. gave 0·2107 gr. gold, and cobalt = 41·24%, and 0·1628 gr. gold = 31·86% gold, and by difference 9·38% cobalt.

The formula $Co_2(NH_3)_{12}(C_2O_4)_2Cl_2 + 2AuCl_3 + 4OH_2$ requires gold 31·56%, cobalt 9·47%. When neutral oxalate of luteocobalt is dissolved in chlorhydric acid, and auro-chloride of sodium is added, beautiful yellow granular crystals are formed which contain no oxalic acid. In this salt, —

0·3042 gr. gave 0·1875 gr. $SO_4Co + Au$ containing 0·1043 gr. gold = 34·25%, and 0·0832 gr. SO_4Co = 10·41% cobalt.

0·6738 gr. gave 0·7591 gr. silver = 37·03% chlorine.

The formula $Co_2(NH_3)_{12}Cl_6 + 2AuCl_3$ requires: —

		Calculated.	Found.
Cobalt,	2	10·33	10·41
Gold,	2	34·50	34·25
Chlorine,	12	37·30	37·03

so that the salt is identical with that described by Genth and myself in the first part of this paper. When platinic chloride is digested with neutral oxalate of luteocobalt, the salt changes its form and color in so marked a degree as to leave no reasonable doubt of the formation of a new salt. On attempting, however, to purify this salt by solution in boiling water and recrystallization, I found that decomposition at once commenced, carbonic dioxyd being given off in abundance. There can hardly be a doubt, I think, that the salt, $Co_2(NH_3)_{12}(C_2O_4)_2Cl_2+PtCl_4$, is at first formed, and subsequently decomposed. Oxalate of luteocobalt dissolves in hot oxalic acid, and yields a pale buff felted mass of crystals of an acid oxalate.

Pyrophosphate. — When sodic pyrophosphate is added to a solution of luteocobalt, a beautiful crystalline precipitate is formed in talcose scales with a high lustre, remarkably insoluble in water. Braun, who first studied this salt, assigns to it the formula, —

$$3(Co_2(NH_3)_6O_3)+5P_2O_5+40OH,$$

(old style) and suggests that it may be a double salt with the formula, —

$$2(Co_2(NH_3)_6O_3.PO_5+8OH)+Co_2(NH_3)_6O_3.3PO_5+24OH,$$

in which case it would contain both orthophosphoric and metaphosphoric oxides. My analyses have led me to the much simpler formula, —

$$Co_2(NH_3)_{12}.(\overset{vi}{P_4O_{13}})+6OH_2,$$

the constitution of the salt being perfectly analogous to that of the pyrophosphate of purpureocobalt already described. The salt analyzed was precipitated from a hot solution of chloride of luteocobalt by a solution of sodic pyrophosphate, well washed with cold water, and dried *in vacuo* over sulphuric acid. Of the crystals,

0·8178 gr. gave 0·4692 gr. by ignition = 57·30% $Co_2P_4O_{12}$.
0·8174 gr. gave 0·4651 gr. by ignition = 56·89% $Co_2P_4O_{12}$.
0·5879 gr. gave 0·0693 gr. water heated up to 120° C. until the weight was constant = 11·78%.
0·7515 gr. gave 0·4359 gr. $P_2O_7Mg_2$ = 43·37% P_4O_{13}.

The water given off up to 120° C. corresponds to five atoms, the calculated percentage being 11·81. The last atom of water is retained at 140° C.

	Calculated.	Found.
$Co_2P_4O_{12}$,	56·95	57·09 (Mean.)
$10NH_3+6OH_2+O$,	43·05	42·91
	100·00	100·00

The formula requires 43·57% P_4O_{13}. Found 43·37%. The analysis was made by fusing the salt with CO_3KNa, and precipitating as ammonio-magnesic phosphate. Iodide of luteocobalt gives the same salt, and does not yield an iodo-pyrophosphate $Lc.P_2O_7.I_2$ as might perhaps have been expected.

Sulphate of Thallium and Luteocobalt. — When a solution of thallous sulphate containing free sulphuric acid is oxidized by potassic hypermanganate, a dark brown precipitate is formed which readily redissolves on the application of heat. The clear solution produces in a solution of sulphate of luteocobalt, after a few minutes, a beautiful crystalline precipitate of yellow talcose scales which have a peculiar silky lustre. These crystals are decomposed by washing even with cold water, a brown powder of thallic hydrate $Tl(OH)_3$ being formed. The decomposition may be prevented by adding sulphuric acid to the water. Of this salt: —

0·5079 gr. gave 0·3169 gr. = 62·39% sulphates of cobalt and thallium.

0·7421 gr. gave 0·6557 gr. SO_4Ba = 36·40% SO_4.

In the last analysis, the thallium was first reduced in a solution containing free chlorhydric acid by metallic magnesium, as zinc did not effect a reduction even after long boiling. The precipitated spongy thallium dissolved completely in the excess of free chlorhydric acid. The formula of the salt is $Co_2(NH_3)_{12}(SO_4)_3+Tl_2.O.(SO_4)_2+5OH_2$, which requires 36·49% SO_4 and 61·81% of the mixed sulphates, $2.SO_4Co+SO_4Tl_2$.

I did not succeed in obtaining analogous salts with the sulphates of roseocobalt, xanthocobalt, or croceocobalt. It is remarkable that the thallic sulphate in this salt is basic. I verified the analysis by a second determination of SO_4, made by decomposing the salt with hot water, filtering off the thallic hydrate formed, and determining the SO_4 in the filtrate by baric chloride. The analysis gave 36·11%.

Dichromate. — Potassic dichromate precipitates luteocobalt from concentrated solutions of the nitrate in beautiful orange needles, which may be redissolved and recrystallized without decomposition. The salt dissolves rather easily in hot water, but different preparations appeared to contain different amounts of water of crystallization. In one preparation in fine crystals : —

$$1{\cdot}3713 \text{ gr. gave } 0{\cdot}5952 \text{ gr. } Cr_2O_3 = 61{\cdot}62\% \; Cr_2O_7.$$

The formula $Co_2(NH_3)_{12}(Cr_2O_7)_3 + 5OH_2$ requires $61{\cdot}17\%$.

METAMERIC SALTS.

I have already stated that roseocobalt and xanthocobalt give beautiful crystalline salts with the electro-negative or chlorous radical of Erdmann's remarkable series. The formula of the octamin salt may be written, —

$$\{Co_2(NH_3)_8(NO_2)_4\}^{''}\{Co_2(NH_3)_4(NO_2)_8\}^{''} \text{ or } Co_2(NH_3)_8(NO_2)_6 + Co_2(NH_3)_4(NO_2)_6,$$

while that of the xanthocobalt salt is, —

$$\{Co_2(NH_3)_{10}(NO_2)_2\}^{\text{iv}}\{Co_2(NH_3)_4(NO_2)_8\}^{''}_2 \text{ or } Co_2(NH_3)_{10}(NO_2)_6 + 2(Co_2(NH_3)_4(NO_2)_6).$$

It will readily be seen that, as already shown, the croceocobalt salt is empirically

$$2. \;\; Co_2(NH_3)_6(NO_2)_6,$$

and the xanthocobalt salt

$$3. \;\; Co_2(NH_3)_6(NO_2)_6,$$

and consequently that both are metameric with the hexamin nitrite of Erdmann $Co_2(NH_3)_6(NO_2)_6$. I will now show that there are two other compounds also metameric with Erdmann's salt, and yet perfectly distinct in chemical structure and properties.

When potassic nitrite is added to a solution of cobalt containing a little free acid, a yellow crystalline substance is gradually precipitated, which is the well-known salt first described by Fischer. The investigations of Professor Sadtler first definitively proved that this salt is essentially $Co_2(NO_2)_{12}K_6$, the number of atoms of water of crystallization varying with the circumstances under which the salt is formed. Professor Sadtler has also described and analyzed the corresponding sodic and ammonic salts. The sodic salt is not immediately precipitated when sodic nitrite is added to an acid solution of cobalt, but in presence of an excess of the alkaline nitrite remains in solution, giving a deep orange-colored liquid. I found that this solution gave beautiful crystalline precipitates with salts of luteocobalt and roseocobalt.

These were first analyzed and described in my laboratory by Sadtler, who found for the luteocobalt salts the formula, —

$$Co_2(NH_3)_{12}(NO_2)_6+Co_2(NO_2)_6+OH_2.$$

In resuming the study of this subject, I found the method of preparation at first adopted somewhat uncertain, because the excess of the alkaline nitrite acts readily upon the cobaltamine, forming other products not always easy to separate. The following method gives better results. One molecule of any soluble salt of the cobaltamine — the nitrates are to be preferred — is to be dissolved with two molecules of cobaltic chloride or nitrate, and a little acetic acid. A solution containing as nearly as possible twelve molecules of sodic nitrite is then to be added. The luteocobalt salt is precipitated almost immediately; the corresponding salt of roseocobalt after a short time.

The salt of luteocobalt obtained in this way is a yellow crystalline body very slightly soluble in cold water, and easily purified by washing. Boiling water dissolves it in very small quantity, giving a pale yellow solution. I have usually obtained it in rather larger deep orange granular crystals by adding a solution of the corresponding much more soluble roseocobaltic salt, $Co_2(NH_3)_{10}(NO_2)_6+Co_2(NO_2)_6$, to a hot neutral solution of nitrate of luteocobalt. It may also be formed by adding a solution of $Co_2(NO_2)_6+6NaNO_2$ in excess of sodic nitrite to a solution of luteocobalt, there being in this case less danger of the formation of other products than with the other cobaltamines. I find the formula of this salt to be

$$\{Co_2(NH_3)_{12}\}\{Co_2(NO_2)_{12}\} \text{ or } Co_2(NH_3)_{12}(NO_2)_6+Co_2(NO_2)_6,$$

as the following analyses, made with three different preparations, clearly show: —

0·3312 gr. gave 0·2056 gr. SO_4Co = 23·78% cobalt.
0·3776 gr. gave 0·2369 gr. SO_4Co = 23·89% cobalt.
0·1785 gr. gave 0·1115 gr. SO_4Co = 23·78% cobalt.

The formula requires 23·79% cobalt for the anhydrous salt. In one preparation, however, I obtained a salt in which

0·4291 lost 0·0087 gr. at 125° C. = 2·16.

This would correspond to Sadtler's formula, which requires 1·78%, if we consider a part of the water as hygroscopic, or that, as is more probable, there was a slight decomposition. In the dried salt, —

0·4204 gr. gave 0·2643 gr. SO_4Co = 23·93% cobalt.

so that the salt when containing an atom of water of crystallization, certainly becomes anhydrous a little below 125° C.

The structural formula of the salt is: —

$$\overset{vi}{Co_2}\left\{\begin{array}{l} NH_3—NH_3—O—N<{}^{O}_{O}>N \\ NH_3—NH_3—O—N<{}^{O}_{O}>N \\ NH_3—NH_3—O—N<{}^{O}_{O}>N \\ NH_3—NH_3—O—N<{}^{O}_{O}>N \\ NH_3—NH_3—O—N<{}^{O}_{O}>N \\ NH_3—NH_3—O—N<{}^{O}_{O}>N \end{array}\right\}\overset{vi}{Co_2}$$

In this case, as in formulating Fischer's salts (p. 17), I have assumed that six units of affinity of the hexatomic complex, Co_2, on the right, are saturated by six units of affinity of *nitrogen*, which is of course equivalent to supposing that a nitrite may be $R—N<{}^{O}_{O}$, and not, according to the usual view, $O=N—OR$. It seems to me that the first view exhibits more clearly the mutual relations of the ammonia and nitroxyl compounds of cobalt, and the existence of such intermediate compounds as the salts of Erdmann's series. But it is also possible that, while the alkaline nitrites have the structural formula, $O=N—OM$, very stable compounds, like $Co_2(NO_2)_{12}K_6$, have the different structure which I have above assumed. It will be seen that the difference corresponds to that between ethylic nitrite, $O=N—O C_2H_5$, and the far more stable nitro-ethan ${}^{O}_{O}>N—C_2H_5$.

When the luteocobalt salt just described, and which we may more briefly express by the formula $Co_2(NO_2)_{12}Lc$, is digested with a solution of thallous nitrate, $TlNO_3$, containing a little free nitric acid, the yellow salt soon becomes red, and finally assumes a fine scarlet tint, while the supernatant liquid becomes yellow, and contains nitrate of luteocobalt. After washing with hot water and drying, a fine crystalline scarlet salt of thallium is obtained, which has the formula,

$$Co_2(NO_2)_{12}Tl_6+2OH_2,$$

as the following analyses show: —

0·3964 gr. gave 0·3724 gr. sulphates of cobalt and thallium = 93·94%.

0·9879 gr. gave 0·0034 gr. water at 102° C. = 0·34%, 0·010 gr. at 130°–135° C. = 1·02%, and 0·0318 gr. at 150° C. = 3·22%.

The formula requires 94·39% of the mixed sulphates $2SO_4Co+3SO_4Tl_2$, and 1·86% water. The salt is partially decomposed above 140° C.

The thallium salt is very slightly soluble even in boiling water. Its formation is expressed by the equation, —

$$Co_2(NO_2)_{12}Lc+6TlNO_3=Co_2(NO_2)_{12}Tl_6+Lc(NO_3)_6.$$

It may also be prepared directly by adding a solution of a salt of cobaltic nitrate or sulphate to a hot solution of thallous nitrate containing a slight excess of free acid, and then adding a solution of sodic nitrite. The salt prepared in this manner, however, is apt to contain a little of the corresponding sodium salt. The thallium salt is a valuable reagent in investigations on the cobalt compounds which contain nitroxyl. NO_2, since, taken in connection with the characteristic silver salt of Erdmann's series, it enables us to recognize and distinguish compounds which contain $Co_2(NO_2)_{12}$ from those which contain $Co_2(NH_3)_4(NO_2)_8$, which is otherwise by no means easy.

The relationship of the luteocobalt salt above described to the other metameric salts of the series may be expressed as follows: —

$$\{Co_2(NH_3)_{12}\}\{Co_2(NO_2)_{12}\}=2.Co_2(NH_3)_6(NO_2)_6,$$

the salt having the same atomic weight as the octamin salt already described represented by the formula, —

$$\{Co_2(NH_3)_8(NO_2)_4\}\{Co_2(NH_3)_4(NO_2)_8\}.$$

Ammonia-cobalt-nitrite of Luteocobalt. — A solution of nitrate of luteocobalt gives with one of Erdmann's salt of potassium. $Co_2(NH_3)_4(NO_2)_8K_2$, a fine granular orange-yellow precipitate, which is slightly soluble in cold water, but dissolves in much boiling water, and crystallizes from the solution without change. Its much greater solubility distinguishes it from the metameric salts containing $Co_2(NO_2)_{12}$. The constitution of this salt is expressed by the formula,

$$\overset{vi}{\{Co_2(NH_3)_{12}\}}\overset{ii}{\{Co_2(NH_3)_4(NO_2)_8\}}_3 \text{ or } Co_2(NH_3)_{12}(NO_2)_6+(Co_2(NH_3)_4(NO_2)_6)_3,$$

as the following analyses show: —

0·3311 gr. gave 0·2077 gr. SO_4Co = 23·88% cobalt.
0·5073 gr. gave 141·5 c.c. nitrogen at 9°C. and 760^{mm} = 33·86% nitrogen.

The formula requires 23·79% cobalt, and 33·87% nitrogen.

A solution of this salt gives with argentic nitrate the characteristic salt, $Co_2(NH_3)_4(NO_2)_8Ag_2$; it also gives, though somewhat sluggishly, the characteristic reactions of salts of luteocobalt. The analyses and reactions leave no doubt as to the true constitution of the salt. Its relations to the other bodies metameric with it may be seen from the expression, —

$$\{Co_2(NH_3)_{12}\}\{Co_2(NH_3)_4(NO_2)_8\}_3 = 4\ Co_2(NH_3)_6(NO_2)_6.$$

It has the same molecular weight as the octamin salt: —

$$\{Co_2(NO_2)_{12}\}\{Co_2(NH_3)_4(NO_2)_8\}_3.$$

In the metameric series to which I have directed attention, at least two other members are theoretically possible. Thus we should certainly expect the reactions and products indicated by the equations: —

$$3.Co_2(NH_3)_{10}(NO_2)_2Cl_4 + 2.Co_2(NO_2)_{12}Na_6 = \{Co_2(NH_3)_{10}\}_3 \{Co_2(NO_2)_{12}\}_2 + 12NaCl.$$

$$3.Co_2(NH_3)_8(NO_2)_4Cl_2 + Co_2(NO_2)_{12}Na_6 = \{Co_2(NH_3)_8(NO_2)_4\}_3 \{Co_2(NO_2)_{12}\} + 6NaCl.$$

The first or xanthocobalt salt would be empirically, $5.Co_2(NH_3)_6(NO_2)_6$, while the second or croceocobalt salt would be $4.Co_2(NH_3)_6(NO_2)_6$. I have more than once been fully confident that I had obtained both these salts; but in the final revision of my work I did not succeed in obtaining either for analysis, and their existence must therefore, for the present, remain doubtful. The difficulty in preparing the salts of the $Co_2(NO_2)_{12}$ series depends mainly upon the fact that it is indispensable to avoid an excess of sodic nitrite in preparing the solution of $Co_2(NO_2)_{12}Na_6$ in that salt, as the sodic nitrite acts readily on the new salts formed. The possible existence of the anhydrous xanthocobalt salt of the $Co_2(NO_2)_{12}$ series is, however, shown by the existence of the compound

$$\{Co_2(NH_3)_{10}(NO_2)_2\}_3\{Co_2(NO_2)_{12}\}_2 + 9OH_2,$$

which I have described with the salts of purpureocobalt, but which, as already stated, belongs, as its reactions show, to the xanthocobalt series.

The metameric compounds, the existence of which may be considered as fully established, are as follows, denoting ammonia by A, and NO_2 by X, for brevity: —

Octamin salt,	$\{Co_2A_8X_4\}\{Co_2A_4X_8\}$	=	2. $Co_2A_6X_6$
Xanthocobalt salt,	$\{Co_2A_{10}X_2\}\{Co_2A_4X_8\}_2$	=	3. $Co_2A_6X_6$
Luteo salt α,	$\{Co_2A_{12}\}\{Co_2X_{12}\}$	=	2. $Co_2A_6X_6$
Luteo salt β,	$\{Co_2A_{12}\}\{Co_2A_4X_8\}_3$	=	4. $Co_2A_6X_6$
Erdmann's salt,			1. $Co_2A_6X_6$

The salts of luteocobalt, the formulas of which may be considered as well established, are as follows: —

Chloride,	$Co_2(NH_3)_{12}Cl_6$
Iodide,	$Co_2(NH_3)_{12}I_6$
Bromide,	$Co_2(NH_3)_{12}Br_6$
Nitrate,	$Co_2(NH_3)_{12}(NO_3)_6$
Sulphate,	$Co_2(NH_3)_{12}(SO_4)_3+5OH_2$
Chromate,	$Co_2(NH_3)_{12}(CrO_4)_3+5OH_2$
Dichromate,	$Co_2(NH_3)_{12}(Cr_2O_7)_3+5OH_2$
Oxalate,	$Co_2(NH_3)_{12}(C_2O_4)_3+4OH_2$
Carbonate,	$Co_2(NH_3)_{12}(CO_3)_3+7OH_2$
Acid carbonate,	$Co_2(NH_3)_{12}(CO_3)_3+CH_2O_3+5OH_2$
Phosphate (Braun),	$Co_2(NH_3)_{12}(PO_4)_2+8OH_2$
Pyrophosphate,	$Co_2(NH_3)_{12}.P_4O_{13}+6OH_2$
Cobalto-nitrite (Sadtler, Gibbs),	$Co_2(NH_3)_{12}.Co_2(NO_2)_{12}$
Ammonia-cobalt-nitrite,	$Co_2(NH_3)_{12}\{Co_2(NH_3)_4(NO_2)_8\}_3$
Sulphato-chloride (Krok),	$Co_2(NH_3)_{12}(SO_4)_2Cl_2+6OH_2$
Sulphato-iodide (Krok),	$Co_2(NH_3)_{12}(SO_4)_2I_2$
Chromo-chloride (Braun),	$Co_2(NH_3)_{12}(CrO_4)_2Cl_2+10OH_2$
Cobalticyanide,*	$Co_2(NH_3)_{12}Cy_6+Co_2Cy_6$
Ferricyanide,*	$Co_2(NH_3)_{12}Cy_6+Fe_2Cy_6$
Chromicyanide (Braun),	$Co_2(NH_3)_{12}Cy_6+Cr_2Cy_6$
Platino-chloride,	$Co_2(NH_3)_{12}Cl_6+3PtCl_4+6OH_2$
Auro-chloride,	$Co_2(NH_3)_{12}Cl_6+2AuCl_3$
Stannoso-chloride (Braun),	$Co_2(NH_3)_{12}Cl_6+3SnCl_2+8OH_2$
Hydrargo-chloride (Krok),	$Co_2(NH_3)_{12}Cl_6+2HgCl_2+3OH_2$
Hydrargo-chloride (Carstanjen),	$Co_2(NH_3)_{12}Cl_6+4HgCl_2+OH_2$
Sulphato-hydrargo-chloride (Krok).	$Co_2(NH_3)_{12}(SO_4)_2Cl_2+2HgCl_2$

* The analyses of the cobalticyanide and ferricyanide made by Genth and myself correspond better with a formula containing one atom of water of crystallization.

Sulphato-platino-chloride,	$Co_2(NH_3)_{12}(SO_4)_2Cl_2+PtCl_4$
Cerous double sulphate (Wing),	$Co_2(NH_3)_{12}(SO_4)_3+3SO_4Ce+OH_2$
Ceric double sulphate (Wing),	$Co_2(NH_3)_{12}(SO_4)_3+Ce_2(SO_4)_3+OH_2$

Hyperiodides, Hyperbromides, &c. — When bromine is added to solutions of the salts of roseocobalt, purpureocobalt, and luteocobalt, yellow or orange crystalline precipitates are formed which contain bromine in excess of the quantity of the chlorous element necessary to form a normal salt. These compounds give off bromine readily on drying, and cannot be obtained pure for analysis. Iodine behaves in a similar manner with some of the cobaltamines, but not with all. I have already described the hyperiodides of the xanthocobalt and croceocobalt series, and shall content myself with having established the existence of this class of compounds which bear a certain resemblance to the hyperiodides of the higher alkaloids.

FORMATION AND PREPARATION OF THE COBALTAMINES.

In our joint memoir Genth and I confined our attention almost exclusively to the determination of the constitution of the cobaltamine salts and to their description, reserving a detailed study of the mode of formation of these compounds for the second part of our work. Circumstances prevented for many years a resumption of the subject. In the mean time the excellent memoir of Dr. Friedrich Rose * has appeared, and in this the formation of the cobaltamines by the oxidation of ammoniacal solutions of cobaltic salts has been carefully studied. The memoir contains also the fullest history of the whole subject which has yet been given. Rose's results may be epitomized as follows: An ammoniacal solution of cobaltic chloride absorbs oxygen, forming a brown solution which, after some days, becomes red by *loss* of oxygen. The red solution can again absorb oxygen and become brown. When strong chlorhydric acid is added to the brown solution, carbonic dioxide and chlorine are evolved, while a reddish-yellow precipitate is formed. This precipitate is a mixture of the chlorides of purpureo-, roseo-, and luteocobalt, of a black salt for which no rational formula

* Untersuchungen über ammoniakalische Kobalt-Verbindungen. Von Dr. Friedrich Rose. Heidelberg, 1871.

has yet been given, and of the two green chlorides. The mother liquor contains cobaltic chloride, the two green chlorides, $Co_2(NH_3)_6Cl_6+2OH_2$, and $Co_2(NH_3)_8Cl_6+2OH_2$, and traces of all the other salts.

Rose determined quantitatively the proportions in which the different salts were formed when different relative quantities of ammonia and cobaltic chloride were employed. His results do not sustain in his opinion the view taken by Genth and myself, that in the oxidation chloride of luteocobalt and an oxychloride which we should now write, $Co_2(NH_3)_{10}.O.Cl_4$, are formed. This view, since the publication of the first part of this memoir, appeared to be strongly supported by experiments of Blomstrand, which showed that iodo-sulphates of roseocobalt and luteocobalt are formed when a solution of cobaltic sulphate in strong ammonia-water is heated with iodine. Blomstrand represents the reaction in this case, as regards the formation of the iodo-sulphate of luteocobalt, by the equation,—

$$\left.\begin{array}{l} Co\left\{\begin{array}{l} NH_3-NH_3-NH_3 \\ NH_3-NH_3-NH_3 \end{array}\right\rangle SO_4 \\ Co\left\{\begin{array}{l} NH_3-NH_3-NH_3 \\ NH_3-NH_3-NH_3 \end{array}\right\rangle SO_4 \end{array}\right\} + 2I = Co_2(NH_3)_{12}(SO_4)_2I_2.$$

The formation of the corresponding iodo-sulphate of roseocobalt may be explained with equal facility. It was natural to expect the similar reaction expressed by the equation, —

$$2\ Co(NH_3)_6Cl_2+O = Co_2(NH_3)_{10}.O.Cl_4+2NH_3\,;$$

but Rose's results show that the *rôle* of the oxygen is, in most cases at least, different from that of the iodine, at least when free oxygen is the oxidizing agent. Rose failed to determine the nature of the brown compound which is formed during the oxidation of an ammoniacal solution of cobaltic chloride, and which is, in his opinion, the source of all the other chlorides. It is consequently impossible to express the derivation of these chlorides from their primitive by means of equations. But with cobaltic nitrate and ammonia the case is different. Fremy long since showed that in this case the nitrate of "oxycobaltiaque," to which he gives the formula, $Co_2(NH_3)_5.O_2.(NO_3)_2+OH_2$, is formed. By passing a rapid current of air through a solution containing cobaltic nitrate, ammonia, and ammonic nitrate, I obtained an olive-brown solution, which after twenty-four hours deposited dark olive-green prisms in abundance. These were dried by pressure between folds of paper, and then for twelve hours over sulphuric acid. Of this salt, —

0·5479 gr. gave 0·0980 gr. SO_4Co = 17·87 % cobalt.
0·8183 gr. gave 0·1459 gr. SO_4Co = 17·83 % cobalt.
0·4640 gr. gave 0·2170 gr. water = 5·19 % hydrogen.
1·0060 gr. gave 0·4605 gr. water = 5·09 % hydrogen.
0.4091 gr. gave 118·5 c.c. nitrogen = 28·97 % nitrogen.
0·3635 gr. gave 109·4 c.c. nitrogen = 29·93 % nitrogen.

These analyses correspond tolerably well with the empirical formula, —

$$Co(NH_3)_5O_2(NO_3)_2+OH_2,$$

which requires, —

		Calculated.	Mean.	Found.		Fremy's formula.
Cobalt,	2	18·55	17·85	17·83	17·87	19·54
Hydrogen,	34	5·34	5·14	5·19	5·09	5·63
Nitrogen,	14	30·85	29·45	28·97	29·93	32·45
Oxygen,	18	45·28	47·51			43·38

In judging the analyses it must be remembered that the salt cannot be recrystallized, as it is instantly decomposed by water. By standing for a long time over sulphuric acid, the salt loses water and some ammonia. In a salt so dried, —

0·5088 gr. gave 0·2690 gr. SO_4Co = 20·12 % cobalt.
0·3290 gr. gave 0·0859 gr. NH_3 = 26·11 % ammonia (by boiling with KHO solution and titrition).
0·4308 gr. gave 0·1124 gr. NH_3 = 26·09 % ammonia (by boiling with KHO solution and titrition).

The undecomposed anhydrous salt would contain 19·66 % cobalt, and would give off by boiling with potash 28·33 % ammonia. I consider the true formula of this salt * to be twice as high as that given above, so that it becomes, —

$$Co_2(NH_3)_{10}.O_4.(NO_3)_4+2OH_2.$$

Fremy found very nearly the same percentages of nitrogen and hydrogen, but a much higher percentage of cobalt, 20·77 %. He also found that the salt is readily decomposed by water with evolution of oxygen. In a single analysis to determine the quantity of oxygen evolved, I obtained the following results: —

* In a letter to the German Chemical Society, I have represented the nitrate of oxycobaltiaque as containing *four* atoms of ammonia to one of cobalt; but a careful revision of my analyses leads to the formula given above. Deutsche Chem. Gesell. Berichte, iv. 790.

1·4510 gr. gave 59·5 c.c. oxygen at 22° C. and 758 mm = 5·25% oxygen.

This would correspond to one atom of oxygen for the formula given above. Fremy also determined the amount of oxygen given off by the action of dilute sulphuric acid, and obtained as a mean of two analyses 5·20%. So far as can be judged from the analyses above, the formula which I have given deserves the preference. On the other hand, Fremy's formula, which I double for the sake of comparison,

$$Co_2(NH_3)_{10}O_2(NO_3)_4+2OH_2,$$

is perhaps somewhat simpler, and explains all the known reactions at least equally well. The corresponding structural formulas may be written, —

$$Co_2\left\{\begin{array}{l} NH_3—NH_3—NO_3 \\ NH_3—NH_3—NH_3—NO_3 \\ O_4 \\ NH_3—NH_3—NH_3—NO_3 \\ NH_3—NH_3—NO_3 \end{array}\right. \qquad Co_2\left\{\begin{array}{l} NH_3—NH_3—NO_3 \\ NH_3—NH_3—NH_3—NO_3 \\ O_2 \\ NH_3—NH_3—NH_3—NO_3 \\ NH_3—NH_3—NO_3 \end{array}\right.$$

I adopt provisionally the formula which agrees best with the analyses, fully recognizing the possibility that the other may prove correct. In this connection I may mention that when iodine is added to a solution containing cobaltic nitrate, ammonic nitrate, and ammonia, an olive-green crystalline precipitate is thrown down which contains iodine, and which may prove to be either the iodide corresponding to the nitrate above discussed, or an iodo-nitrate corresponding to the oxy-nitrate. The formation of this nitrate may be expressed by the equation, —

$$4Co(NO_3)_2+24NH_3+2OH_2+8O = 2.\{Co_2(NH_3)_{10}.O_4.(NO_3)_4\} \\ +2O(NH_4)_2.$$

It is remarkable that the action of iodine upon an ammoniacal solution of cobaltic nitrate is not analogous to its action upon an ammoniacal solution of the sulphate. When the nitrate is heated with chlorhydric acid, a small quantity of chloride of purpureocobalt is, as I find, always formed. We may have the reaction expressed by the equation: —

$$Co_2(NH_3)_{10}O_4(NO_3)_4+12HCl = Co_2(NH_3)_{10}Cl_6+4NO_3H+ \\ 4OH_2+6Cl\,;$$

but the greater part of the nitrate is decomposed. The formation of the chloride of purpureocobalt under the circumstances is, I think, a strong argument in favor of doubling the formula given by Fremy, or at least of regarding the cobalt as hexatomic in this salt.

The above results appear to me to render it probable that the brown solution formed by the oxidation of an ammoniacal solution of cobaltic chloride contains chiefly

$$Co_2(NH_3)_{10}.O_4.Cl_4.$$

According to Rose, the brown solution gives off oxygen by long contact with the air, forming the well-known red liquid which yields, by boiling with sal ammoniac or chlorhydric acid, chloride of purpureo-cobalt. If we suppose that six atoms of oxygen are given off from two molecules of the oxychloride, the salt, —

$$Co_2(NH_3)_{10}OCl_4,$$

will remain in solution, and it is easy to see that this, by boiling with chlorhydric acid or ammonic chloride, will yield chloride of purpureo cobalt, since we have —

$$Co_2(NH_3)_{10}OCl_4+2HCl=Co_2(NH_3)_{10}Cl_6+OH_2.$$

This is precisely the view taken by Genth and myself as regards the nature of the red solution, though we did not trace its origin to the brown oxychloride. Genth and I stated in our paper that the presence of ammonic chloride was *not necessary* for the *formation* of chloride of roseocobalt by the oxidation of an ammoniacal solution of cobaltic chloride. We did not state, as Rose * appears to have understood us, that it is a matter of indifference whether ammonic chloride is present or not. Rose has shown that in the presence of this salt a much larger relative amount of chloride of purpureocobalt is formed. Thus, as a mean of eight experiments, he obtained from one hundred grams cobaltic chloride, oxidized in presence of sal ammoniac, 134·6 grams chloride of purpureocobalt, and 12·12 grams chloride of luteocobalt. When no sal ammoniac was present, he obtained, as a mean of eight experiments, 90·66% chloride of purpureocobalt, and 16·82 grams chloride of luteocobalt. Rose's results in no way disprove the existence in the oxidized solution, after giving off oxygen to the air, of the oxychloride $Co_2(NH_3)_{10}.O.Cl_4$; and this view, which is perfectly consistent with the facts, still gives the simplest explanation of them.

Genth and I always obtained the largest relative quantity of luteocobalt when the solution exposed to the air contained cobaltic chloride

* Loc. cit. p. 76.

and sulphate, ammonia and coarsely powdered ammonic chloride in large excess. I have obtained the same results in frequent repetitions of the process. According to Rose, this result is due not to the formation of a greater amount of luteocobalt salts in consequence of the presence of sal ammoniac, but to the fact that the precipitation of the sulphato-chloride, $Co_2(NH_3)_{12}(SO_4)_2Cl_2$, as fast as it is formed, prevents its further decomposition. Rose's own experiments, cited above, show that the larger quantity of chloride of luteocobalt was formed, when no sal ammoniac was present, when only cobaltic chloride was employed. He suggests that the quantity of luteocobalt formed depends upon the longer action of a concentrated solution of ammonia upon the oxidized solution. If this be the case, the luteocobalt must be formed by the direct oxidation of the solution, and not by the decomposition of the brown salt, whatever that may prove to be. Yet Rose assumes that all the other cobaltamines are formed by the decomposition of this brown salt.

The results of Fremy, in connection with those of Rose, appear to show that in the oxidation of an ammoniacal solution of cobaltic chloride at least two brown salts are formed. These are the chloride of oxy-cobaltia, $Co_2(NH_3)_{10}O_4Cl_4$, and the chloride of fuscocobalt (octamin oxy-chloride), $Co_2(NH_3)_8OCl_4$, the last named being in relatively small quantity. By the action of chlorhydric acid upon each of these salts the chlorides of luteocobalt and purpureocobalt are formed. This appears in the case of the octamin salt from the experiments of Fremy,* Schiff,† and Braun ‡; in the case of the salt of oxy-cobaltia (tetroxy-decamin), from those of F. Rose. In Rose's experiments relatively small quantities of the hexamin and octamin chlorides, $Co_2(NH_3)_6Cl_6$, and $Co_2(NH_3)_8Cl_6$, were always found in the mother liquor after the precipitation of the chlorides of purpureo- and luteocobalt by chlorhydric acid. It seems at least probable that the octamin chloride is formed from the brown oxy-chloride or fuscocobalt salt of Fremy, since we may with great probability expect the reaction expressed by the equation, —

$$Co_2(NH_3)_8OCl_4+2HCl = Co_2)NH_3)_8Cl_6+OH_2.$$

Rose also obtained in his experiments a nearly black crystalline salt, the analyses of which, however, did not lead to any rational formula. He

* Ann. de Chimie et de Physique [3] T. xxxv. 286.

† Ann. der Chemie und Pharmacie, cxxi. 124, cxxiii. 1.

‡ Ann. der Chemie und Pharmacie, cxl. ii., p. 60.

compares his results with the two formulas (old style), $Co_9Cl_{11}ON_{16}H_{45}$, and $Co_9Cl_{11}O_2N_{16}H_{46}$. I find that his analyses agree fairly well with the formula, —

$$Co_2(NH_3)_6.O.Cl_4 + NH_4Cl.$$

Thus we have, —

		Calculated.	Found (mean).
Cobalt,	2	27·34	28·16
Chlorine,	5	40·55	41·64
Nitrogen,	7	22·71	23·13
Hydrogen,	22	5·09	5·33

If we suppose that the black salt consists at least *essentially* of $Co_2(NH_3)_6.O.Cl_4$ the formation of Rose's dark green chloride of dichrocobalt is readily explained by the equation. —

$$Co_2(NH_3)_6.O.Cl_4 + 2HCl = Co_2(NH_3)_6Cl_6 + OH_2,$$

The existence of such a double chloride as $Co_2(NH_3)_6.O.Cl_4 + NH_4Cl$ is in itself not very probable. nor is it easy to see how such a salt could be dissolved in concentrated sulphuric acid, and precipitated by chlorhydric acid without change. Farther investigations are required to determine the constitution of the salt definitively.

Terreil * appears to have first shown that salts of the cobaltamines are formed when powerful oxidizing agents are added to ammoniacal solutions of cobaltic salts. Terreil employed hypermanganates and hypochlorites; Braun,† the hyperoxides of lead and manganese; Mills, ‡ iodine, bromine, and potassic dichromate; Blomstrand, § iodine and cobaltic sulphate. On repeating these processes, I find that that of Mills with potassic dichromate is by far the best for preparing nitrates of roseocobalt and purpureocobalt. Blomstrand's method is inconvenient upon the large scale in consequence of the insolubility of the sulphato-iodide of luteocobalt, but answers well on the small scale, and gives a fine lecture-table experiment. A good method of preparing the salts of luteocobalt in quantity is still wanting, as the chloride and nitrate form valuable reagents in various analytical operations.

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* Zeitschrift für Anal Chemie, v. p. 114.
† Comptes Rendus, lxii. p. 139.
‡ Phil. Mag. (4) xxxv. p. 245.
§ Chemie der Jetztzeit, p. 295.

THEORETICAL VIEWS.

Since the appearance of the first part of this paper many chemists have given expression to theoretical views of the constitution of the ammonia-cobalt salts. Of these I think it will be necessary to notice only those in which the atomicity of cobalt is taken into account, the older theories having passed away with the chemistry of which they formed a part. So far as I can determine, Frankland* first endeavored to reduce the formulas of the cobaltamines to atomistic expressions. In the first edition of his lecture notes he gives for the chlorides of purpureocobalt and luteocobalt respectively the formulas, —

$$\mathrm{Co_2}\left\{\begin{array}{l}\mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_3Cl}\\ \mathrm{NH_3Cl}\\ \mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_2(NH_4)Cl}\end{array}\right. \qquad \mathrm{Co_2}\left\{\begin{array}{l}\mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_2(NH_4)Cl}\\ \mathrm{NH_2(NH_4)Cl}\end{array}\right.$$

It is easy to see that the other series of salts may be formulated in a similar manner. Frankland's view was an important step in advance. It may fairly be objected to it, however, that it involves the replacement of hydrogen in ammonium by ammonium and by chlorine, a view which was not new, and which is certainly defensible, but which has never been generally received by chemists. If we replace in ammonium, NH_4, one atom of hydrogen by one atom of chlorine, and another atom of hydrogen by an atom of ammonium, it is difficult to see how the new ammonium, $NH_2(NH_4)Cl$, can possess a sufficiently well-marked *chlorous* power to unite with the highly *zincous* cobalt so as to form an extremely stable compound.

In a paper on the theory of atomicities,† I have given another view of the constitution of the cobaltamines and of the analogous platinamines. If nitrogen be regarded as pentatomic, ammonia will be diatomic, and any number of atoms of ammonia may be regarded as constituting a single diatomic whole. Taking the atomicity of cobalt ($Co = 59$) as 6, two atoms of the metal may be supposed to unite to form a complex with eight units of affinity, since we have $\equiv\overset{\mathrm{vi}}{\mathrm{Co}}=\overset{\mathrm{vi}}{\mathrm{Co}}\equiv$; of these eight units two will be saturated by the diatomic ammonia,

* Lecture Notes, 1st edition, p. 196. † Am. Journal, Vol. xliv. Nov. 1867.

the other six by chlorine, &c. Upon this view chloride of purpureocobalt becomes $(10NH_3) = Co_2 = Cl_6$, and chloride of luteocobalt $(12NH_3) \overset{''}{=} Co_2 \equiv Cl_6$. In this manner the old theory of couplets or conjugate ammonias may be rationalized and brought into harmony with modern ideas. Two strong objections may be urged against the theory here proposed. The first is that it requires us to consider an atom of cobalt as hexatomic, while it exhibits in no other compound an atomicity higher than four. The other objection has, I think, much greater weight. To explain upon this view the cases of isomerism, to which I have myself directed attention, it becomes necessary to assume that there are at least three allotropic forms of cobalt, — an assumption wholly unsupported by any other and independent evidence. On mature consideration I have therefore rejected this theory. The objection which I have urged against my own view, that it requires us to consider cobalt as hexatomic, with the atomic weight 59, may be avoided by considering the metal as tetratomic, and regarding the two atoms as *united* by 6, 8, 10, or 12 atoms of ammonia, so that the general formula of a normal cobaltamine chloride will be —

$$\begin{array}{ccccccccc} & & Cl & & & & Cl & & \\ & & | & & & & | & & \\ Cl & — & Co & — & (nNH_3) & — & Co & — & Cl \\ & & | & & & & | & & \\ & & Cl & & & & Cl & & \end{array}$$

since n atoms of ammonia will always form a diatomic whole. The other objection, that the theory obliges us to assume the existence of several allotropic forms of cobalt, will, however, still remain.

The view which I now adopt is in substance that of Blomstrand, which affords, as I think, the simplest and most satisfactory explanation of the whole series of ammonia-metallic compounds at present known, and which, while not free from theoretic difficulties, is yet in harmony with all the facts.

According to this view, two atoms of tetratomic cobalt are associated to form a hexatomic molecule, the six units of affinity being, in all the cases at present known, in combination with four or six atoms of ammonia, regarded as a diatomic. Six units of affinity remain, and may be incompletely saturated by other atoms of ammonia or completely by chlorous elements or residues. Thus, on Blomstrand's view, the chlorides of purpureocobalt or roseocobalt and luteocobalt have respectively the formulas, —

$$\overset{\text{vi}}{Co_2}\left\{\begin{array}{l} Cl \\ NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-Cl \\ Cl \end{array}\right. \quad \text{and} \quad \overset{\text{vi}}{Co_2}\left\{\begin{array}{l} NH_3-Cl \\ NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-Cl \\ NH_3-Cl \end{array}\right.$$

As I have adopted this view throughout, further illustrations will be unnecessary. The advantages of the theory are, I think, first that it regards cobalt as tetratomic, and reduces the whole series virtually to the type of Co_2O_3, or Co_2Cl_6, and secondly that it enables us to explain the different cases of isomerism without arbitrary assumptions as to the existence of allotropic forms of cobalt. Thus it is easy to see that there may well be a difference between compounds having respectively the symmetrical structural formulas, —

$$\text{I. } Co_2\left\{\begin{array}{l} NH_3-Cl \\ NH_3-NH_3-Cl \\ NH_3-NH_3-Cl \\ NH_3-NH_3-Cl \\ NH_3-NH_3-Cl \\ NH_3-Cl \end{array}\right. \quad \text{II. } Co_2\left\{\begin{array}{l} Cl \\ NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-Cl \\ Cl \end{array}\right.$$

$$\text{III. } Co_2\left\{\begin{array}{l} Cl \\ NH_3-Cl \\ NH_3-NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-NH_3-Cl \\ NH_3-Cl \\ Cl \end{array}\right.$$

$$\text{IV. } Co_2\left\{\begin{array}{l} Cl \\ Cl \\ NH_3-NH_3-NH_3-NH_3-NH_3-Cl \\ NH_3-NH_3-NH_3-NH_3-NH_3-Cl \\ Cl \\ Cl \end{array}\right.$$

and that supposing that the six units of affinity of Co_2 are qualitatively exactly equal, the complex, $Co_2(NH_3)_{10}Cl_6$, admits of being arranged in a great variety of ways. Now since the salts of roseocobalt and purpureocobalt resemble each other as regards the types to which they belong and as either of these types may be formulated in a great variety of ways, it becomes very difficult to determine which structural formula to adopt for the compounds of either series.

Thus the salts of roseocobalt and of purpureocobalt, usually at least, belong either to the types ReX_6 and PeX_6, to ReX_4Y_2 and PeX_4Y_2, or to $ReX_2Y_2Z_2$. Now the salts of either of these types may be equally well referred to either of the structural formulas given above. To which of them are we to refer salts of roseocobalt, and to which salts of purpureocobalt?

Blomstrand gets over the difficulty in part by the short and easy method of declaring that chloride of roseocobalt is only the hydrate of chloride of purpureocobalt. I think I have shown conclusively that this view is wholly untenable. But, even if we admit its correctness, to which of the four structural formulas shall we assign chloride of purpureocobalt alone, since all four explain its relations to other chlorides, and its products of replacement equally well?

The case is the same with the other cobaltamines, though in these we have no isomerisms to explain, in the present state of our knowledge at least. The dodecamin and octamin series exhibit the two types LcX_6, OcX_6, and LcX_4Y_2, OcX_4Y_2, with perfect distinctness; but in addition we have in the case of the dodecamin series the type, LcX_3Y_3, as, for instance, in the phosphate described by Braun, $Co_2(NH_3)_{12}(P_2O_8)+8OH_2$, and perhaps also in the pyrophosphate $Co_2(NH_3)_{12}P_4O_{13}+6OH_2$, though this salt may be referred to the type, LcX_6, if we consider (P_4O_{13}) as a hexatomic complex. Luteocobalt may therefore be saturated, if I may so speak, by ones as in $LcCl_6$, by twos as in $Lc(SO_4)_2I_2$, and by threes as in $Lc(PO_4)_2$. It would seem as if we in this manner arrive most naturally at the structural formulas for the dodecamin series, —

$$\overset{vi}{Co_2}\left\{\begin{array}{l} a—a—Cl \\ a—a—Cl \\ a—a—Cl \\ a—a—Cl \\ a—a—Cl \\ a—a—Cl \end{array}\right. \qquad \overset{vi}{Co_2}\left\{\begin{array}{l} \begin{array}{l} a—a—O \\ a—a—O \end{array}\!\!> SO_2 \\ a—a—I \\ a—a—I \\ \begin{array}{l} a—a—O \\ a—a—O \end{array}\!\!> SO_2 \end{array}\right.$$

$$\overset{vi}{Co_2}\left\{\begin{array}{l} \left\{\begin{array}{l} a—a—O \\ a—a—O \\ a—a—O \end{array}\right\} PO \\ \left\{\begin{array}{l} a—a—O \\ a—a—O \\ a—a—O \end{array}\right\} PO \end{array}\right.$$

in which the six ammonia groups have equal weights or qualitative values, so that the six units of affinity of Co_2 must also be of the same kind and the same inten ity. But, if we examine the list of salts of roseocobalt which I have given, we find that Krok has described a salt with the formula, —

$$Co_2(NH_3)_{10}(NO_3)_3Cl_3+3HgCl_2\,;$$

and among the salts of purpureocobalt we find the formula, —

$$Co_2(NH_3)_{10}(NO_3)_3Cl_3 + Co_2(NH_3)_{10}(NO_3)_6.$$

Roseocobalt and purpureocobalt may therefore also form compounds in which the six units of affinity are saturated by threes. Now since these salts contain only ten atoms of ammonia; and since these can only be distributed in pairs of different structure, as in formulas I., II., III., and IV., it follows that we cannot fairly draw the inference that in the dodecamin series the atoms of ammonia are arranged in six perfectly equivalent pairs.

Blomstrand gives to chloride of xanthocobalt the structural formula, —

$$\overset{vi}{Co_2}\left\{\begin{array}{l} O—NO \\ a—a—Cl \\ a—a—a—Cl \\ a—a—a—Cl \\ a—a—Cl \\ O—NO \end{array}\right.$$

upon the ground that cobalt unites with O.NO in Fischer's salt $Co_2(NO_2)_{12}K_6$ with peculiar energy. We seem in this way to gain a *ποῦ στῶ* for this series; and, if we admit the force of the argument, we must write the formula of chloride of roseocobalt, —

$$Co_2\left\{\begin{array}{l} Cl \\ a—a—Cl \\ a—a—a—Cl \\ a—a—a—Cl \\ a—a—Cl \\ Cl \end{array}\right.$$

On the other hand it is a question whether the remarkable stability of $Co_2(NO_2)_{12}K_6$ can fairly be attributed to any special affinity of cobalt for NO_2. We have a complex whole, which we find remarkably stable; but is not this stability the resultant — so to speak — of the whole structure, just as the strength of an arch resides in the whole arrangement of its elements, and not in any single one? The other cobalto-nitrites, as, for instance, Sadtler's salts, $Co(NO_2)_2 + NaNO_2$, and $Co(NO_2)_2 + 2NaNO_2$, are not remarkably stable, but rather the reverse. The salts of xanthocobalt are easily decomposed, both by acids and alkalies. For these reasons it does not seem to me that Blomstrand's arrangement of the atoms in these salts deserves any special preference at present.

Blomstrand's views as to the constitution of the metal-ammonias form part of a complete system to the exposition of which he has devoted a large work.* I must refer to this work for the arguments which he adduces in support of his theory, since no abstract can do them full justice. But I may be permitted here to notice one or two points of fundamental importance.

Blomstrand begins with a discussion of the platinamines, our knowledge of which has been so greatly increased by the splendid researches of Clévé. He assigns arbitrarily to the chloride of Reiset's first base the formula, —

$$\overset{\text{II}}{\text{Pt}}\begin{cases}\text{a—a—Cl}\\ \text{a—a—Cl}\end{cases}$$

When chlorine is passed into a solution of this salt, the chloride of Gros's base is formed, and Blomstrand attributes to it again arbitrarily the formula, —

$$\overset{\text{V}}{\text{Pt}}\begin{cases}\text{Cl}\\ \text{a—a—Cl}\\ \text{a—a—Cl}\\ \text{Cl}\end{cases}$$

He employs the same mode of formulation in the case of the chlorides of Reiset's second and Gerhardt's first base; namely, —

$$\overset{\text{II}}{\text{Pt}}\begin{cases}\text{a—Cl}\\ \text{a—Cl}\end{cases} \qquad \text{and} \qquad \text{Pt}\begin{cases}\text{Cl}\\ \text{a—Cl}\\ \text{a—Cl}\\ \text{Cl}\end{cases}$$

I admit that it seems most natural to attribute to the formula of the chloride of Reiset's first base the symmetrical formula, $\text{Pt}\begin{cases}\text{a—a—Cl},\\ \text{a—a—Cl}\end{cases}$ instead of the unsymmetrical formula, $\text{Pt}\begin{cases}\text{a—a—a—Cl}\\ \text{a—Cl}\end{cases}$; but even if we start from $\text{Pt}\begin{cases}\text{a—a—Cl},\\ \text{a—a—Cl}\end{cases}$ as from a fixed point, how is it possible to say with certainty that under the action of chlorine there may not be a re-arrangement of the atoms of ammonia, so that we have for the chloride of Gros's base the structural formula, —

$$\overset{\text{IV}}{\text{Pt}}\begin{cases}\text{a—Cl}\\ \text{a—Cl}\\ \text{a—Cl}\\ \text{a—Cl}\end{cases}$$

which has a higher degree of symmetry, or is, in other words, more homogeneous than Blomstrand's formula, —

* Chemie der Jetztzeit. Heidelberg, 1869.

$$\overset{iv}{Pt}\begin{cases} Cl \\ a—a—Cl \\ a—a—Cl \\ Cl \end{cases}$$

and which explains the formation of the different salts at least equally well? In this case, as in the cases of the platinamines generally, we have precisely the same difficulties which meet us in applying the theory to the cobaltamines. We reason throughout from perfectly arbitrary fundamental assumptions. Our only fixed points are the atomicities of platinum and cobalt. All else is purely speculative. In the present state of our knowledge we are not able to say whether a chain of atoms of ammonia, like $—NH_3—NH_3—NH_3—$, has more or less powerful affinities than the single divalent atom, $—NH_3—$, or even whether, $—NH_3—Cl$, is more or less *chlorous* than a single chlorine atom. But these points are of fundamental importance in the application of the theory of atomicities to the metal-ammonias. Certainly the great majority of chemists maintain that there is a perfect equivalence of value in the units of affinity of the different elements, while admitting that in complex molecules, as in the benzol ring, *positional* differences may result from peculiarities of structure.

Blomstrand, on the other hand, maintains not merely that the four units of affinity in tetratomic platinum are qualitatively different two by two, but even that it is possible to determine in the case of which pair the most powerful affinities are exerted. Thus he asserts that if we write for platinum, —

$$\overset{iv}{Pt}\begin{cases} c \\ a \\ b \\ d \end{cases}$$

the two "points of attack," *a* and *b*, act differently from *c* and *d*. With logical consistency he extends this view to nitrogen, cobalt, and carbon, standing, so far at least as carbon is concerned, wholly alone, I believe, in opinion, the question of a difference between the four units of affinity in carbon having been long since discussed, and by common consent decided in favor of their perfect equivalence.

While then I write the structural formulas of the chlorides of purpureocobalt and of roseocobalt respectively: —

$$Co_2\begin{cases} a—Cl \\ a—a—Cl \\ a—a—Cl \\ a—a—Cl \\ a—a—Cl \\ a—Cl \end{cases} \qquad Co_2\begin{cases} Cl \\ a—a—Cl \\ a—a—a—Cl \\ a—a—a—Cl \\ a—a—Cl \\ Cl \end{cases} + 2OH_2$$

Chloride of purpureocobalt. Chloride of roseocobalt.

I expressly admit that the mode of formulation is in each case perfectly arbitrary.

The more carefully I have studied the subject, the more full has become my conviction that in the present state of our knowledge we cannot assign absolutely definite structural formulas to the platinamines and cobaltamines upon Blomstrand's theory. While, therefore, I adopt this theory, I do so because I think that with all its defects it is by far the simplest and most comprehensive yet proposed. But I regard the particular structural formulas which I have employed simply as convenient illustrations, — provisional formulas which the progress of science may at any time modify.

In my forthcoming work on the metals of the platinum group, I shall describe a few other salts of the cobaltamines, which are chiefly of interest in connection with those metals; and I hope also to show that some of the cobaltamines are valuable analytical reagents. In closing my labors, I wish again to direct the attention of chemists to the advantages offered by this class of salts in investigations. We have in croceocobalt, xanthocobalt, and luteocobalt, respectively, diatomic, tetratomic, and hexatomic bases, possessing the important property of forming extremely well-defined and highly crystalline salts. I suggest the employment of these bases as means of determining the atomicities of relatively chlorous molecules, as, for instance, of the polymeric modifications of phosphoric acid, and in other cases in which our knowledge is still imperfect. The cobaltamines themselves still form an extensive and most attractive field of labor. With all that has been done, there is no part of this field which will not yield an abundant harvest of interesting and theoretically valuable results.

My grateful acknowledgments are due to my assistant, Mr. W. E. Cutter, who has aided me in the analytical part of my work with most patient and conscientious labor.

Cambridge, June 8, 1875.

II.

ON THE SOLAR MOTION IN SPACE AND THE STELLAR DISTANCES.

(*Second Paper.*)

BY TRUMAN HENRY SAFFORD.

IN a previous paper, I have examined some of the older known proper motions, and shown that they are favorable to the assumption that the distances of the stars are, upon the average, inversely proportional to their proper motions. We cannot expect that this will be equally true in all regions of the heavens. It will be necessary, as materials accumulate for the study of this problem, and other collateral ones, to pursue the investigation more into detail; including more stars, and examining their motions as related to their position on the celestial sphere, and especially to the apex of solar motion. The present paper contains such a detailed investigation for an important class of stars. Those here investigated are the two hundred and fifty whose proper motions Argelander has discussed in the seventh volume of the Bonn Observations, Part I.; I am myself preparing for another purpose a similar discussion of about one hundred and fifty more, and other material of the same kind is soon to be published in great quantities. So that the present paper is also of use in fixing the form of the discussion.

From the formulæ, —

$$\cos\chi = \sin D \sin\delta + \cos D \cos\delta \cos(\alpha - A);$$
$$\sin\chi \cos\psi' = -\sin D \cos\delta + \cos D \sin\delta \cos(\alpha - A);$$
$$\sin\chi \sin\psi' = \cos D \sin(\alpha - A);$$
$$\Delta\alpha \cos\delta = \Delta\varsigma \sin\psi;$$
$$\Delta\delta = \Delta\varsigma \cos\psi;$$

where

α, δ, the star's right ascension and declination,

$\Delta\alpha$, $\Delta\delta$, its annual proper motion in these co-ordinates,

A, D, the right ascension and declination of the apex of solar motion assumed known,

χ, the star's angular distance from the apex,

ψ', the angle of position at the star of the arc of a great circle directed away from the apex,

ψ, the angle of position of the star's apparent motion,

are calculated the values of the following table.

I have assumed as before, —

$$A = 259°50'8 \quad D = 32°29'1.$$

I noticed, too late for use in this series, that if we put

$$\sin m \sin M = \sin D;$$
$$\sin m \cos M = \cos D \cos (\alpha - A),$$

we can more readily use the formulæ, which then become

$$\cos \chi = \sin m \cos (\delta - M);$$
$$\sin \chi \cos \psi' = \sin m \sin (\delta - M);$$
$$\sin \chi \sin \psi' = \cos D \sin (\alpha - A) = \cos m,$$

or

$$\tan \psi' = \frac{\cot m}{\sin (\delta - M)};$$

$$\sin \chi = \frac{\cos m}{\sin \psi'},$$

by tabulating m, M, and log. cot m, log. cos m, or like functions, with the argument α.

In the following table, the stars are indicated by Argelander's numbers, and arranged in the order of their annual proper motions, the largest (Groombridge, 1830) first.

The columns contain in their order the star's number, Argelander's values of Δs and ψ (Bonner Beobachtungen, Bd. VII. S. 109–113), and those of ψ', $\psi' - \psi$, and log. sin χ, which I have computed by the preceding formulæ.

In order to get an approximate idea of what these stars indicate, with reference to the relation between distance and annual motion, I have taken the means of the cosines of $\psi' - \psi$ in groups of twenty-five stars each; the means of the natural sines of χ are not systematically variable to any great extent throughout the table.

Group.	Value of Δs.	Mean ($\cos(\psi' - \psi)$)
I.	7″053 — 1″171	0.586
II.	1. 103 — 0. 707	0.615
III.	0. 697 — 0. 583	0.468
IV.	0. 582 — 0. 489	0.390
V.	0. 485 — 0. 438	0.587
VI.	0. 435 — 0. 350	0.588
VII.	0. 348 — 0. 291	0.403
VIII.	0. 290 — 0. 249	0.582
IX.	0. 247 — 0. 185	0.592
X.	0. 184 — 0. 079	0.747
	General mean	0.556

The mean sine of χ is about equal to the integral

$$\int_{0}^{\frac{1}{2}\pi} \sin^2 \chi \, \delta \chi$$

divided by the integral

$$\int_{0}^{\frac{1}{2}\pi} \sin \chi \, \delta \chi$$

or unity; hence equal to $\frac{1}{4}\pi = 0.7854$.

The value of $\frac{\zeta}{r \Delta s}$ will then, from the present series, be roughly equal to $0.556 \div 0.785 = 0.708$,
with a probable error of about $\pm$ 0.023.

But it will be noticed that in the present group of stars the values of cos. $(\psi' - \psi)$ *increase* as the proper motions become smaller; in the former paper they appeared to *decrease;* making it still more probable that the variations in both series arise from the errors of observation, and the very various regions in which the stars are situated, and not from any general deviation from constancy in the ratio

$$\frac{\zeta}{r \Delta s}.$$

The value of this ratio, from the previous series, was found equal to 0.666 for forty-three groups of the largest proper motions, and to 0.46 for eleven groups of smaller, or in the mean about 0.622; the best of the two values agreeing nearly with the present determination.

This is sufficiently noteworthy, as the stars of the former series were, on the whole, those visible to the naked eye, or of the magnitudes one to six inclusive; of the present ones, very few are brighter than the sixth, and many are of the eighth and ninth; so that so far the phenomena indicate hardly any dependence upon magnitude. In a future paper, I shall discuss a considerable number of other notable proper motions, which I myself have been lately employed in determining for a catalogue of latitude stars; and I intend to gradually accumulate materials for a more minute investigation of the whole subject, separating the stars according to their magnitudes and the region of the heavens in which they are situated.

The delicacy of the investigation is very great, owing to the danger of taking that for stellar motion which is simply the result of the errors of observation. Of course the old observers had indifferent instruments; but as a rule they used them well, if their work had plan and coherency enough to be preserved. Bradley's observations (1755) are still very accurate and indispensable; Piazzi and Groombridge (1800, 1810) are now old enough to determine many proper motions; the early work of Struve, Bessel, and Argelander (1814–1830), makes up in accuracy what it lacks in antiquity.

But too many of the modern observers are careless in their computations, and unsystematic in their plan of work; so that for many important stars there are no very late observations, while for many others a good many indifferent observations can be found and reduced with considerable trouble. The subject is becoming more and more chaotic, and will continue to do so, unless observers bind themselves by more rigid rules not to make observations save with the utmost precision, the most thorough system, and the most intelligent plan, directed towards a definite object. Of this fortunately there is good hope, as is shown in the interest in the great zones planned by Argelander, and now in progress under the auspices of the international "Astronomische Gesellschaft."

The next step in the discussion will be to include the more numerous proper motions soon to be determined. Of those which have already been computed, Argelander's older values, Lundahl's, have already been taken account of in my previous paper. These, with O. Struve's (which are nearly identical with a portion of Argelander's and Lundahl's and Main's), will shortly be redetermined in a more perfect manner, under Struve's and Auwers's direction, by a combination of Bradley's observations re-reduced with the Pulcova and Greenwich modern observations. Galloway's southern proper motions have been re-determined by the Melbourne observations, and those made at the Cape of Good Hope; but a careful study of these will be necessary, as good ancient observations in that region are scarce. The great northern zones will in a few years furnish many more.

Mädler's proper motions are, as I have before stated, rather precarious for some stars; he has criticised the ancient observations too hastily.

We are now justified in grouping any certain proper motions into normal places, taking in each case the total amount of proper motion as the unit; or at least in so classifying stars which are apparently near each other in the heavens, and not excessively far apart in amount of $\Delta\zeta$. We may regard it as settled that the star's distances are inversely proportional *upon the whole* to their proper motions.

TABLE OF INDIVIDUAL STARS.

Argelander's number.	Δ s	ψ	ψ′	ψ′ — ψ	log cos (ψ′ — ψ)	log. sin χ
112	7″053	144°59′	246°43′	101°44′	9.3082 n	9.9604
104	4. 748	186 34	240 6	53 32	9.7741	9.9857
105	4. 403	282 22	242 24	— 39 58	9.8845	9.9767
2	2. 813	82 31	122 11	39 40	9.8864	9.9879
31	2. 359	51 54	136 20	84 26	8.9868	9.9193
140	2. 325	128 6	240 49	112 43	9.5868 n	9.8999
49	2. 236	126 1	160 51	34 50	9.9142	9.9739
240	2. 093	82 35	106 59	24 24	9.9594	9.9448
156	2. 015	151 14	214 52	63 38	9.6475	9.9546
70	1. 968	156 35	211 34	54 59	9.7588	9.9786
81	1. 688	247 30	225 11	— 22 19	9.9662	9.9950
181	1. 606	206 2	193 6	— 12 56	9.9888	9.7380
204	1. 537	221 41	114 8	—107 33	9.4793 n	9.7700
7	1. 436	90 19	114 58	24 39	9.9585	9.9479
177	1. 433	197 47	203 30	5 43	9.9978	9.7100
89	1. 426	249 25	235 0	— 14 25	9.9861	9.9878
78	1. 401	254 21	223 47	— 30 34	9.9350	9.9737
247	1. 383	135 58	122 42	— 13 16	9.9882	9.9991
43	1. 375	153 49	158 32	4 43	9.9985	9.9980
206	1. 333	101 15	143 47	42 32	9.8674	9.9779
161	1. 306	247 24	220 12	— 27 12	9.9491	9.8548
192	1. 269	197 8	6 23	169 15	9.9923 n	9.7700
76	1. 261	302 0	255 10	— 46 50	9.8351	9.8046
187	1. 207	208 54	180 23	— 28 31	9.9438	9.7013
71	1. 171	187 33	213 9	25 36	9.9551	9.9777
157	1. 103	296 16	294 32	— 1 44	9.9998	9.7477
74	1. 013	164 15	235 31	71 16	9.5067	9.8440
37	0. 997	133 37	149 18	15 41	9.9836	9.9954
120	0. 991	174 10	235 54	61 44	9.6754	9.9984
73	0. 969	201 2	216 4	15 2	9.9848	9.9853
133	0. 963	156 43	254 54	98 11	9.1534 n	9.8860
150	0. 944	294 13	221 11	— 73 2	9.4651	9.9376
203	0. 906	127 39	105 18	— 22 21	9.9660	9.7457
94	0. 891	172 21	237 39	65 18	9.6210	9.9841
137	0. 880	285 58	232 44	— 53 14	9.7771	9.9574
211	0. 870	86 50	128 2	41 12	9.8765	9.9021
126	0. 868	160 47	232 20	71 33	9.5004	9.9962
127	0. 864	281 0	233 7	— 47 53	9.8265	9.9870
218	0. 859	186 42	118 7	— 68 35	9.5625	9.9014
185	0. 848	7 49	343 3	— 24 46	9.9581	9.4214
228	0. 843	86 5	120 22	34 17	9.9171	9.9700
8	0. 816	69 27	124 18	54 51	9.7602	9.9872
85	0. 788	178 25	229 27	51 2	9.7986	9.9979
173	0. 741	162 42	212 28	49 46	9.8102	9.7166
52	0. 733	125 14	169 31	44 17	9.8549	9.9853

TABLE OF INDIVIDUAL STARS (*continued*).

Argelander's number.	Δ s	ψ	ψ′	ψ′ — ψ	log. cos (ψ′ — ψ)	log. sin χ
20	0″730	110°37′	131°53′	21°16′	9.9694	9.9786
129	0. 719	173 34	236 55	63 21	9.6518	9.9584
61	0. 719	135 49	183 44	47 55	9.8262	9.9725
198	0. 707	177 43	151 56	— 25 47	9.9545	9.9658
39	0. 707	27 13	104 27	77 14	9.3444	9.6806
221	0. 697	240 43	133 37	—107 6	9.4685 n	9.9947
114	0. 690	214 10	250 26	36 16	9.9065	9.9466
53	0. 688	144 7	171 45	27 38	9.9474	9.9913
65	0. 681	121 15	199 10	77 55	9.3208	9.9972
46	0. 678	147 46	158 31	10 45	9.9923	9.9748
77	0. 669	207 12	219 37	12 25	9.9898	9.9995
111	0. 666	247 44	250 3	2 19	9.9996	9.9516
215	0. 667	38 40	63 22	24 42	9.9583	9.8788
63	0. 666	185 16	194 7	8 51	9.9948	9.9654
21	0. 652	113 18	133 52	20 34	9.9714	9.9844
219	0. 643	209 43	68 30	—141 13	9.8918 n	9.8827
110	0. 640	273 10	247 51	— 25 19	9.9562	9.9588
9	0. 639	185 45	124 17	— 61 28	9.6792	9.9832
196	0 636	346 27	59 59	73 32	9.4525	9.6490
33	0. 626	222 40	143 50	— 78 50	9.2870	9.9838
97	0. 624	158 52	239 14	80 22	9.2236	9.9815
200	0. 623	231 14	54 17	—176 57	9.9994 n	9.7447
12	0. 623	82 9	127 4	44 55	9.8501	9.9805
246	0. 619	40 11	112 10	71 59	9.4904	9.9583
212	0. 618	39 21	59 6	19 45	9.9736	9 8765
225	0. 604	235 45	97 28	—138 17	9.8730 n	9.9042
145	0. 600	244 46	224 40	— 20 6	9.9727	9.9873
207	0. 597	63 15	59 59	— 3 16	9.9993	9.8316
210	0. 591	46 56	139 1	92 5	8.5605 n	9.9804
238	0. 583	76 44	99 12	22 28	9.9657	9.9300
191	0. 582	152 15	5 59	—146 16	9.9199 n	9.6935
64	0. 582	141 39	252 16	110 37	9.5467 n	9.5224
106	0. 577	110 43	239 46	129 3	9.7994 n	9.9885
217	0. 572	175 1	124 48	— 50 13	9.8061	9.9233
60	0. 571	179 49	182 9	2 20	9.9996	9.9989
24	0. 561	124 1	138 35	14 34	9.9858	9.9826
243	0. 558	101 32	122 18	20 46	9.9708	9.9989
224	0. 556	222 52	112 1	—110 51	9.5514 n	9.9267
199	0. 547	295 0	98 2	163 2	9.9807 n	9.6564
80	0. 546	248 57	240 6	— 8 51	9.9948	9.9044
241	0. 542	92 51	122 32	29 41	9.9389	9.9996
59	0. 542	279 8	181 34	— 97 34	9.1195 n	9.9975
117	0. 538	174 41	237 44	63 3	9.6563	9.9932
190	0. 536	270 0	2 13	92 13	8.5875 n	9.7582
176	0. 516	318 14	218 14	—100 0	9.2397 n	9.4943

TABLE OF INDIVIDUAL STARS (*continued*).

Argelander's number.	Δ s	ψ	ψ′	ψ′ — ψ	log. cos (ψ′ — ψ)	log. sin χ
14	0″516	138°48′	125°59′	— 12°49′	9.9890	9.9555
118	0. 514	277 22	237 4	— 40 18	9.8823	9.9965
91	0. 512	270 0	306 8	36 8	9.9072	9.9996
134	0. 510	266 11	261 48	— 4 23	9.9987	9.8738
26	0. 509	43 50	131 29	87 39	8.6128	9 9174
69	0. 497	274 2	210 28	— 63 34	9.6485	9.9590
175	0. 493	278 9	337 14	59 5	9.7108	9.7722
162	0. 493	257 35	249 38	— 7 57	9.9958	9 6740
88	0. 491	227 19	239 20	12 1	9.9904	9.9629
86	0. 489	204 12	234 25	30 13	9.9366	9 9833
220	0. 485	110 0	127 8	17 8	9.9803	9.9519
159	0. 481	205 23	217 41	12 18	9.9899	9.9157
234	0. 480	219 5	115 19	—103 46	9.3765 n	9.9631
113	0. 479	167 32	236 36	69 4	9.5530	9.9998
101	0. 476	256 7	237 48	— 18 19	9.9774	9.9946
201	0. 473	173 24	98 16	— 75 8	9.4092	9.6907
163	0. 472	153 36	316 22	162 46	9.9801 n	9.8066
125	0. 471	221 24	233 7	11 43	9.9909	9.9930
68	0. 469	245 59	204 54	— 41 5	9.8772	9.9498
195	0. 468	165 12	142 16	— 22 59	9.9642	9.6846
179	0. 466	331 38	346 56	15 18	9.9843	9 7717
45	0. 466	123 14	159 40	36 26	9.9056	8.9657
23	0· 466	216 37	129 8	— 87 29	8 6426	9.9196
58	0. 464	191 54	180 12	— 11 42	9.9909	9.9994
124	0. 462	248 47	262 40	13 53	9.9871	9.9039
226	0. 461	165 26	125 42	— 39 44	9.8859	9.9911
144	0. 460	262 30	250 12	— 12 18	9.9899	9.8619
141	0. 457	254 31	235 34	— 18 57	9.9758	9.9227
186	0. 455	300 30	351 41	51 11	9.7972	9.6639
99	0. 447	254 49	250 3	— 4 46	9.9985	9.9476
30	0. 446	105 36	144 14	38 38	9.8927	0.0000
35	0. 445	108 11	147 3	38 52	9.8913	9.9882
222	0. 441	142 48	131 55	— 10 53	9.9921	9.9925
15	0. 439	283 11	129 58	—153 13	9.9507 n	9.9739
148	0. 438	147 26	238 19	90 53	8.1880 n	9.8383
166	0. 435	294 1	312 38	18 37	9.9767	9.7518
108	0. 435	285 34	256 58	— 28 36	9.9435	9 9367
135	0. 434	150 0	233 33	83 33	9.0505	9.9566
233	0. 430	30 12	95 12	65 0	9.6259	9.9200
136	0. 417	297 55	258 29	— 39 26	9.8878	9.8707
19	0. 414	116 33	117 21	0 48	0.0000	9.9044
128	0. 400	309 53	279 24	— 30 29	9.9354	9.8942
98	0. 400	263 50	240 12	— 23 38	9.9620	9.9809
72	0. 399	228 24	214 3	— 14 21	9.9862	9.9972
151	0. 398	273 53	224 43	— 49 10	9.8155	9.9085

TABLE OF INDIVIDUAL STARS (*continued*).

Argelander's number.	Δ s	ψ	ψ′	ψ′ — ψ	log. cos (ψ′ — ψ)	log. sin χ
216	0″392	69°55′	92°28′	22°33′	9 9655	9.8372
75	0. 389	195 11	216 16	21 5	9.9699	9.9998
180	0. 388	180 0	300 23	120 23	9.7040 n	9.1846
245	0. 387	92 40	115 47	23 7	9.9636	9 9711
82	0. 381	205 44	222 0	16 16	9.9823	9.9794
122	0. 375	224 26	265 11	40 45	9.8794	9 9149
131	0. 372	219 42	231 29	11 47	9.9908	9.9826
142	0. 371	164 52	279 1	114 9	9.6119 n	9.8444
235	0. 369	213 34	123 22	— 90 12	7.5429 n	9 9980
18	0. 366	145 0	126 58	— 18 2	9.9781	9.9522
47	0. 363	297 22	160 3	—137 19	9 8664 n	9.9990
229	0. 361	71 25	109 23	37 58	9 8967	9.9354
184	0. 360	264 6	348 59	84 53	8.9503	9.7008
4	0. 356	92 35	118 48	26 13	9.9529	9.9680
149	0. 350	272 18	221 40	— 50 38	9.8023	9.9370
152	0. 348	141 59	292 51	150 52	9.9413 n	9.7904
165	0. 342	164 24	213 5	48 41	9.8197	9.8851
182	0. 340	151 38	327 56	176 18	9.9991 n	9.3245
183	0. 335	187 30	187 44	0 14	0.0000	9.8587
119	0. 332	256 57	249 59	— 6 58	9.9968	9.9455
167	0. 328	297 5	310 29	13 24	9.9880	9.7233
93	0. 323	179 29	234 39	55 10	9.7568	9.9969
121	0. 320	274 42	265 23	— 9 19	9.9942	9.9171
5	0. 320	95 21	113 9	17 48	9.9787	9.9464
90	0. 319	170 12	235 15	65 3	9.6251	9.9911
178	0. 318	207 40	322 41	115 1	9.6262 n	9.5065
62	0. 315	138 44	188 12	49 28	9.8128	9.8759
193	0. 314	195 45	170 1	— 25 44	9.9546	9.9348
130	0. 314	162 45	230 14	67 29	9.5831	9.9955
51	0. 314	200 52	105 39	— 95 13	8.9587 n	9.2918
38	0. 314	123 0	147 20	24 20	9.9596	9.9672
237	0. 312	187 41	114 38	— 73 3	9.4647	9.9633
239	0. 311	273 30	122 43	—150 47	9.9409 n	9.9998
174	0. 310	191 37	338 49	147 12	9.9246 n	9.8057
231	0. 310	116 6	124 17	8 11	9.9956	9.9996
208	0. 309	67 48	136 6	68 18	9.5679	9.9438
147	0. 303	230 30	224 47	— 5 43	9 9978	9.9551
172	0. 302	282 44	202 15	— 80 29	9.2184	9.8814
249	0. 298	88 16	105 33	17 17	9.9799	9.9396
248	0. 291	111 58	104 20	— 7 38	9.9961	9.9371
29	0. 290	191 42	136 56	— 54 46	9.7611	9.9444
10	0. 286	169 10	122 41	— 46 29	9.8379	9.9741
109	0. 285	332 18	253 55	— 78 23	9.3040	9.9435
56	0. 283	165 16	179 0	13 44	9.9874	9.9709
84	0. 282	121 9	244 50	123 41	9.7440 n	9.9082

TABLE OF INDIVIDUAL STARS (*continued*).

Argelander's number.	Δ s	ψ	ψ′	ψ′ — ψ	log. cos (ψ′ — ψ)	log. sin χ
197	0″281	200°50′	151°20′	— 49°30′	9 8125	9 9140
55	0. 280	115 22	175 30	60 8	9.6972	9.9375
250	0. 279	84 51	116 12	31 21	9.9315	9.9668
244	0. 279	137 34	122 19	— 15 15	9.9844	9.9992
28	0. 279	96 48	112 4	15 16	9.9844	9.8152
202	0. 277	202 41	137 22	— 65 19	9.6208	9.8560
169	0. 276	281 16	309 56	28 40	9.9432	9.6630
154	0. 274	296 27	268 32	— 27 55	9.9463	9.7252
95	0. 273	67 4	238 43	171 39	9.9954 n	9.9819
168	0. 269	177 10	302 48	125 38	9.7654 n	9.6503
44	0. 268	166 39	101 33	— 65 6	9.6243	9.6649
11	0. 267	134 47	123 22	— 11 25	9.9913	9.9668
160	0. 266	183 58	227 16	43 18	9.8620	9.8225
67	0. 265	207 1	243 1	36 0	9.9080	9.9752
6	0. 262	120 51	116 38	— 4 13	9.9988	9.9581
205	0. 258	51 54	59 26	7 32	9.9962	9.8082
34	0. 258	134 48	146 47	11 59	9.9904	9.9928
155	0. 252	291 38	267 51	— 23 47	9.9615	9.7221
194	0. 249	215 47	163 24	— 52 23	9.7856	9.9061
153	0. 249	180 0	225 1	45 1	9.8494	9.8870
139	0. 247	238 53	260 38	21 45	9.9680	9.8553
100	0. 247	158 30	240 48	82 18	9.1271	9.9806
132	0. 244	80 6	261 50	—178 16	9.9998 n	9.8777
13	0. 243	93 32	125 29	31 57	9.9286	9.9711
36	0. 240	94 5	145 5	51 0	9.7989	9.9521
25	0. 240	180 0	117 27	— 62 33	9.6637	9.8466
27	0 239	178 5	129 3	— 49 2	9.8166	9.8990
170	0 235	297 2	317 51	20 49	9.9707	9.6593
158	0. 235	170 55	288 57	118 2	9.6721 n	9.7295
16	0. 226	113 9	129 32	16 23	9.9820	9.9686
103	0. 222	232 29	248 31	16 2	9.9828	9 9548
171	0. 213	237 22	202 20	— 35 2	9.9132	9.8860
66	0. 213	185 42	206 16	20 34	9.9714	9.9073
209	0. 209	28 54	86 31	57 37	9.7288	9.7870
96	0. 209	187 29	242 48	55 19	9.7551	9.9663
67	0. 204	177 18	206 18	29 0	9.9418	9.9073
123	0. 201	357 49	261 3	— 96 46	9.0712 n	9.9140
57	0. 200	202 49	179 46	— 23 3	9.9639	9 9612
236	0. 197	106 33	123 16	16 43	9.9812	9.9979
87	0. 196	219 56	232 17	12 21	9.9898	9.9979
242	0. 191	168 1	122 36	— 45 25	9.8463	9.9999
48	0. 190	102 27	155 23	52 56	9.7801	9.9096
115	0. 187	237 0	238 5	1 5	9.9999	9.9917
189	0. 185	222 49	178 40	— 44 9	9.8558	9.7411
104	0. 185	355 21	279 53	— 75 28	9.3996	9.6466

TABLE OF INDIVIDUAL STARS (*continued*).

Argelander's number.	Δ s	ψ	ψ′	ψ′ — ψ	log. cos (ψ′ — ψ)	log sin χ
223	0″184	67°35′	67°14′	— 0 21	0.0000	9.9023
213	0. 184	188 8	119 53	— 68 15	9.5689	9.8730
50	0. 184	157 13	133 57	— 23 16	9.9632	9.5844
232	0. 182	79 45	124 5	44 20	9.8545	9.9988
116	0. 182	286 59	237 44	— 49 15	9.8148	9.9933
32	0. 179	95 27	142 24	46 57	9.8342	9.9720
54	0. 175	323 40	175 18	—148 22	9.9301 n	9.9685
17	0. 174	124 43	132 5	7 22	9.9964	9.9847
1	0. 174	223 10	122 11	—100 59	9.2799 n	9.9895
22	0. 163	111 15	133 27	22 12	9.9666	9.9654
83	0. 161	219 2	227 57	8 55	9.9947	9.9896
138	0. 154	270 0	226 22	— 43 38	9.8596	9.9934
79	0. 154	234 20	223 18	— 11 2	9.9919	9.9974
40	0. 150	115 16	151 7	35 51	9.9088	9.9411
214	0. 149	112 33	134 34	22 1	9.9671	9.9627
102	0. 149	263 26	255 21	— 8 5	9.9957	9.9365
188	0. 143	327 39	359 38	31 59	9.9285	9.4335
227	0. 137	104 55	127 2	22 7	9.9668	9.9993
42	0. 136	156 21	151 10	— 5 11	9.9982	9.8923
146	0. 133	286 38	289 3	2 25	9.9996	9.8452
230	0. 123	58 3	91 17	33 14	9.9224	9.9156
3	0. 108	76 30	123 16	46 46	9.8357	9.9931
143	0. 100	306 15	298 51	— 7 24	9.9964	9.8935
92	0. 096	288 14	249 30	— 38 44	9.8921	9.9357
41	0. 079	139 30	155 7	15 37	9.9837	9.9980

III.

ON THE VEILED SOLAR SPOTS.

By L. Trouvelot.

Read by William A. Rogers, Oct. 12, 1875.

It is now pretty well established that the visible surface of the sun is a gaseous envelope called "the chromosphere;" mainly composed of incandescent hydrogen gas, with which are occasionally associated some metallic vapors usually occupying the lower strata. To all appearances, the granulations called "rice grains," the faculæ and the protuberances, are phenomena belonging to the chromosphere; in fact, they are the chromosphere itself seen under the particular forms and aspects peculiar to it. Ordinarily this envelope has a thickness of 10″ or 15″. This thickness, however, is by no means constant, varying from day to day within certain narrow limits.

At no time since I have observed the sun, have I seen the chromosphere so thin and shallow as during the present year, and especially between June 10 and August 18. I had before quite often observed local depressions and upheavals of the chromosphere, sometimes extending over large surfaces, but I had never before observed such a general subsidence.

So thin was the chromosphere during this period, that it was sometimes very difficult to obtain its spectrum by placing the slit of the spectroscope tangent to the limb of the sun. This was especially the case on the afternoon of August 9.

This unusual thinness of the chromosphere could be easily recognized without the assistance of the spectroscope. Indeed, the phenomenon was even more interesting seen through the telescope, as, with it, the structure of the photosphere, lying as it does under the envelope of the chromosphere, could be better seen through the thin veil formed by the greatly attenuated chromospheric gases.

That the gases forming the chromosphere are sometimes thin enough to become transparent is a phenomenon which I have observed hundreds of times; as is abundantly proved by the numerous drawings of protuberances which I have made at the Harvard College Observatory, in which the limb of the sun is seen through the base of the protuberances in front of it. In plate X, figure 3, there occurs a very striking instance, where two small prominences are seen through a larger protuberance nearer the observer.

During this period of general subsidence, the granulations appeared to be smaller and farther apart than usual, and consequently the light-gray colored background upon which they are seen projected was more distinct, as it occupied more space than formerly. During this period, the light-giving element would appear to have been less than usual.

I am not aware that the phenomena of which I shall speak in this communication have been before observed; but I cannot speak positively on this point, owing perhaps to the somewhat confused nomenclature of solar physics.

Ever since I have observed the sun with instruments of a large aperture, I have noticed that the light-gray colored background seen between the granulations is by no means uniform, as it is generally stated to be. On the contrary, it is greatly and strikingly diversified. Aside from the very small black dots called "pores," patches of a darker gray are irregularly distributed all over the surface of the sun. But partly owing to the effect of perspective, and partly on account of the thicker strata of the chromospheric gases through which they are necessarily seen near the limb, they disappear gradually as they approach the border.

These dark spots have been so remarkable during the present year, and so conspicuous during the period of the greatest subsidence of the chromosphere, that I have availed myself of every favorable opportunity to study them. So strongly were they marked, that when one had passed the field of view, it could be easily found again among many others, even after the lapse of several hours. Of the most striking and complicated, I have made sketches.

In order to be able to count how many of these gray spots could be seen in different heliographic latitudes, and also to estimate their area with respect to the whole surface of the sun, Mr. W. A. Rogers, Assistant at the Harvard College Observatory, kindly ruled for me on glass a reticule of small squares. Though the problem is apparently a simple one, it nevertheless presented many difficulties; partly owing to the minuteness and delicacy of these objects, partly on account of the unsteadiness of the atmosphere, and partly to the many defects caused by the great amount of heat concentrated at the focus of the objective. However, the observations show clearly that, though the number of gray spots varies but little in different latitudes, in general the spots become larger and more complicated as they approach the equatorial zones.

The most marked characteristic of the gray spots is their vagueness of outline. They are never sharply defined like ordinary spots, but they appear blurred and diffused like an object seen through a mist. As I shall endeavor to show presently, these objects are really seen through the chromospheric gases which are spread as a veil over them, causing this vagueness of outlines. For this reason, I propose for them the name of *Veiled Solar Spots.*

The veiled solar spots, especially in the lower latitudes, have a remarkable tendency to assemble into small groups after the manner of ordinary spots. Sometimes three or four are seen in contact, while there are comparatively large intervals where none are to be seen. I have in several instances seen the actual formation into groups of distinct veiled spots.

The granulations of the chromosphere are seen projected upon the veiled spots, just as anywhere else, but they are not there so regularly distributed; some being closely crowded together, while others are widely scattered. Small faculæ are often formed in this manner by the aggregation of several granules into one mass. Once in a while, the granulations appear as if they were under the power of a propelling force by which they arrange themselves in files, and sometimes in capricious figures which are very remarkable.

In many cases I have observed that the granulations projected upon the veiled spots have an extraordinary mobility, to be seen nowhere else, except perhaps in the immediate vicinity of ordinary spots in full activity. Often their form and position are totally changed within a few minutes, and sometimes even within a few seconds. This was especially the case June 21. At 8h. 30m. on that day, I was observing a group of veiled spots not far from the centre of the sun, when my attention was drawn to the extraordinary mobility of the granulations covering this group. In an instant they changed their form and position, some crowding together as though briskly attracting each other, while others would fly apart as if repelled by an invisible force. Under this tumultuous conflict of forces, new veiled spots would appear and disappear in an instant, faculæ would form and vanish; in fact, all was in motion and confusion on that particular part of the sun. It was evident that immense forces were in conflict under the chromosphere.

At 2h. 0m. P.M., on the same day, several small black spots had opened through the chromosphere upon the group of veiled spots observed in the morning. At 8h. 0m. on the following morning, the group of small black spots was considerably increased, having quite a large spot on the preceding side, followed by twelve or fifteen smaller ones. On June 24, this group had attained to its maximum size. It was then very large and complicated. In fact, it was the largest group of sun spots observed thus far during the present year.

On August 8, I noticed a group of veiled spots a little south of the sun's centre. The following morning at 7h. 0m., there was at the same place a small group of half a dozen black spots disposed in a crescent shape. At 2h. 0m. P.M., the black spots had vanished, but the veiled spots still remained, having retained the characteristic crescent form of the black spots and many other details observed in the morning; and, as a proof that the chromosphere covered this spot, *the granulations could be plainly seen upon the whole, indicating clearly that this spot was seen through the veil of the chromospheric gases.*

On August 24, the same phenomenon took place. Just following the principal spot of the only group then to be seen on the surface of the sun, there was a fine group of veiled spots. The following day some black spots had made their appearance upon them. On August 27, the black spots had vanished, but in their place the veiled spots seen at first still remained, and they continued to be seen there for several days.

To all appearances, the black spots which I had seen disappear under the chromospheric gases, and which continued as veiled spots, were exactly alike and undistinguishable from the many other veiled spots scattered all over the sun; and, had I not seen the opening of the photosphere, with the black spots, I could not have had any idea of the true nature of the veiled spots.

So far, I have only spoken of veiled spots observed in the zones where the ordinary sun spots make usually their appearance; but, as I have said, the veiled spots are scattered all over the surface of the sun.

During this period, I had many occasions to observe very remarkable and characteristic veiled spots in very high heliographic latitudes north and south. On July 15, within a few degrees of the north pole of the sun, I observed a remarkable veiled spot, unusually large and dark. Upon it were several bright slender faculæ projected in crest shape to very high altitudes. These faculæ appeared to be precisely like those observed in lower latitudes near ordinary sun spots.

Upon this veiled spot could unmistakably be seen a small black spot, not a pore; a real opening of both chromosphere and photosphere.

On August 9, I observed another remarkable veiled spot within about 10° from the north pole, and upon it could be seen three small black spots.

On August 13, at 11h. 0m., I observed a very dark veiled spot within 6° or 8° from the north pole. It had upon it a group of small faculæ, so characteristic of the spots of lower latitudes. At 4h. 30m. in the afternoon, this veiled spot was still darker, and upon it, near a facula, a pretty large black spot was visible.

On August 24, I observed a remarkable veiled spot at about 75° south latitude.

On September 6, another large group of veiled spots was seen within 10° or 15° of the north pole. At 10h. 20m., some faculæ had formed upon it, and two black spots were distinctly visible. At 5h. 0m. in the afternoon, this group was still visible.

On September 8, within a few degrees of the north pole, I observed a fine group of two veiled spots, unusually dark and large, and near one of these spots there was a pretty large and bright facula. Ten minutes later the dark veiled spots had vanished, leaving in their place some bright faculæ. One minute later the veiled spots began to reappear, but under another form, to disappear again the next moment.

A little south-west from this last group, but in the same field of view, was another group of veiled spots apparently in full activity. Upon it three or four black spots were visible for some seconds. Upon these veiled spots the granulations had an extraordinary mobility; so much so, that I expected at every moment to see a large spot make its appearance, but in less than a minute the veiled spots and the black spots had both vanished, and in their place were formed in an instant, some very bright faculæ.

To all appearances, the veiled spots seen in high latitudes differ but very little from the ordinary sun spots of the lower latitudes, except in regard to magnitude and activity. The difference seems particularly to be that, in the first, the umbra, instead of being freed from the gases and vapors, is partly or wholly choked with them; while, besides, the chromosphere covers it. The forces which open the photosphere in high latitudes, it would seem, have not sufficient energy to repel or dissolve the chromospheric gases; or, if they have, it is in a very feeble degree, but, even then, the phenomenon is generally of short duration.

Though I had no means of making accurate measurements of the position of the spots seen in high latitudes, the error of my estimation cannot be very great. In any case a few degrees would certainly cover it, and it remains a fact that I have observed spots at least within 10° of the north pole of the sun. The importance of this observation will appear when it is stated that very few spots have been observed outside of the zones lying 40° on either side of the equator. I know of but two instances on record in which spots have been observed beyond this limit. La Hire observed a spot 70° from the equator, and more recently, in the month of June, 1846, M. Peters observed at Naples a spot 50° from the equator.

It is further to be remarked that, according to the conclusions of the English observers, the solar spots attain higher latitudes during the years of the maximum number of spots, and recede more and more towards the equator as the minimum is approaching; and it is to be noted that the present year is precisely, or at least very nearly, a minimum year. It is doubtless owing to the unusual thinness of the chromosphere during this period that spots have been observed in so high latitudes this year. It is true that the spots were small, but, nevertheless, they were genuine spots, with all the characteristics of larger spots.

It is difficult for one who has seen the phenomena which I have described, to come to any other conclusion than this: that the veiled spots are breaks or true openings in the photosphere, seen through the imperfectly transparent gases composing the chromosphere, openings themselves partly or wholly filled by the vapors ejected by the forces from the interior of the photosphere. If this hypothesis should prove to be the expression of a fact, then we should expect to find that the photosphere is perforated by thousands of crevasses either partly or entirely filled with the vapors and gases from the interior, which cannot be ejected entirely outside for want of sufficient energy, save for a comparatively very small number situated in the equatorial zones, where this energy appears maximum, and is able to repel and dissolve the gases from the interior.

Before the observations of this year, I had arrived at precisely the same conclusions in regard to the openings of the photosphere in all latitudes, and to the existence of invisible spots concealed by the chromosphere. These conclusions were derived from my observations with the spectroscope, made at Harvard College Observatory during a period of thirty-five months. A discussion of these observations is reserved for a future communication.

Though one can hardly form a settled opinion with regard to the cause of the general depression of the chromosphere, on account of the imperfect data, it seems natural, however, to suppose that the phenomenon is connected in some way with the minimum period of sun spots. Judging by the great number of veiled spots observed, and by the myriads of pores seen between the granulations, it would seem that both the chromosphere and photosphere have been much thinner than usual during the present year.

If there are breaks in the photosphere at many points of the surface of the sun, it becomes easy to account for the unusual thinness of the chromosphere this year, because, as observed by myself and others, at certain phases of the spots, the chromospheric gases, rushing with impetuosity into the umbra, go down under the photosphere like gigantic waterfalls, diminishing consequently the thickness of the chromosphere. That this takes place I shall give ample proof in another communication.

It seems evident that the chromosphere near a spot is kept off from falling into the opening by a force from the interior. As soon as this force decreases in energy, immediately the chromosphere tends to cover it, and even to precipitate itself through the opening when this force becomes extinct. The observations show this plainly.

When a spot is decreasing, it is quite common to observe that the umbra and penumbra appear as if they were seen through a heavy fall of snow, their surfaces being covered by numerous bright flocculent granulations surrounded by a kind of bluish fog. In a few instants of very rare definition, I have been surprised to see faint traces of this flocculent appearance upon almost all the spots; indeed it would seem that the spots are rarely free from some faint traces of the chromospheric gases. Probably the bright flocculent objects observed upon the umbra and penumbra of spots, are the granulations of the chromosphere dissolved to a greater or less degree by the forces emanating from the spots.

Perhaps it may not be idle to remark that, during the period mentioned, I have almost every day observed small groups of faculæ in the polar regions, especially near the north pole of the sun; while, for the most part, they have been entirely absent from the equatorial regions, where they are commonly found.

To conclude, my observations show: —

1°. That during this year, and especially during the interval from June 10 to August 18, and to a less degree to September 14, the chromosphere has been notably thinner than usual upon the entire surface of the sun.

2°. That the granulations have been smaller and less numerous.

3°. That the light-gray colored background seen between the granules has been more conspicuous and has occupied more space than usual.

4°. That there are spots, which I have named "veiled spots," which are seen through the chromosphere which is spread over them like a veil.

5°. That these veiled spots are true openings of the photosphere, like those of the ordinary spots.

6°. That during this period these spots have been larger, darker, and more numerous than I have before seen them.

7°. That the veiled spots are scattered throughout all latitudes, though more complicated in the regions where the ordinary spots make their appearance.

8°. That I have observed spots at least within 10° of the north pole of the sun.

9°. That the flocculent objects sometimes seen projected upon the umbra and penumbra of spots are the remaining portion of the granulations composing the chromosphere, more or less dissolved by the forces emanating from the interior of the photosphere.

Cambridge, October 1, 1875.

IV.

ON PHOTOGRAPHS OF THE SOLAR SPECTRUM.

By Robert Amory, M.D.

Read, May 25, 1875.

The photographs I now present to the Academy were taken by the action of sunlight, thrown by a collimating lens (21 inches focal length) upon one of Mr. Rutherford's ruled speculum plates, containing 12,080 lines to the inch, and reflected therefrom upon an achromatic lens of five feet focus; the image was then received upon a sensitized collodion film. It will be observed that the solar lines are more numerous than those shown by the photograph-map (herewith also presented) of Professor J. W. Draper, and published in 1872, which was taken from a ruled speculum plate containing only 6,480 lines to the inch. One of my photograph plates has been enlarged to the same scale as that of Professor Draper's, and comprises solar lines whose wave-lengths, as compared with Ängstrom's map, are between 4,590 and 3,700. I likewise present photographs of the absorption bands of Uranium acetate, in which the three bands can be distinctly seen, as well also as the solar lines of that portion of the spectrum.

In the apparatus used for these experiments, I would call the attention of the Academy to the following observed fact: that, if the slit of the collimator is placed exactly at the principal focus of the collimating lens, the solar lines are in focus for all the different orders of the spectrum upon the true arc of a circle. If, however, the slit is outside of the principal focus, these solar lines are in focus on a curve which is not the arc of a circle, but whose radius gradually becomes shorter in the higher orders. If, again, the slit is inside of the principal focus, the radius of the curve gradually becomes longer in the higher orders. The diagram I present may, perhaps, illustrate this fact more clearly. Any one may verify it by direct experiment.

Moreover, in using a dark chamber of large width between the sensitized film and the lens used for projection of the image from the grating, and placing between this projecting lens and the sensitized film a diaphragm which allows only that portion of the spectrum actually photographed to pass through, I have had no trouble from diffused light. In my earlier experiments, a dark tube of the same calibre as the diameter of the projecting lens would always mar the sensitized plate, on account of the diffused light, no matter how carefully the tube was fitted with diaphragms.

V.

MISCELLANEOUS BOTANICAL CONTRIBUTIONS.

By Asa Gray.

Presented, Oct. 12, 1875.

The following notes and characters relate mainly to Californian botany, the writer having been engaged in the preparation of the *Gamopetalæ* for Professor Brewer's Botany of California, now printing. Some of the observations are such as could not well be recorded in that work; and the characters of certain new genera and species may appropriately be introduced to the botanical world in a continuation of the "Contributions" which have from time to time been communicated to the Academy, and published in its Proceedings. My first note has reference to two plants of the Atlantic United States, which have long been confounded.

Sedum pusillum Michx. Glauco-pallidum, 1–3-unciale; foliis alternis teretiusculis oblongis (lin. 2–3-longis); floribus ad summitatem ramorum laxe cymosis tetrameris; pedicellis petala alba oblongo-ovata acutiuscula subæquantibus; folliculis elongato-oblongis stylo brevissimo subito apiculatis; seminibus ovali-oblongis. — On granite rocks; Flat Rock near Camden, South Carolina, Michaux; Stone Mountain, Georgia, W. M. Canby, 1869, and A. Gray, 1875. This little plant I found on Stone Mountain, in great abundance from the base to near the summit, in full blossom on the 19th of April last. Fruiting specimens were sparingly collected at the same station in May, 1869, by Mr. Canby, who, however, did not distinguish it from *Diamorpha pusilla* Nutt., which accompanies it, but is most abundant towards and upon the summit of this singular granitic mountain. I cannot learn that the true *Sedum pusillum* has been elsewhere seen, except, long ago, by Michaux. But the two are probably associated at other stations. At least they must be so at Flat Rock. For there Nuttall collected, in winter, old fruiting specimens of the plant he described in his Genera Plantarum, p. 110, as "*Tillæa? cymosa* (*Sedum pusillum* Michx.)," and on p. 293 as "*Diamorpha pusilla* (*Sedum pusillum*

Michx.)." Until now no one has supposed that there were two plants in question, because no botanist had been attracted to them by seeing the two plants in flower together. The specimens in Michaux's herbarium are in fruit, or mainly so, but the phrase "flores albi octandri" is appended to the character in the Flora. Michaux might have collected and confounded the two; but Professor Bureau, who kindly compared specimens for me, informs me that the *Sedum* in the herbarium of Michaux is unmixed with *Diamorpha*. The two plants are different enough in aspect as well as in botanical characters. The *Sedum* is the larger, earlier to blossom, of a pale and glaucous hue, and, with its profusion of pure white flowers, is more conspicuous, even showy; the pods are abruptly pointed with a very short style, have the introrse dehiscence proper to the genus, and the seeds are oblong.

The *Diamorpha*, of barely half the size, and with proportionally wider leaves, has a dull purplish hue, extending more or less to the flowers; the sepals are distinct nearly to the base and narrower; the petals oval and obtuse; the ovaries and pods tapering from a broader base into a subulate style; the seeds round-oval; and the cruciform union of the pods at base and their peculiar dorsal valvular dehiscence, peculiar to the genus, are as described by Nuttall.

With these two plants was associated another rarity; viz., the *Arenaria brevifolia* of Nuttall, in full blossom at the same season. Mr. Canby also collected it, and very naturally took it for *Arenaria glabra* Michx., to which, indeed, it is too closely related, but is probably distinct.

Cleomella oocarpa. Diffusa, spithamæa ad subpedalem; foliolis oblongo-linearibus; racemo sæpissime densifloro; bracteis inferioribus foliis conformibus, superioribus simplicibus; setulis stipularibus manifestis; staminibus petala superantibus; ovario apice 3-ovulato; capsula ovata lineam longa stylo breviusculo superata stipite (pedicellum subæquante) triplo breviore; seminibus 1–2 lævibus. — Sterile saline plains of Humboldt County, Nevada, Torrey, A. Gray; and adobe hillsides and plains on the borders of the Mesa Verde, South-west Colorado, T. S. Brandegee, in Hayden's Exploration, 1875. This has been confounded with *C. plocasperma*, Watson, Bot. King Exp. p. 33, which, thus far, has been collected only by Mr. Watson and the Rev. R. Burgess, and has a larger and dilated rhombic pod, on a stipe which generally little exceeds it in length, more numerous and laterally inserted ovules, seeds with peculiar marking, shorter stamens, &c.

POLYGALA ACANTHOCLADA. Fruticulosa, bipedalis, ramosissima, subcinereo-pubescens, spinis gracilibus armata; foliis lineari-spathulatis rigidulis (lin. 3–4 longis); floribus subaxillaribus sparsis albidis lin. 2 longis pedicello basi bibracteato parum brevioribus; alis obovatis sepalis cæteris duplo majoribus corollam adæquantibus; carina breviter cymbiformi nuda dorso umbonata. — Sides of bluffs, on the San Juan River, in the south-eastern border of Utah, T. S. Brandegee, in Hayden's Exploration. Resembles *P. subspinosa* of Watson, but woody; the flowers scattered, pale, and less than half the size; the free portion of the corolla of five short and obtuse lobes nearly equal in length and little longer than the united portion, emarginate; the keel not much larger, a conical boss on the upper part of the back; no crest. Spines of the branchlets often compound. No fruit seen.

GLOSSOPETALON NEVADENSE. Cinereo-puberulum; foliis ovalibus e basi squamacea dilatata manifeste stipulifera; floribus tetrameris. — Northern part of Washoe County, Nevada, J. G. Lemmon and E. L. Case. An interesting addition to an anomalous genus, upon the affinity of which more light may now be thrown. I had noticed the likeness of the fruit and seed to that of the Staphyleaceous genus *Euscaphis*, and I can now bring to view other points, which altogether must exclude it from *Celastraceæ*, and in my opinion refer it to the *Sapindaceæ*, suborder *Staphyleineæ*,* notwithstanding the alternate entire leaves. Mr. Wright's original specimens of *G. spinescens* show no clear trace of stipules; but in fresh ones from Parry's Southern Utah collection (No. 27), they are evident on vigorous shoots, in the form of a setaceous-subulate cusp on each side and near the apex of the deltoid squamaceous base of the leaf. As in analogous cases, they are wanting to the fascicled leaves. As in the original specimens of *G. spinescens*, so in these, although seeds seem to be full-grown and well-formed, I find not a single developed embryo. If this should prove to be straight and the albumen wanting, I should refer the genus to *Rosaceæ* near to *Purshia*; but I expect it will turn out otherwise.

PETALOSTEMON TENUIFOLIUS. Multicaulis e radice perenni, pubescens, nunc glabratus; foliis 3–5-foliolatis; foliolis mox involutis filiformi-linearibus petiolo brevioribus parce glandulosis; spicis longius pedunculatis ex ovata demum cylindricis densifloris; bracteis ovatis caudato-aristatis cum calyce sericeo-villosis eglandulosis; corolla roseo-

* "*Staphylea*" Benth. & Hook. is only the plural of *Staphylea*, and *Staphyleeæ* is overcharged with vowels.

purpurea, vexillo rotundato-cordato cucullato. — Arkansas, at the crossing of Red River, Dr. Newberry; New Mexico, Mr. Dieffendorfer (ex T. C. Porter), J. T. Rothrock. Much branched, apparently a foot or less in height, bearing numerous spikes on slender peduncles: leaflets about half an inch long: spikes at first white with the silky down, in age fulvous.

Galium angulosum. Fruticosum, patenti-ramosissimum, hispidum; ramis insigniter costato-5–7-angulatis; foliis crebris sublineari-oblongis fere eveniis, costa subtus prominula, caulinis 5–7-nis (lin. 3–4 longis), ramulorum 4–6-nis paullo minoribus, ultimis florem brevipedunculatum fulcrantibus conformibus; corolla flavescente; fructu ut videtur carnosulo vel baccato fere lævi. — Guadalupe Island, on rocky precipices in the middle of the island, Dr. E. Palmer. This species seemingly belongs to the *Relbunium* section; but only forming fruit was collected; its surface is obscurely granulate. The leaves on the crowded and divaricate branches are as long as the internodes or longer; and the ultimate whorl and its internode are just like the preceding ones, in which respect it differs much from *G. Relbun* and its near allies. The numerous ribs to the stem are remarkable, and they are visible even on portions that have become woody.

Brickellia microphylla Gray, var. scabra. Foliis parvulis rigidioribus papilloso- vel hirtello-scabris; pappo tantum 16–20-chæto. — Rocks, Southern Colorado, Dr. Parry, T. S. Brandegee in Hayden's Exploration, 1875.

Aplopappus (Ericameria) Palmeri. Fruticosus, 4-pedalis, paniculato-ramosissimus; ramis floridis nunc virgatis sursum floriferis nunc in paniculam effusam ramulosam solutis; foliis filiformibus (pollicaribus, fasciculorum brevioribus) parum punctatis; involucro turbinato, squamis lato-linearibus chartaceis granuloso-subglandulosis apicem obtusissimum versus fimbriolato-ciliatis; ligulis 3–4 flores disci 11–15 haud superantibus; acheniis breviter linearibus villosulis. — Tecate Mountains, in Lower California, twenty or thirty miles below the State boundary, Dr. E. Palmer. Allied to *A. laricifolius*, &c. Heads only four lines long.

Bigelovia (Aplodiscus) spathulata. Ramosissima, pauci-pedalis, glabra, parum glutinosa; ramulis floridis brevibus foliosis; foliis (semiuncialibus) cuneato- seu obovato-spathulatis retusis integerrimis coriaceis vix punctatis eveniis, costa obscura; capitulis corymbosis (lin. 4–5-longis) 16-floris; involucri turbinati squamis coriaceis, intimis latiuscule linearibus pallidis, exterioribus sensim brevioribus crassioribus viridulisque, in bracteolas pedicelli brevis transeuntibus; styli appendicibus tenui-subulatis parti stigmatiferæ latiori æquilongis; acheniis sericeo-villosis subturbinatis. — Near the entrance of the Tantillas Great Cañon, in Lower California, near the borders of the State, Dr. E. Palmer. This singularly resembles our *Aplopappus cuneatus;* but it has no trace of rays; the leaves are destitute of glutinous exudation and are obscurely when at all punctate; the scales of the involucre are not carinate; the akenes shorter and silky; and the bristles of the pappus not (as in that plant) clavellate-thickened. It must stand near to *B. Menziesii;* but the style-appendages are as in the *Chrysothamnus* section.

BIGELOVIA (CHRYSOTHAMNOPSIS, post No. 15 revisionis) ENGELMANNI. Spithamæa et ultra e basi fruticosa, fere glabra et viridis; foliis crebris angustissime linearibus rigidulis mucronato-acutatis patentibus (poll. 1–2 longis semilin. ad lineam latis), costa valida; capitulis sessilibus fastigiatim corymboso-glomeratis; involucro oblongo-turbinato 15–20-floro, squamis oblongo-lanceolatis cuspidato-acuminatis, exterioribus sensim brevioribus haud folioso-appendiculatis; corollis 5-dentatis; appendicibus styli breviter crassiuscule subulatis; acheniis lineari-oblongis glaberrimis. — Plains of the eastern part of Colorado, at Hugo Station on the Arkansas Pacific Railroad, Dr. Engelmann and Dr. Parry, 1874; H. N. Patterson, 1875.

BIGELOVIA GREENEI. (CHRYSOTHAMNUS, * * + ante No. 19 revisionis.) Pedalis, glaberrima; foliis angustissime linearibus mucronatis minutim remotiuscule hirtello-ciliolatis; capitulis corymboso-fasciculatis angusto-oblongis; involucri squamis oblongis margine tenuiter scariosis apice subito caudato-acuminatis; pappo rigidulo. — Huerfano Plains, southern part of Colorado, Rev. E. L. Greene, 1872.

DIPLOSTEPHIUM CANUM. (APLOSTEPHIUM, ligulis paucis parvis stylo suo brevioribus, pappo simplici.) Frutex ramosus, validus, tomento implexo dealbatus; foliis spathulatis vel angusto-oblongis basi attenuatis subpetiolatis integerrimis planis e costa valida subreticulato-venosis; capitulis laxe cymosis vel subpaniculatis, primariis in dichotomiis sessilibus; involucro brevi-oblongo crebre tomentoso, squamis obtusis; floribus purpurascentibus, radii 4–6, ligula inconspicua disco breviore 2–3-dentata; disci 12–20, corollis 5-dentatis, appendicibus styli brevibus acutiusculis; acheniis linearibus subcompressis 4–5-nerviis sericeo-hirtellis; pappo e setis rigidulis plerumque æqualibus, vel perpaucis exterioribus minimis. — Guadalupe Island, off

Lower California, Dr. E. Palmer; who mentions it as "a large shrub, about four feet high, of rather loose habit, found only in the crevices of high rocky cliffs, March 28. Flowers yellow." A purple hue in the small rays is evident, and the disk-corollas seem to have turned purplish also, as they are apt to do in the heterochromous *Asterineæ.* The plant agrees so well in habit, and so nearly in character, with *Diplostephium* of South America that it may fairly be referred to that genus, some species of which are equally destitute of an outer abbreviated pappus, while some are said to want the ray altogether. The general aspect is also much that of the *Inuleæ*, an Old World group; but the anthers are completely tailless, and the appendages of the style-branches are manifest, although not strongly marked internally, the stigmatic lines not ending abruptly. Still more does it recall some of the South American *Vernoniæ* in appearance and especially in inflorescence. It seems best not to constitute genera upon single species with no more salient characters than these, but a subgeneric distinction may mark its peculiarities. The heads are barely half an inch long.

Aster Coloradoensis. Machæranthera sed perennis, nanus, tomentuloso-canescens; caulibus in caudice lignescente confertis plurimis monocephalis; foliis imis spathulatis, summis fere linearibus, omnibus argute dentatis, dentibus spinuloso-setiferis; involucri hemisphærici squamis pluriserialibus subulatis laxiusculis; ligulis 35–40 linearibus purpureis elongatis; acheniis brevibus turbinatis creberrime cano-villosis. — Colorado Rocky Mountains; in South Park, on banks, gravel-bars, or open hills, Canby, Porter, Wolf and Rothrock, Greene; and San Juan Pass in the south-western part of the State, at 12,000 feet, Brandegee. A species several times collected and passed over as a very dwarf form of *A. canescens*, from which it is wholly distinct. The tufted stems are only 2 or 3 inches high.

Dicoria Brandegei. Diffusa, pube substrigulosa cinerea; foliis lanceolatis obtusis subintegerrimis; capitulis laxe racemoso-paniculatis parvis; involucri squama interna florem fœmineum fulcrante unica cæteris haud longiore achenio oblongo turgido margine calloso-dentato subdimidio breviore. — On the Rio Montezuma de San Juan, near the south-western corner of Colorado, T. S. Brandegee in Hayden's Exploration, 1875. An interesting accession to the genus, requiring considerable modification of the character, there being only one female flower; its broad subtending scale hardly enlarging, thin but not scarious or colored; the exserted and naked akene more thick, convex and angled on the back, developing on the margins only rigid blunt teeth for the wing; paleæ of the receptacle only one or two among the male flowers. Filaments monadelphous to the top, as in *D. canescens*, and anthers pointless; the style abortive and functionless as a pollen-distributor.

Franseria ilicifolia. Fruticosa, hirsutula; foliis rigido-coriaceis oblongis vel ovatis basi auriculata subamplexicaulibus penniveniis et reticulato-venulosis grosse dentatis, dentibus apiceque sæpius acuminato-spinescentibus; capitulis masculis haud visis, fœmineis fructiferis globosis bilocularibus dispermis aculeis crebris longis hamatis armatis, rostris 2 aculeis haud longioribus parum crassioribus. — Great Cañon of the Tantillas Mountains, near the northern border of Lower California, Dr. E. Palmer. Flowering branches very leafy to the summit, hirsute or hispid: leaves an inch or two in length, tipped with a very sharp rigid spine; fruiting involucre half an inch in diameter, including the slender prickles, which are 2 lines long.

Wyethia coriacea. Pedalis, villoso-pubescens, paucifoliata; foliis longe petiolatis coriaceis eximie reticulatis aut lato-ovatis basi nunc truncata nunc obliqua vel acuta, aut oblongis in petiolum angustatis; capitulis paucis breviter pedunculatis; involucro oblongo e squamis 5–6 oblongis lanceolatisve ligulas æquantibus vel superantibus cum interioribus perpaucis parvulis subpaleaceis; acheniis glabris, radii oblongis obcompressis, disci angustioribus prismaticis 4–5-angulatis, omnibus exaristatis. — On the Mesa Grande, 70 miles north-east of San Diego, California, Dr. E. Palmer. A remarkable dwarf species, with leaves varying from 3 to 5 inches long, and sometimes nearly as broad, on petioles 2 to 4 inches long; the broader ones with some of the lower and stronger primary veins or ribs converging to the apex, or running into false veins by anastomosis. Heads an inch or so in length. Rays 5 to 8; ligules only half an inch long. Pappus of 4 to 6 short ovate or triangular scales, a little united at base, rather unequal, one or two occasionally lanceolate or subulate and longer, but awnless.

Helianthus gracilentus. Perennis, tripedalis; caule ramisque gracilibus fere glabris lævibus; foliis breviusculis lanceolatis integerrimis utrinque hirtello-scabris subcinereis, inferioribus oppositis breviter petiolatis; pedunculis paucis gracilibus nudis; capitulis parvulis; involucro disco breviore, squamis inappendiculatis oblongo-lanceolatis acutis gradatim imbricatis hirtello-puberulis; ligulis 12–16 elongatis, disco fusco-flavescente; paleis apice deltoideis; achenio glaberrimo complanato pappi paleis 2 subulato-aristiformibus (corolla paullo brevioribus) dimidio breviore. — California, in the mountains 45 miles north-east of San Diego, Dr. Palmer. Larger leaves 3 inches long, somewhat triple-nerved; the upper successively smaller. Disk little over half an inch in diameter; rays from two-thirds to a full inch in length.

Iva Hayesiana. Frutescens, striguloso-puberula; caule (ad bipedalem et ultra, basi haud viso) erecto demum paniculato-ramoso; foliis integerrimis obtusis, caulinis oppositis spathulato-oblongis vel sublanceolatis in petiolum attenuatis, ramealibus bractealibusque alternis ad linearia; capitulis longe laxiuscule quasi spicatis vel racemosis; involucro e squamis circiter 5 rotundatis discretis imbricatis. — San Diego County, California; Warner's Pass, Sutton Hayes (1858); and Jamuel Valley, south-east of San Diego, Dr. E. Palmer. A well-marked species, resembling *I. cheiranthifolia* rather than *I. axillaris.* Heads numerous in elongated leafy-bracted spikes or racemes, and these in an ample panicle; the ultimate floral leaves or bracts hardly exceeding the nodding heads. In memory of the estimable discoverer, the late Mr. Sutton Hayes, whose specimens, however, were indeterminable, the heads having all fallen from their short peduncles.

Encelia (Geræa) viscida. Herbacea, viscido-glandulosa; caule forte bipedali (basi ignoto) ramis costaque foliorum pilis longis patulis multi-articulatis barbatis; foliis ovatis oblongisve plerumque basi auriculata vel cordata semiamplexicaulibus subserratis; capitulis ramulos breves foliatos terminantibus; involucro extus viscido, squamis exterioribus herbaceo-membranaceis lato-linearibus obtusis parum inæqualibus, intimis scariosis paleis receptaculi similibus; ligulis nullis; corollis radii pallide-flavis; acheniis angusto-cuneatis calloso-marginatis biaristatis præsertim ad margines albo-villosissimis. — Near Larkens' Station, on the southern borders of California, 80 miles east of San Diego, Dr. Palmer. Head nearly three-fourths of an inch long: akenes 4 or 5 lines long, and their subulate awns 2 or 3 lines. The habit is that of a *Hulsea*, rather than of any of its congeners.

Perityle incana. Suffrutescens, procera, tomento applanato incana: foliis (etiam inferioribus?) alternis crassiusculis fere trisectis, segmentis cuneatis 2–3-fidis, lobis pauci-incisis; capitulis compluribus in cymam compositam corymbosam nudam congestis: involucro viridulo; ligulis nullis; appendicibus styli brevinsculis acutiusculis; acheniis oblongis subturgidis undique villosis; pappo exaristato e squamellis plurimis angustissimis basi coroniformi-concretis. — Guadalupe Island, off Lower California, Dr. E. Palmer. On precipices inaccessible to goats in the interior of the island, conspicuous by its very white foliage and abundant golden-yellow blossoms. A remarkable and anomalous species, but certainly of this genus, having all the characters. One of the genuine species already published is rayless. In size (probably 2 or 3 feet high), in the dense tomentum, and in the naked dense corymbs or cymes, this is peculiar. The squamellæ of the pappus are as long as the breadth of the akene.

Hemizonia (Hartmannia) frutescens. Fruticosa, erecta, ultra bipedalis, hirsutula, subviscida; ramis floridis virgatis fastigiatis foliosissimis: foliis filiformibus (pollicaribus, fasciculorum brevioribus) integerrimis raro 1–3-lobatis; capitulis thyrsoideo-racemosis (lin. 3 altis); ligulis 8–9 aureis obovato-oblongis 2–3-dentatis involucro glabriusculo æquilongis; disci floribus 10–12 receptaculi convexi paleis totidem linearibus fere discretis circumdatis; pappo e paleis 5 linearibus vel subulatis fimbriato-denticulatis. — Rocky precipices in the interior of Guadalupe Island, off Lower California, Dr. E. Palmer. Disk-akenes well-formed, but apparently sterile. This and the following are striking additions to the *Hartmannia* section of the genus.

Hemizonia (Hartmannia) floribunda. Erecta, glanduloso-pubescens, forte tripedalis (basi ignota); ramis crebris foliosissimis; foliis linearibus obtusis integerrimis ($\frac{1}{4}$–$\frac{1}{2}$-pollicaribus): capitulis ramulos terminantibus paniculatis (lin. 3–4 altis); involucro creberrime glanduloso disco breviore: ligulis plus 20 majusculis biseriatis cuneatis apice 3-lobatis aurantiacis: fl. disci totidem: receptaculo parum convexo inter discum et radium paleis linearibus discretis onusto; acheniis disci plerumque fertilibus pappo e paleis 5–8 late ovatis obtusissimis integerrimis dorso margineque hirsutulis coronatis. — California, near the southern boundary, on the Fort Yuma Road, 80 miles east of San Diego. Dr. E. Palmer. Belongs to the subdivision which includes *H. angustifolia* and *H. corymbosa*.

Artemisia Palmeri. (*Seriphidium*, licet receptaculum paleis onustum.) Ut videtur elata et herbacea, cinereo-puberula: foliis 3–5-partitis, ramealibus integerrimis lobisque augusto-linearibus elongatis subtus tomentoso-incanis margine revolutis; panicula amplissima floribunda: involucri squamis ovatis subscarioso-membranaceis; acheniis immaturis disco epigyno majusculo. — San Diego County, California, in Jamuel Valley, 20 miles below San Diego, Dr. E. Palmer. Habit nearly of *A. Californica*, but apparently herbaceous throughout, and with the leaves or lobes broader and flat, a line or more in diameter.

Heads a line and a half in diameter: flowers all perfect; most of them subtended by paleæ, the outer ones similar to the involucral scales, the inner shorter and smaller.

Senecio Palmeri. Suffruticosus, tomento implexo candidissimus, ramosissimus; foliis in ramis floridis confertis oblongo-spathulatis subintegerrimis in petiolum sat gracile attenuatis; pedunculo elongato nudo corymboso-7–14-cephalo; involucro ecalyculato incano, squamis 20–30 linearibus; ligulis 12–18 ovalibus aureis; acheniis sericeo-incanis. — Abundant through the northern half of the Guadalupe Island, Lower California. One of the most conspicuous plants, about a yard high; the foliage strikingly white, and the flowers bright yellow. Heads fully half an inch high, many-flowered; rays 4 lines long.

Pyrrhopappus Rothrockii. Gracilis; caule ultrapedali e radice fusiformi perenni? simplici vel inferne ramoso folioso mono–oligocephalo; foliis linearibus integerrimis vel basim versus parce pinnatifido-laciniatis dentatisve; pedunculo gracili fere nudo; capitulo angusto circiter 20-floro; involucri squamis exterioribus paucis subulatis adpressis; acheniis rugulosis sursum scabris; pappo maturo sordide albo! — Fisch's Ranch in Southern Arizona, at 5000 feet altitude, J. T. Rothrock, in Wheeler's Exploration, 1874.

PALMERELLA, Nov. Gen. *Lobeliacearum.*

Calycis tubus turbinatus, ovario biloculari multiovulato adnatus; limbus 5-partitus, lobis angustis æqualibus. Corollæ tubus lineari-elongatus (intus pubentissimus), omnino saltem superne integer; fauce nunquam dilatata; limbo patente valde inæquali, lobis 2 minoribus spathulato-linearibus, 3 majoribus oblongis basi connatis. Filamenta corollæ tubo longissime adnata, dein monadelpha et uno latere sæpius alterius adnata: antheræ oblongæ, 2 setis paucis rigidis inæqualibus vertice penicillatæ, 3 paullo majores nudæ. Cæt. *Lobeliæ.* Fructus maturus haud visus.

P. debilis. Herba glaberrima, gracilis, ultrapedalis, ramosa; foliis alternis tenuibus lineari-lanceolatis integerrimis eglandulosis sessilibus 2–3-pollicaribus, floralibus sensim diminutis bracteis racemi laxi pauci–pluriflori referentibus; corollæ tubo albido ¾-pollicari, lobis læte cyaneis, 2 minoribus, majoribus lineas 3–4 longis. — Great Cañon of the Tantillas Mountains, near the northern borders of Lower California, Dr. Edward Palmer, to whom this genus is dedicated in acknowledgment of his indefatigable and fruitful explorations of the botany of the south-western frontiers of the United States, from Arizona to the islands off Lower California, in which region he has accomplished more than all his predecessors.

The genus differs from *Lobelia* in the remarkable adnation of the stamens, as well as in the integrity of the corolla tube, at least its upper portion. It soon splits from the base upwards for a good distance, and, indeed, before withering the lower part of the corolla is much disposed to separate into five claws (liberating also the lower part of the filaments); but this occurs in many species of *Lobelia*. From *Rhizocephalum*, of Weddell, this is distinguished by the habit, the very dissimilar lobes of the corolla and its narrower throat, and the completely 2-celled ovary, which probably matures numerous minute seeds.

SPECULARIA Heister. Although the two sections made by Alph. De Candolle are untenable, since species of the Old World (*S. falcata*, for instance) have lenticular seeds, and an American one, much confounded with *S. perfoliata*, has the valvular openings of the capsule near the summit, yet the American species may be well distinguished from the European, and into two sections, by taking account of the cleistogamous flowers. These are regularly produced in our species, and not in those of the Old World. (They have recently been said to occur sometimes in *S. hybrida* and *S. falcata*, but I have not found any trace of them.) They were noticed by Linnæus in the species known to him, but were wrongly thought to be incomplete and imperfect, as Dr. Torrey remarked, when he accurately described them over half a century ago. They were what we termed precociously fertilized flowers, of necessity close-fertilized, — a term to which Mr. Darwin took objection in the instance of *Impatiens* and *Viola*, and with reason if the name stands in the way of recognition of their special adaptation to close fertilization; and the proper name of "cleistogamous" is now established. But one of our species of *Specularia*, as well as the genus *Lespedeza*, lends support to our original view, by showing close fertilized blossoms as if in various stages of arrest of development. There is a mistake in Dr. Torrey's remark (in Flora of the State of New York, 1, p. 429), that Ruiz and Pavon's plate of *Campanula biflora* represents the two kinds of blossoms. It is curious that this species should have been confounded with our common northern one, as by Alph. De Candolle in the Prodromus, and by Mr. Bentham in his recent notes upon that order in Jour. Linn. Soc. 15, p. 13. The views which we here take may be best exhibited in a conspectus of the American species.*

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* SPECULARIÆ AMERICANÆ.

§ 1. CAMPYLOCERA. Flores dimorphi, præcociores cleistogami. Capsula elongata, valvulis infra-apicalibus dehiscens, sero saltem in præcocioribus ab apice longitudinaliter subdissiliens. Ovarium in floribus cleistogamis quandoque abortu uniloculare, placenta laterali. — *Campylocera* Nutt. in Trans. Amer. Phil. Soc. n. ser. 8, p. 257 (1843).

1. S. LEPTOCARPA. Caule virgato; foliis lanceolatis; floribus in axillis arcte sessilibus; stigmatibus 2–3; ovario in fl. cleistogamis nonnullis abortu uniloculari calycis lobis 3–4 superato; capsulis fere cylindricis gracilibus valvulis subapicalibus adscendentibus 1–3 pertusis, præcocioribus sæpius decurvatis raro tortis; seminibus oblongis. — *Campanula leptocarpa* Engelm. in herbariis. *Campylocera leptocarpa* & var. *glabella* Nutt. l. c. *Specularia Linsecomia* Buckley in Proc. Acad. Philad. 1861, p. 460. — Arkansas, Nuttall, Engelmann; Texas, Wright, Buckley; Colorado to the Rocky Mountains, Parry, Vasey. As to the twisting of the capsule on its axis, in the manner of *Downingia*, mentioned by Nuttall, it is hardly if at all to be seen in our specimens.

2. S. LINDHEIMERI Vatke in Linnæa, 38, p. 713. Procerior; caule erecto vel reclinato (1–3-pedali) superne nunc paniculato; foliis oblongo-lanceolatis imisve ovalibus; floribus brevi-pedunculatis vel subsessilibus magis paniculatis; stigmatibus loculisque ovarii semper 3–4; calycis lobis etiam in cleistogamis 5; capsulis angulatis basi angustatis haud curvatis tortisve valvulis 2–3 paullo infra apicem pertusis; seminibus fere orbiculatis. — W. Texas, Lindheimer, Wright, Buckley. I take this to be the "*Campanula Coloradoense*" Buckley, l. c., from his character of "stigmas 4–5" (I have seen only 4), and therefore have adopted the specific name. The seeds are described as "ellipsoid," of the preceding species "elliptical." The expanded corollas are an inch in diameter, about twice the size of those of *S. leptocarpa*. The capsules apparently are never one-celled, although the partitions separate readily from the axis, one carrying away the placenta, and there is a tendency to be septicidal. The perforations, moreover, are by valves that open from above downward, or by mere ruptures. In many of the cleistogamous flowers, the corolla has attained considerable development, so as to suggest a gradation between the two kinds.

§ 2. DYSMICODON Endl. Flores dimorphi, præcociores cleistogami calyce 3–4-lobo, normales serotini, calyce 5-lobo. Capsula brevior, aut sub apice aut infra medium pertusa. Semina lenticularia. — *Dysmicodon* Nutt. l. c. *Triodallus* Raf., ubi? *Specularia* § *Triodallus* Torr. Fl. N. Y.

3. S. BIFLORA. Caule gracili ad angulos retrorsum serrulato-hirtello vel sublævi; foliis ovatis oblongisve rariter crenulatis, superioribus lanceolatis flore fulcrato brevioribus; floribus in axillis solitariis binisve sessilibus; calycis lobis in cleistogamis brevibus ovatis vel subulatis, in normalibus lanceolato-subulatis elongatis corollam vix adæquantibus; capsulis cylindraceis subfusiformibus vix costatis, valvulis infra-apicalibus. — *Campanula biflora*, Ruiz & Pav.

ARCTOSTAPHYLOS ANDERSONII. *A. tomentosæ* affinis; ramis gracilioribus setis longis albis hispidis; foliis tenuiter coriaceis fere sessilibus glabris (costa subtus setosa excepta) viridibus oblongo-lanceolatis basi sagittato-cordatis sæpe spinuloso-serrulatis; drupis viscosissimo-hirtis. — Hills behind Santa Cruz, California, Dr. C. L. Anderson, 1873.

HESPERELÆA, Nov. Gen. *Oleacearum.*

Calyx tetrasepalus, æstivatione imbricativus, deciduus. Petala 4, spathulata, unguiculata, æstivatione apicem versus imbricata, accrescentia, decidua. Stamina 4, hypogyna, petalis alterna: filamenta subulata: antheræ oblongæ, subintrorsæ, mucronatæ. Ovarium ovoideum: ovulis in loculis binis ab apice pendulis: stylus columnaris: stigma crassum, bilobum, lobis dorso parum sulcatis. Fructus sine dubio drupaceus. — Arbor 3–4-orgyalis, glabra; foliis plerumque oppositis integerrimis oblongis coriaceis e costa valida penniveniis; paniculæ floribundæ ramis pedicellisque brevibus articulatis; floribus sulphureis hermaphroditis nunc ovario imperfecto polygamis.

HESPERELÆA PALMERI. Guadalupe Island, off Lower California; found only in a cañon on the eastern side. Leaves 2 inches or more in length. Sepals oblong, somewhat scale-like and concave, greenish becoming yellowish. Petals when full grown nearly half an inch long, pale lemon-colored; the claw about the length of the sepals and the filaments. A very marked new genus, of the Oleineous tribe, remarkable for the wholly distinct and unguiculate petals, with imbricative æstivation, and the apparently uniformly isomerous stamens.

Fl. Per. 2, p. 55, t. 200, fig. 6. *C. Monteridensis* Spreng. Syst.? ex char. *C. Ludoviciana* Torr. (ined.?). *C. intermedia* Engelm. in herbariis & ex Nutt. l. c. *Dysmicodon Californicum & ovatum,* Nutt. l. c. *Specularia ovata* Torr., Vatke, l. c. — S. Carolina to Arkansas, Texas, and in California; also in S. America. Singularly confounded with the next. It much more resembles *S. falcata* of the Old World, which, however, has longer calyx-lobes, and, so far as I have seen, homomorphous flowers.

4. S. PERFOLIATA A. DC. Prodr., excl. syn. nonnul.; Torr. Fl. N. Y. 1, p. 428, t. 65. *Campanula flagellaris* HBK. Nov. Gen. 3, t. 265. *Dysmicodon perfoliatum* Nutt. l. c. Subhispida; foliis rotundato-cordatis quasi amplexicaulibus; capsulis brevioribus basi angustioribus, valvulis infra medium sitis. — Canada to Texas, Oregon, Mexico, &c. *Triodallus rupestris* Raf., according to specimens in herbaria, is a depauperate and diffuse state, in which only the close-fertilized blossoms are developed.

Gentiana Newberryi. Pneumonanthe, nana; foliis radicalibus rosulatis obovatis vel spathulatis; caulibus floridis 2–4 circa innovationem centralem folia parvula spathulata vel sublanceolata basi connato-vaginantia (summa florem unicum stipantia) gerentibus; calycis lobis lanceolatis oblongisve tubo subæquilongis; corolla cærulescente late infundibuliformi, appendicibus plicarum bifidis vel subulato-laciniatis lobis ovatis mucronatis brevioribus; seminibus ovalibus ala lata cinctis. — *G. calycosa?* Gray in Pacif. R. Rep. 6, p. 86, non Griseb. — Oregon and California, in the Sierra Nevada, from Crater Pass (Newberry) to Mariposa County, Bolander. Related to *G. frigida*. Corolla over an inch long, pale blue, white within, and greenish-dotted. Flowering stems an inch or two in length.

Gentiana setigera. Pneumonanthe; caulibus sat validis (pedalibus) adscendentibus e caudice crasso foliosis; foliis inferioribus orbiculato-ovalibus, superioribus obtusissimis, summis 4 florem involucrantibus, omnibus basi connato-vaginante; calycis lobis ovalibus tubo æquilongis; corolla oblongo-campanulata, appendicibus plicarum brevibus parvulis setas capillares 2–3 lobis ovatis fere adæquantes gerentibus. — Red Mountain, Mendocino County, California, Bolander, No. 840 of Kellogg and Harford's distribution. Leaves 7 to 10 pairs on the stem, thick, an inch or less in length. Corolla an inch and a half long, and the blue lobes nearly half an inch long. Forming seeds orbicular and winged.

Halenia Rothrockii. Annua, ultraspithamæa, laxiflora; foliis linearibus; corolla lutea, calcaribus subulatis divaricatis parum adscendentibus calycis lobos lineares subæquantibus. — Arizona, on Mount Graham, at 9000 feet, Dr. J. T. Rothrock, in Wheeler's Expedition, 1874.

Microcala quadrangularis Griseb. Whether this South American species is indigenous to California would appear uncertain as to the vicinity of San Francisco. But Dr. Bolander found it "near Mendocino, under *Pinus contorta*," where it seems unlikely to have been brought by the agency of men or cattle. Dr. Engelmann indicated to me that the stamens are inserted in the very sinuses, not below on the tube as figured by Progel in the Flora Brasiliensis. Then the stigma, as Dr. Engelmann has also shown in both species of the genus, is separable or in age actually divides into two.

Gilia Larseni. Eugilia, depressa, surculis filiformibus repentibus apice foliatis perennans, pubescens; foliis omnibus alternis confertis pedatim 5–7-partitis summisve trifidis, lobis lineari-oblongis majoribus subcuneatis 2–3-fidis; floribus inter folia subsessilibus; corolla infundibuliformi violacea (semipollicari) calyce 2–3-plo longiore, lobis late ovalibus; ovulis solitariis. — California, on Lassen's Peak, J. G. Lemmon and John Larsen, 1875. Habit of the *Navarretia* section; but the lobes of the leaves and of the calyx are not even mucronate, and the flowers are sparse.

Gilia (Ipomopsis) Haydeni. Fere glabra, e basi indurata perenni vel bienni paniculato-ramosissima, pedalis; foliis linearibus, imis vix spathulatis parce pinnatilobatis dentatisve, ramealibus plerisque minimis subulatis integerrimis; paniculis subthyrsoideis floribundis calycibusque parum glandulosis; corolla cæruleo-purpurea gracili infundibularitubulosa (ultra-semipollicari), tubo lobis suis ovatis calyceque 3–4-plo longiore; antheris oblongo-sagittatis subsessilibus fauci insertis; ovarii loculis 8–9-ovulatis; seminibus paucis oblongis, tegumento humectato nec spirillifero nec mucilaginoso! — Mesa San Juan, southern borders of Colorado or adjacent part of Utah, T. S. Brandegee, in Hayden's Exploration of 1875. Dedicated to the indefatigable explorer and geological surveyor, in charge of this and many other successful explorations of our Rocky Mountain regions. The species has the habit and color of corolla of the *Eugilia* division, but the long narrow corolla and bractless pedicels of *Ipomopsis*.

Gilia Brandegei. Eugilia, perennis, pube glandulosa fragrante viscosissima; caulibus erectis spithamæis vel subpedalibus thyrsifloris; foliis circumscriptione linearibus pinnatisectis, segmentis plurimis sessilibus parvis aut oblongo-linearibus rarius ovalibus integerrimis aut bipartitis verticillos 3–4-foliolatos simulantibus; corolla aurea infundibuliformi-tubulosa calyce cylindraceo semiquinquefido 2–3-plo longiore, fauce parum ampliata, lobis ovalibus brevibus; ovulis in loculis paucis. — South-western part of Colorado, in San Juan Gap on the face of perpendicular cliffs, T. S. Brandegee, in Hayden's Exploration, 1875. A showy as well as most remarkable species, with trumpet-shaped golden-yellow corolla, about an inch long. Leaves 2 or 3 inches, and their divisions only one or two lines in length. The likeness of this plant in foliage, flowers, and fragrant viscosity to *Polemonium confertum* var. *mellitum* is most striking. That species is itself sufficiently anomalous in *Polemonium*, on account of its lengthened corolla; but its filaments are really declinate-curved, while they appear to be not at all so in the present plant. If this character be relinquished, nothing will be left absolutely to distinguish either *Polemonium* or *Lœselia*.

LŒSELIA Linn. § GILIOPSIS. Flores paniculati vel sparsi, ebracteati. Corollæ lobi subcuneati, apice eroso-truncati vel subtridentati. Folia angustissima nuda. (Ovula in loculis 8–10. Semina ut in spec. propriis exalata!)

LŒSELIA TENUIFOLIA. E basi frutescente multicaulis, spithamæa ad pedalem, glabella; ramis gracilibus apice laxe paucifloris; foliis fere acerosis cuspidato-mucronatis integerrimis vel inferioribus sublinearibus pauci-pinnatipartitis, lobis subulatis; calycis lobis subulatis tubo dimidio brevioribus; corolla punicea tubuloso-infundibuliformi (pollicari), tubo lobis 3–4-plo longiore; genitalibus longius exsertis. — Northern borders of Lower California, Tantillas Mountains, especially at the entrance of the Great Cañon, W. Dunn, E. Palmer. Longer leaves an inch long; the upper gradually reduced to small subulate bracts, but none at the base of the calyx. One lobe of the corolla separated from the others by deeper sinuses; the long capillary filaments (which are inserted low down on the tube) more or less declined to that side, and their summits a little incurved.

LŒSELIA EFFUSA. Spithamæa ad pedalem, e radice annua laxe ramosissima, glabella; ramis ramulisque paniculato-floribundis gracillimis rigidulis; foliis omnibus fere filiformibus mucrone apiculatis integerrimis (radicalibus evanidis); calycis dentibus brevibus latis; corolla brevi-infundibuliformi purpurea, tubo calycem paullo superante lobis inæqualibus haud longiore; genitalibus (sat declinatis apice incurvis) corollam parum excedentibus. — Tantillas Mountains, borders of Lower California, Dr. E. Palmer. Stem sometimes as if lignescent at base; but the root plainly annual. Leaves from half to a quarter of an inch long, or less. Pedicels sometimes as long as the flowers, mostly shorter than the calyx. Corolla ("pink," but in the dried specimens violet-purple) barely half an inch long, the limb rather ample and spreading, one or two lobes rather smaller and more separated. Capillary stamens inserted low on the tube of the corolla. Ovules, seeds, &c., as in the preceding.

Except for the declined stamens and some inequality of the corolla, these two species would be referred to *Gilia*, the former to the section *Ipomopsis*, the latter to *Eugilia*. But they accord with *Lœselia*, except in the total absence of dilated bracts, which, considering the case of *Gilia*, cannot be the generic character. The seeds do not supply a character. These in *Lœselia*, as remarked in the yet unpublished portion of the Genera Plantarum by Bentham and Hooker, develop mucilage when wet; the mucilage-cells are underneath a rather firm pellicle, as in several species of *Gilia;* moreover, in no species that I have examined is there any membranaceous margin, still less a wing; the slight border which sometimes gives an appearance of one comes from the drying of the somewhat translucent mucilaginous coating. The characters which distinguish *Gilia, Polemonium*, and *Lœselia* are by no means as definite as was supposed before such connecting forms as these and the preceding were known. But I conclude that these two plants must constitute a section of *Lœselia*.

LACHNOSTOMA HASTULATUM. Gracillimum, volubile, pube densa brevi undique cinereum; foliis parvis (lin. 2–3 longis et petiolo subæquilongo) hastatis; floribus solitariis fere sessilibus; sepalis linearibus; corollæ 5-partitæ lobis lato-linearibus tantum puberulis intus glabrioribus; corona simplici asclepioidea, nempe e squamis 5 cuculliformibus apice tridentatis intus ligula brevi subulata auctis; folliculis fusiformibus parce molliter muricatis. — Cañon Tantillas, within the northern borders of Lower California, Dr. Palmer. Corolla greenish-white, only 2 lines long. Follicles nearly 2 inches long.

PHACELIA (EUPHACELIA) PHYLLOMANICA. Elata, ramosa, foliosissima, pube et brevi molli densa et superne longiore villosa canescens; foliis pinnatisectis, segmentis 17–25 crebris oblongo-linearibus pinnatifidis, lobis brevibus oblongis nunc paucidentatis; spicis thyrsoideo-congestis primum densis; floribus sessilibus; calyce e phyllis aut omnibus foliaceis pinnato-3–5-partitis aut 1–3 lato linearibus integerrimis corolla violacea parum brevioribus; plicis brevibus latissimis; staminibus subexsertis. — Var. INTERRUPTA: viridula, pube laxiore; foliis tenuioribus, segmentis paucioribus sparsioribus hinc inde ad lobulum reductis, majoribus sinuato- vel crenato-bipinnatilobatis. — A striking species of the *P. tanacetifolia* section, perhaps not an annual, destitute of hispid hairs and of glands, but rather viscid in the inflorescence; the dissected foliaceous calyx peculiar. The annular disk is very conspicuous.

EMMENANTHE PUSILLA. Exigua, piloso-pubescens; foliis crassiusculis oblongo-lanceolatis vel spathulatis integerrimis in petiolum sat gracilem attenuatis; racemo 3–7-floro laxo, primario scapiformi; corolla minima (alba?) sepalis linearibus parum spathulato-dilatatis capsulaque ovoidea obtusissima mutica dimidio breviore; stylo perbrevi; seminibus 10 valde grosseque rugosis *Microgenetis*. — Western Nevada, at Steamboat Springs, S. Watson (part of No. 878, early young plants confounded with *Phacelia pusilla*), and in the same district in

May, 1875, Lemmon. A congener of *E. glaberrima* Torr., which also appears to have a white rather than yellow corolla. Plant 1 to 3 inches high, slender. Leaves 2 to 5 lines long and with petiole of almost equal length. Peduncle and raceme filiform; pedicels mostly shorter than the calyx; the latter in flower one line, in fruit two lines long. Very short and small style deciduous from the capsule. Seeds less than half a line long.

HARPAGONELLA, Nov. Gen. *Borraginacearum.*

Calyx inequalis obliquus, e sepalis 3 a basi solutis immutatis, 2 alte connatis in cucullum fructiferum dorso glochidiatum auctis. Corolla tubo brevissimo subrotata, lobis æstivatione imbricatis, fauce fornicibus obtusis instructa. Stamina brevia, tubo inclusa: antheræ minimæ, ovatæ. Stylus brevis: stigma subcapitatum. Ovarii segmenta subglobosa, gynobasi planiusculæ affixa, duo abortiva; ovula in fertilibus erecta, anatropa, foramine infero. Nuculæ 2, collaterales, læves, oblongæ vel subclavatæ, ab areola parva adscendentes, una nuda sæpe infertilis, altera major intra cucullum calycinum 6–7-cornutum (cornibus undique patentibus setis uncinatis armatis) arcte clausa. Semen nuculæ conforme, basifixum: cotyledones ovatæ, radicula brevi infera vel centripeta. — Herba pusilla, annua, *Pectocaryæ* facie; foliis linearibus, pedunculis sparsis brevibus extra-axillaribus post anthesin deflexis, floribus minimis, corolla alba. (Benth. & Hook. Gen. Pl. 2, p. 846, adhuc ined.)

HARPAGONELLA PALMERI. — Guadalupe Island, off Lower California, 1875, Dr. E. Palmer. A slender and sparingly branched annual, 2 to 5 inches high, cinereous-hirsute. Leaves linear, an inch or less long, and the floral gradually reduced to bracts a line or two long. Peduncles in fruit a line long, stout, and strongly recurved. Calyx in flower barely a line long, 5-parted, except between two of the sepals, which coalesce to the middle; below the sinus of the coalescent divisions is an external tufted appendage, which at length develops into the soft-spiny horns. Short style slender to the base. Gynophore not elevated. The two lobes of the ovary on the side of the flower next to the three nearly separate and unchanged sepals (which we may designate the lower side of the flower) are uniformly and early abortive; the other portion of the calyx accrescent, and soon gibbous-involute into a sort of coriaceous burr, of about 2 lines in length, armed with a few (usually 7) spiny horns, of a line or two in length, which spread in all directions, and are beset for nearly their whole length with short and very stiff backwardly hooked bristles; the burr closing on the ventral side, and completely covering a fertile nutlet: the other nutlet is free, and is certainly sometimes fertile, but more commonly, although enlarging, it seems to fail to mature a seed. The adaptive character of this little plant, viz., the transference of the burr-like apparatus for the dissemination of the seed from pericarp to the calyx, and the investment by the latter of only one of the two ripening nutlets, is most remarkable. The habit is that of *Pectocarya*, with which it is associated upon the island; but the structure is very different.

ECHIDIOCARYA, Nov. Gen. *Borraginacearum.*

Calyx 5-partitus; segmentis linearibus, fructiferis laxis. Corolla infundibuliformis, sub fauce nuda parum constricta, lobis æstivatione imbricatis. Filamenta brevissima: antheræ oblongæ. Ovarii lobi gynobasi vix elevatæ impositi: stylus brevis: stigma didymum. Nuculæ 4, latæ, ovato-pyramidatæ, inermes, subrugoso-muriculatæ, dorso ventroque carinulatæ, carina ventrali apice breviter producta, areola basilari late concava in stipitem longe producta, stipitibus infra medium per paria connexis introrsum apertis gynobasin conicam claudentibus; cicatrice lata excavata post nuculas delapsas in gynobasi relicta. Semen breve, leviter curvum: cotyledones latæ subplanæ. — Herba annua, diffusa; foliis (oblongo-linearibus) floribusque *Eritrichii* sect. *Plagiobothridi* referentibus, corolla parva alba vel cærulescente. (Char. maxima ex parte e Benth. & Hook. Gen. Pl. 2, p. 854, adhuc ined.).

ECHIDIOCARYA ARIZONICA. — Verde Mesa, Arizona, Dr. Smart.

CONVOLVULUS (CALYSTEGIA) OCCIDENTALIS. Aut glaber, aut minute pubescens, volubilis; foliis nunc ovato-triangularibus sinu profundo angusto nunc lanceolato-hastatis immo lineari-sagittatis, lobis posticis sæpe 1–2-dentatis; pedunculo elongato intra bracteas ovatas vel oblongas quandoque bifloro; corolla alba vel erubescente, limbo lato; stigmatibus fere linearibus. — Common throughout the western part of California, on and near the coast. The more luxuriant and broader-leaved forms so much resemble *C. sepium* that only the shape of the stigmas surely distinguishes them. But I have never seen *C. sepium* with a second flower, while this often has two, and rarely even three from the pair of bracts. The Californian species abundantly confirm Mr. Bentham's remark in the Flora Australica, that the characters of *Calystegia* are too artificial, and it may now be added too transitional, to warrant the adoption of the genus.

Convolvulus (Calystegia) Californicus Choisy, which is *Calystegia subacaulis* Hook. & Arn., has the same narrow (at most oblong-linear) stigmas, with very short or merely trailing stems, obscurely if at all hastate and obtuse leaves, and oblong or oval bracts, very similar to the outer sepals and not surpassing them.

Convolvulus (Calystegia) villosus, the *C. n. sp.?* Torr. in Pacif. R. Rep. 4, p. 127, and *Calystegia villosa* Kellogg in Proc. Calif. Acad. 5, p. 17, is an allied species, usually silvery white with a dense and soft tomentum, trailing or feebly twining, and the leaves varying from reniform-hastate to sagittate, the bracts oval or ovate, and only equalling the calyx, the corolla cream-color. The following, instead of the calyx-like membranaceo-foliaceous bracts close to the calyx and enveloping it, has a foliaceous pair at some distance below.

Convolvulus luteolus Gray. Aut glaber, aut pubescens, gracilis, volubilis; foliis triangulari-hastatis vel sagittatis, lobis nunc bifidis; pedunculis folio æquilongis uni- raro bifloris sub flore bracteas 2 lineares seu lanceolatas folioformes gerentibus; sepalis rotundatis; corolla pallide lutea pollicari vel longiore. — *Ipomœa sagittæfolia* Hook. & Arn., Bot. Beechey, p. 151, licet stigmatibus linearibus. Var. fulcratus. Magis pubescens; flore foliis hastatis vel sagittatis stipato. *C. Californicus* Torr. Pacif. R. Rep. 4, p. 127, non Choisy. — California, in various parts of the State, especially in the southern and western portions; its bracts from one to four lines long, and about the same distance below the calyx. The variety, which often much resembles *C. villosus*, abounds in the foot-hills of the Sierra Nevada, and has bracteal leaves commonly half an inch long.

Cuscuta salina Engelm. is a new species added to the Californian flora: it includes *C. subinclusa* var. *abbreviata*, and *C. Californica* var.? *squamigera* of Engelmann's monograph. It affects saline soil and Chenopodiaceous plants, especially *Salicornia*, and occurs on the coast from San Francisco Bay to British Columbia.

CHAMÆSARACHA. Vide Proc. Am. Acad. 10, p. 62. As Mr. Bentham has justly remarked (Gen. Pl. 2, p. 891. ined.), this is better completely separated from the genus *Saracha*; and only three species are made out, *C. Coronopus*, *C. sordida*, and *C. nana*. *Saracha acutifolia* of Miers, which is not well described, appears to be a *Physalis*.

Solanum Xanti. *Pachystemonum*, *Dulcamara*, basi suffruticosa excepta herbaceum, aut subglabrum aut pilis simplicissimis sæpe glandulosis pubescens, 1–2-pedale; ramis gracilibus subflexuosis; foliis membranaceis ovatis seu ovato-oblongis petiolatis basi subcordatis vel subcuneatis nunc integris nunc lobis lateralibus utrinque auriculatis; cymis umbelliformibus primum terminalibus pauci–plurifloris nunc furcatis; pedicellis filiformibus; corolla violacea plano-rotata angulato-subquinqueloba pollicem diametro; calyce 5-lobo, fructifero erecto sub bacca (purpurea?) globosa modice ampliato. — California, through the southern and eastern parts of the State, but extending to Sierra County, J. G. Lemmon, and to Nevada, near Carson, Anderson. It is named in honor of L. I. Xantus, one of the earlier collectors of the species. This has been confounded with *S. umbelliferum*, Dr. Bigelow's specimen from Cocomungo having been referred to that species by Torrey in the Botany of Whipple's Expedition, as was that of Anderson from Nevada, by Watson in King's Expedition. Besides other marks, the pubescence is notably different (but sometimes almost wanting), consisting of simple and few-jointed hairs, some of which are glandular. It is so variable in foliage that the following plant is probably referable to it.

Var. Wallacei. Majus; ramis junioribus pedunculisque pilis longis pluri-articulatis viscidis villosis; cyma furcata ampliore; corolla sesquipollicem diametro læte violacea. — Island of Catalina, off San Pedro, California, Wallace. No. 586 of Coulter's Californian collection, of which my specimen wants the flowers, and which is glabrous and has cordate leaves, may be a form of this.

Solanum umbelliferum Esch. This variable species abounds around San Francisco and in all that part of California. Eschscholtz described a form with ovate acute leaves, but they are more commonly obtuse, and the smaller ones inclined to obovate. *S. Californicum* of Dunal is this ordinary form, and *S. genistoides* a depauperate and small-leaved summer state of the same. The species is well marked by the somewhat furfuraceous or tomentose pubescence, which, under a lens, is seen to be composed of repeatedly branching hairs.

COLLINSIA Nutt. This genus is exceedingly well marked, but the species are difficult of discrimination. Eleven species may be distinguished, of which nine are in the Californian flora, and two in the Mississippi region and eastward.*

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* COLLINSIA Nutt.

§ 1. *Confertifloræ*, pedicellis brevibus vel subnullis. Occidentales.

* Corolla valde declinata, fauce saccata subtransversa (in tubum proprium quasi hemitropa) vix longiore quam lata: filamenta superiora basi parce barbata: glandula (rudimentum staminis quinti) parva, sessilis.

TONELLA Nutt. There are two well-marked species. Although the character of solitary ovules, assigned in Proc. Am. Acad. 7, p. 378, holds in only one of them, yet the form of the corolla — with rotately expanding lobes and the lower one open, not at all enclosing the stamens and style — appears to mark the genus as a good one. Moreover, the middle leaves are almost all 3-parted or divided. The species are: —

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1. C. BICOLOR Benth. Calycis lobis acutis; corollæ bicoloris nunc albæ fauce ventricosa valde obliqua, labio superiore quam inferius parum breviore. — *C. heterophylla* Graham, Bot. Mag. t. 3695, foliis imis trifidis. — Chiefly in the western part of California.

2. C. TINCTORIA Hartweg in Benth. Pl. Hartw. Viscidior; pedicellis brevioribus vix ullis; calycis lobis linearibus vel angusto-oblongis sæpius obtusis; corollæ (ochroleucæ, nunc albæ nunc purpureo notatæ) fauce ventricosissima transversa, labio superiore brevissimo, lobis lateralibus intus parce barbatis. — *C. barbata* Bosse in Bot. Zeit. 12, p. 905 (1853). *C. septemnervia* Kellogg in Proc. Calif. Acad. 2, p. 224, fig. 69. — Mainly in and towards the Sierra Nevada.

* * Corolla minus declinata, fauce gibbosa obliqua longiore quam lata: caules humiliores: folia plerumque crenato-dentata, crassiuscula, obtusa.

+ Filamenta pl. m. barbata: labium superius corollæ (sub lobis parum callosum) haud cristatum: calycis lobi latiores obtusi.

3. C. BARTSIÆFOLIA Benth. in DC. Puberula, subglandulosa, vel superne viscidulo-hirsuta, erecta; verticillis florum 2–5; corollæ labio superiore fauci obliquo æquilongo, lobis lateralibus emarginatis vel obcordatis; glandula sessili elongata porrecta. — *C. bicolor* var.? *parviflora* Benth. Pl. Hartw. No. 1884. *C. hirsuta* Kellogg, l. c. p. 110, fig 34, forma hirsutior. The low transverse callosity at the junction of the limb of the upper lip of the corolla with the throat, which is visible in several species, is more evident in this; it borders a small hood-like depression.

4. C. CORYMBOSA Herder, Ind. Sem. Petrop. 1867, & Gartenfl. 1868, t. 568. Glabra vel subpuberula, decumbens; foliis carnosulis latioribus; floribus in capitulum unicum congestis; corolla bicolore rectiuscula, labio superiore brevissimo, lobis fere obsoletis; glandula parva complanata stipitata. — Coast of the northern part of California.

+ + Filamenta glabra: corollæ labium superius sub lobis fornicato-cristatum: calycis lobi angustiores acutiusculi; flores parvuli violacei.

5. C. GREENEI Gray, Proc. Am. Acad. 10, p. 75. — Lake County, California, E. L. Greene.

§ 2. *Laxifloræ*, pedicellis elongatis aut solitariis aut umbellato-verticillatis.

* Glabræ: folia inferiora saltem radicalia rotunda vel oblonga, pl. m. dentata: calycis lobi acuti, fructiferi capsulam superantes.

1. T. COLLINSIOIDES Nutt. ex Benth. in DC. Prodr. 10, p. 593 Tenella, sparsiflora; floribus minimis; corolla calyce paullo longiore, lobis posticis et lateralibus subconformibus oblongis ab antico multo latiore sinubus profundioribus magis discretis; ovarii loculis uniovulatis. — *Collinsia tenella* Benth. in DC. Prodr. l. c. — Oregon, near the coast to Mendocino County, California, Nuttall, E. Hall, Bolander, and Kellogg.

2. T. FLORIBUNDA. Vegetior, 1–2 pedalis; racemis floribundis virgatis e verticillis 3–7-floris; corolla ampla (lin. 3–4 lata) calyce multo

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+ Orientales, lætifloræ: folia caulina plerumque ovato-lanceolata: corollæ fauce valde gibbosa labiis fere dimidio breviore: filamenta superiora inferne pl. m. barbata: glandula (in *C. verna*) subulata porrecta.

6. C. VERNA Nutt. Corolla bicolore (labio superiore albo, inferiore cæruleo) lobis tantum emarginatis. — New York to Missouri.

7. C. VIOLACEA Nutt. Corolla concolore violacea, lobis obcordato-bifidis, superioribus dimidio minoribus. — Arkansas. *Antirrhinum tenellum* is more likely to belong to this than to the preceding species.

+ + Occidentales mediocrifloræ: corolla fauce lata ventricoso-saccata limbo pl. m. breviore: pedicelli flores subæquantes.

8. C. GRANDIFLORA Dougl. in Bot. Reg. t. 1107. Floribunda; foliis floralibus lanceolatis linearibusque plerumque 3–7-natis; verticillis 3–9-floris; calycis lobis acuminatissimis; corolla bicolore (albo-cærulea) maxime declinata, fauce in tubo fere transversa, lobis parum emarginatis, labio superiore bicalloso; filamentis glabris; glandula sessili capitata. — North-western California to Washington Territory.

9. C. SPARSIFLORA Fisch. & Meyer. Gracilis, diffusa; foliis oppositis, floralibus superioribus minimis tantum ternatim verticillatis; pedicellis solitariis binisve, summis nunc ternis; calycis lobis ovatis vel deltoideo-lanceolatis acutis; corolla vix bicolore, fauce valde obliqua; filamentis inferne hirsutis; glandula sessili elongato-subulata. — *C. parviflora* var. *sparsiflora* Benth. in DC. *C. solitaria* Kellogg, l. c. p. 10. — North-western California.

+ + + Boreali-occidentales, parvulæ, parvifloræ: pedicelli floribus longiores: corolla subconcolor e calyce paullo vel dimidio exserta, fauce oblongo obliquo labiis longiore: filamenta glabra: glandula capitata brevi-stipitata.

10. C. PARVIFLORA Dougl. in Lindl. Bot. Reg. t. 1802. — *C. minima* Nutt. in Jour. Acad. Philad. 7, p. 47. — From Lake Superior to California and northward.

* * Glandulosa, viscida: folia linearia, radicalia oblanceolata, omnia integerrima: calycis lobi angusti, obtusi, capsula breviores: corolla parvula, læte cærulea, calyce multo longior: filamenta glabra: glandula sessilis subulata.

11. C. TORREYI Gray, Proc. l. c. 7, p. 378. — California, through the higher region of the Sierra Nevada.

longiore; labii inferioris trisecti lobis 3 fere conformibus obovatis iis labii superioris bifidi minoribus; ovarii loculis 3–4-ovulatis. — *Collinsia grandiflora* Hook. Kew. Jour. Bot. 3, p. 298, non Lindl. Willow thickets of the Valley of the Kooskooskee, in the western part of Idaho, Spalding, Geyer. The sessile gland representing the fifth stamen is at the very base of the corolla; in the preceding species it is higher up on the tube and smaller.

Pentstemon barbatus Nutt., var. trichander. Humilior e caudice lignescente; antheris longe parceque lanoso-barbatis! — S. W. Colorado, T. S. Brandegee, in Hayden's Exploration, 1875. Mr. Brandegee was struck with this as different from *P. barbatus* in its growth and aspect; but I see no character to distinguish it from the var. *Torreyi* of that variable species, except the long hairs on the anthers, and sometimes a few on the filaments. This has not been elsewhere met with in the *Elmigera* section. But it occurs with such variability and apparent inconstancy in *P. glaber* and some allied species, that it may not be relied on here.

Pentstemon Clevelandi. *P. spectabili* quoad folia et inflorescentiam haud dissimilis; foliis superioribus arcte sessilibus nec connatis, floralibus minimis; thyrso racemiformi nudo floribundo; pedicellis breviter filiformibus; calycis parvi lobis ovatis capsulam 3–4-plo brevioribus; corolla sanguinea tubuloso-infundibuliformi (fere pollicari), fauce paullo ampliata, lobis brevibus rotundatis patentibus; filamento sterili apice dilatato hinc barbato. — Cañon Tantillas in Lower California, received from D. Cleveland in flower, and later from Dr. Palmer in fruit.

MIMULUS Linn. Having had occasion to elaborate the species belonging to the Californian flora, I have thought it best to give a synoptical view of all the known North American *Mimuli*. Some are difficult to limit, and the extent of the genus was also uncertain. There are three or four groups of species, which would necessarily rank as genera distinct from true *Mimulus*, if they were not connected by transitions. Perhaps the most marked of these is represented by two dwarf Californian annuals with long filiform tube to the corolla, and a cartilaginous capsule, the valves of which bear the half-septa and placentæ. One of them was probably the type of the genus *Eunanus* Benth. in DC. But the tube shortens and broadens in a long series of species, which at length pass into true *Mimulus*, in which the placenta sometimes partially and rarely completely divides. Equally peculiar in habit are the shrubby species or forms on which the genus *Diplacus* Nutt. was founded. Here the two placentæ are hardly at all united in the axis, even in the blossom; which is otherwise that of a true *Mimulus*. Then there is a low annual species with short corolla and thin-walled capsule, but the placentæ dividing with the valves, which is so peculiar in wanting the angles or keels which are so conspicuous in *Mimulus* that it was referred to a peculiar section of *Herpestis*. Altogether it seems necessary to regard the whole as one polymorphous genus, and to arrange our species as in the subjoined conspectus.*

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* MIMULUS Linn.

§ 1. EUNANUS. (*Eunanus* Benth. in DC.) Herbæ annuæ, plerumque nanæ: calyx 5-dentatus, 5-angulatus, angulis dentibusque pl. m. plicato-carinatis: corolla in typicis tubo gracili elongato: stylus superne glandulosus vel pubescens: stigma aut bilamellatum, aut labiis latis petaloideo-dilatatis connatis peltatum vel infundibuliforme: capsula valvis medio septiferis placentas divisas auferentibus. — Species 11, Californicæ, habitu variæ, pube pl. m. viscida vel glandulosa.

* Capsula cartilaginea, 2–4-sulcata, sero dehiscens, basi obliqua vel gibbosa: calyx basi gibbosus, ore valde obliquo: corolla purpurea, fauce variegata vel maculosa,

+ Tubo filiformi longe exserto: flores primarii caule multo longiores. (*Œnoe* Gray in Pl. Hartw., & sect. in Bot. Calif.)

1. M. TRICOLOR Lindl. Jour. Hort. Soc. 4, p. 222, "Junio, 1849." Foliis oblongis vel sublinearibus basi attenuatis sessilibus; calyce sursum ampliore (dentibus longioribus) basi parum gibbo; corollæ labiis æquilongis, lobis consimilibus; capsula brevi-ovali seu ovata subcompressa, marginibus anticis et posticis acutis; seminibus obovatis obliquis iis subsequentium multo majoribus. — *Eunanus Coulteri* Gray ex Benth. Pl. Hartw. p. 329, "Augusto, 1849." — It is well that Lindley's name takes precedence, as there was a mistake in supposing that this species was in Coulter's collection.

Var. ANGUSTATUS. Foliis linearibus parvulis, tubo corollæ bipollicari tenerrimo. — *Eunanus Coulteri* var. *angustatus* Gray, Proc. Am. Acad. 7, p. 381.

2. M. DOUGLASII. Foliis ovatis oblongisve in petiolem contractis; calyce basi mox valde gibboso; corollæ labio inferiore abbreviato, superiore amplo erecto; capsula lineari seu lineari-oblonga tereti 4-sulcata; seminibus ovalibus modo *Eunani* utrinque apiculatis. — *M. nanus* var. *β. subuniflorus* Hook. & Arn. Bot. Beech. p. 378. *Eunanus Douglasii* Benth. in DC. Prodr. 10, p. 374. The stigma is sometimes of two very unequal lobes, as described by Bentham, sometimes of two broad and rounded unequal lobes, sometimes peltate and nearly circular, as in most of the following.

+ + Tubo corollæ e calyce parum exserto: flores folia vix superantes.

3. M. LATIFOLIUS. Spithamæus, viscosus; foliis radicalibus exiguis evanidis, caulinis amplis late ovatis membranaceis basi angustatis subpetiolatis;

Hedeoma hyssopifolia. (*Euhedeoma*, ante *H. piperitam.*) Glabella; caulibus e caudice perenni ramoso erectis gracilibus subpedali-

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calyce basi mox valde gibboso; corollæ labio inferiore superiore erecto dimidio breviore; capsula lineari-oblonga subcurvata lateribus sulcata; seminibus præcedentis. — Guadalupe Island, Lower California, Dr. E. Palmer, 1875. A near relative of the preceding, but caulescent from the first, flowering only from about the fourth node. Leaves about an inch long; corolla two-thirds of an inch long, the narrow tube little if at all exceeding the longer tooth of the calyx; stamens not very unequal; stigma of two ample ovate-oblong lips, sometimes united into a funnelform body; capsule 5 lines long, somewhat laterally compressed, the posterior edge acute, and the anterior not sulcate.

* * Capsula coriacea vel membranacea, symmetrica: calyx basi æqualis, campanulatus vel breviter oblongus: stigma sæpissime peltatum.

+- Corolla parvula, tubo tenui exserto: calycis dentes subæquales.

4. M. leptaleus. Caule ramoso 1–3-pollicari; foliis e spathulato-oblongis ad lanceolata vel linearia (parum semipollicaribus); calycis campanulati dentibus ovatis seu triangularibus tubo suo multo capsula oblongo-ovata obtusa paullo brevioribus; corolla rubra, tubo filiformi sursum parum ampliato (lin. 3–5 longo), limbo obliquo (lin. 1½–3 lato). — Gravelly soil, in the Sierra Nevada, California, at 5000 feet and upwards, south of the Yosemite, Miss Dix, A. Gray, and in Sierra County, Lemmon. A tiny species. Capsule 2 lines long.

+- +- Corolla majuscula, infundibuliformis, lin. 7–11 longa, tubo proprio e calyce subæquali vix parumve exserto. Species nimis affines; caule unciali ad spithamæum.

5. M. Bigelovii. Foliis oblongis, superioribus ovatis acutis vel acuminatis; calycis dentibus e basi lata subulatis acutissimis (lin 2 longis) tubo lato-campanulato dimidio brevioribus, anticis minoribus; corolla fauce cylindracea limbo amplo rotato-patente; capsula membranacea. — *Eunanus Bigelovii* Gray in Pacif. R. Rep. 4, p. 121. — Southern part of California, and adjacent parts of Nevada to Southern Utah.

6. M. nanus Hook. & Arn. (var. α. *pluriflorus*). Foliis obovatis ovatis oblongisve nunc lanceolatis; calycis dentibus lato-lanceolatis vel triangularibus acutis (lineam longis) tubo quadruplo brevioribus; corolla nunc rubro-purpurea nunc flava, tubo e calyce parum exserto sensim in faucem amplam dilatato; capsula chartacea. — *Eunanus Tolmiei* Benth. l. c. *E. Fremonti* Watson, Bot. King, p. 226, non Benth. — California, especially its eastern borders, Nevada, and through the interior to the eastern borders of Oregon and the western part of Wyoming. Hooker and Arnott's specific name is retained; but most of their characters relate to *M. Douglasii*.

Var.? bicolor (*Eunanus bicolor* Gray, l. c. 7, p. 381), fauce corollæ subito obconica intus atro-purpurea, limbo luteo.

7. M. Fremonti. Foliis angusto-oblongis imisve spathulatis obtusis; calycis dentibus ovatis obtusis vel acutiusculis fere æqualibus (vix lineam longis);

bus; foliis integerrimis nervosis præter infima ovalia seu oblonga parva lineari-lanceolatis, floralibus verticillastris laxe 3–5-floris brevioribus;

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corollæ rubro-purpureæ tubo incluso sensim in faucem infundibuliformem ampliato. — *Eunanus Fremonti* Benth. l. c. — Southern part of California.

+ + + Corolla majuscula, tubo proprio calyce inæquali obliquo incluso.

++ Genuini, corolla infundibuliformi.

8. M. Parryi. Glabriusculus, 2–4-pollicaris; foliis oblongis oblanceolatisve integerrimis (semipollicaribus); calycis ore valde obliquo, dentibus acutis, supremo ovato tubo triplo breviore, cæteris minoribus e basi lata subulatis; corolla infundibuliformi (lin. 8 longa) aut flava aut rubro-purpurea; capsula calyce fere inclusa. — Gravelly hills, near St. George, S. Utah, Parry (coll. 1874, No. 147).

9. M. Torreyi. Viscido-pubescens, spithamæus ad pedalem; foliis oblongis vel sublanceolatis integerrimis (semi–ultra-pollicaribus); calycis ore sat obliquo, dentibus brevibus latis obtusissimis, supremo majore; corolla infundibuliformi ($\frac{1}{2}$–$\frac{3}{4}$-pollicari) rubro-purpurea; capsula chartacea. — *Eunanus Fremonti* Gray in Pacif. R. Rep. 6, p. 83, non Benth. — Common in moist grounds along the Sierra Nevada, California, from the northern part of Plumas County (where it was first collected by Dr. Newberry, in Williamson's Expedition) to Mariposa County, as also at Donner Lake, &c., by Dr. Torrey, to whose memory it is dedicated.

++ ++ Ambigui, elatiores, corolla subito ampliata e tubo perbrevi: folia nunc exserte denticulata, inferiora flores superantia.

10. M. Bolanderi Gray in Proc. Am. Acad. 7, p. 380. Subpedalis, viscido-pubescens; foliis oblongis; calycis ore valde obliquo, dentibus lanceolatis, supremo (lin. 3 longo) tubo oblongo dimidio breviore; corolla purpurea pollicari; capsula fusiformi-subulata subcoriacea. — *M. brevipes* Gray in Pacif. R. Rep. 4, p. 120, non Benth. — Foot-hills and the lower ranges of the Sierra Nevada, Bigelow, Bridges, Bolander. Stigma sometimes bilamellate or oblique.

11. M. brevipes Benth. Ultrapedalis, viscido-pubescens; foliis lanceolatis linearibus imisve oblongis; calycis dentibus valde inæqualibus e basi lata acuminatis, supremo tubo late campanulato subdimidio breviore; corolla latissima flava; capsula ovata acuminata coriacea. — Only in the south-western part of California, from San Diego to Santa Barbara.

§ 2. DIPLACUS Gray. (*Diplacus* Nutt.) Corolla, calyx (angusto-prismaticus), stigma, etc., *Eumimuli:* placentæ axi vix coadunatæ: capsula (crasso-coriacea) et dehiscentia *Eunani.* Frutex glutinosus, Californicus, foliis subcoriaceis.

12. M. glutinosus Wendl.: — Var. puniceus, var. linearis, & var. brachypus (*Diplacus longiflorus* Nutt.), cum syn. DC. Prodr.

§ 3. EUMIMULUS. (*Mimulus* Linn., Benth. in DC.) Corolla tubo brevi vel breviusculo: calyx 5-dentatus, angulis dentibusque plicato-carinatis: stigma æqualiter bilamellatum: capsula vix sulcata, valvis coriaceis vel membranacalyce angusto-tubuloso vix hirtello, dentibus setaceis subincurvis, inferioribus superiora sat superantibus tubo pubero corollæ elongatæ

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cois medio septiferis columnam centralem placentiferam integram vel bifidam nudantibus. Herbæ annuæ vel surculoso-perennes.

* Orientali-Americani; foliis penninerviis; corolla violacea, tubo subincluso fauce palato fere clausa.

13. M. RINGENS Linn. — Canada to Texas.

14. M. ALATUS Solander. — S. New England to Illinois and southward.

* * Occidentales; corolla nec violacea nec cærulea,

+– Sesqui–bipollicaris, flammea vel rosea, ringens: calycis dentes subæquales: herbæ perennes: testa seminum opaca laxa. (*Erythranthe* Spach.)

15. M. CARDINALIS Dougl. Corolla coccinea, tubo parum exserto, limbo obliquo, labio superiori erecto lateribus reflexis, inferiori lobis reflexis; staminibus exsertis.

16. M. LEWISII Pursh. Corolla saturate rosea, tubo exserto, lobis patentibus; staminibus inclusis.

+– +– Corolla aut pollicaris, aut minor, nunc parva: testa seminum præter *M. luteum* tenuis et polita.

++ Foliosi, glabri vel pubentes, haud villosi.

= Calyx saltem fructifer ore obliquo, dente supremo majore: folia sæpius dilatata, aut subito aut insigniter petiolata.

17. M. LUTEUS Linn., cum varietatibus insignioribus, i. e., ALPINUS Gray, in Proc. Acad. Philad. 1863, p. 71 (*M. Tilingii* Regel, *M. cupreus* Veitch, etc.), & var. DEPAUPERATUS (*M. microphyllus* Benth., *M. tenellus* Nutt. herb.).

18. M. DENTATUS Nutt. in DC. Species sylvestris, Oregana, vix cognita, inter *M. luteum* et *moschatum* quasi media.

19. M. JAMESII Torr. & Gray, ex Benth. in DC. *M. glabrato* proximus sed distinctus videtur.

20. M. ALSINOIDES Dougl., et var. MINIMUS Benth.

21. M. LACINIATUS. Annuus, tener, glaber; caulibus diffusis; foliis oblongis vel spathulatis laciniato-pauci-dentatis lobatisve nunc hastatis uninerviis, petiolo longo filiformi; floribus minimis; calyce brevi, fructifero ovato, dente supremo maximo; corolla brevi (lin. 2 longa) flava. — California, on the South Fork of the Merced at Clark's Ranch, A. Gray.

= = Calyx ore fere æquali, dentibus subsimilibus: Californici, annui, parvuli, caulibus erectis.

a. Folia omnia petiolata.

22. M. PULSIFERÆ. Glanduloso-puberulus, viscidus; foliis ovato-oblongis seu ovato-lanceolatis imisve rotundatis parce denticulatis vel integerrimis basi acuta vel cuneata trinervatis pedunculo æquilongis; calycis tubo fructifero oblongo, dentibus brevissimis ovato-triangulatis corollæ luteæ dimidio ad-

brevioribus. — Arizona, on Mount Graham at 9000 feet, August, J. T. Rothrock, in Wheeler's Exploration. Corolla remarkably long and exserted for the genus, 7 or 8 lines long, twice the length of the calyx; upper lip 2-lobed. Leaves crowded, the main ones from half to three-fourths of an inch long, and a line wide; the parallel veins running towards the apex; the upper gradually reduced until at length shorter than the calyx; the lowest leaves much shorter, broader, and beneath with strong more or less diverging nerves.

æquantibus. — California, in the Sierra and Indian Valleys of the Sierra Nevada, Bolander, Mrs. Pulsifer-Ames. Tube of the calyx in fruit 3 or 4 lines long; corolla 5 lines long.

b. Folia præter infima sessilia.

23. M. INCONSPICUUS Gray in Pacif. R. Rep. 4, p. 120. Glaber; foliis ovatis integerrimis; calycis quasi truncati dentibus minimis; corolla aut lutea aut rosea.

24. M. BICOLOR Benth. Viscido-pubescens; foliis lineari-oblongis lanceolatisve basi attenuatis denticulatis vel parce dentatis; dentibus calycis conspicuis triangularibus; corolla sat longa lutea, labio inferiore albo. — *M. Prattenii* Durand in Jour. Acad. Philad. n. ser. 2, p. 98 (1855). Calyx sæpius purpureo guttatus.

25. M. RUBELLUS Gray. Viscido-puberulus vel glabellus; foliis a spathulato-oblongis ad linearia plerumque integerrimis, imis latioribus; calycis oblongi dentibus brevibus rotundatis; corolla calyce aut paullo aut duplo longiore lutea rubra vel purpurea. — *M. montioides* Gray Proc. Am. Acad. 7, p. 380, pro parte.

Var. LATIFLORUS S. Watson, Bot. King. (*M. montioides* Gray, l. c. pro parte.) Forma sæpius pygmæa, corolla multo majore (nunc semipollicari), tubo longius exserto, limbo amplo aureo, fauce purpureo guttata.

++ ++ Foliosi, villosi, visciduli; foliis omnibus petiolatis membranaceis sat latis dentatis pl. m. penniveniis; calyce æquali vel vix obliquo; corolla lutea.

26. M. FLORIBUNDUS Dougl. in Bot. Reg.

27. M. MOSCHATUS Dougl. in Bot. Reg., cum forma longiflora.

++ ++ ++ Scaposi vel subscaposi, stolonibus perennantes.

28. M. PRIMULOIDES Benth. Herbula læta; floribus longissime pedunculatis aureis.

§ 4. MIMULOIDES. (*Herpestis* § *Mimuloides* Benth.) Corolla, stigma, etc., *Eumimuli*: calyx 5-fidus, campanulatus, nec prismaticus nec carinato-angulatus, lobis planis: capsula *Eunani*. Herba annua, humilis, pilis longis mollibus villosa.

29. M. PILOSUS S. Watson, Bot. King Exp. p. 225. *Herpestis* (*Mimuloides*) *pilosa* Benth. in Comp. Bot. Mag. 2, p. 57, & DC. l. c. p. 394. — The anther-cells are barely oblong, not "linear." The stigma is bilamellar, not "entire." And the plant is surely a *Mimulus*, although the calyx is peculiar in wanting the plicate angles.

Calamintha Palmeri. Sect. *Acinos:* odore et facie *Hedeomæ*, annua, a basi ramosa, spithamæa, pube molli; foliis obovatis vel spathulato-oblongis in petiolum attenuatis integerrimis, floralibus decrescentibus conformibus; bracteis minimis subulatis; verticillastris 6–9-floris, superioribus folia floralia æquantibus; calyce parce hirsuto basi vix gibboso, fauce villosissima, labiis tubo brevioribus, superiore latiore fructifero recurvo patente; corolla purpurea calyce vix duplo longiore, tubo incluso; antheræ loculis parallelis, connectivo haud incrassato. — Guadalupe Island, Lower California. "Common in the interior of the island, not cropped by the goats," Dr. Palmer. Flower only 3 lines long: pedicels a line or so in length. Calyx shorter than in *C. Acinos*, in fruit less declined or ascending. Except for the four fertile stamens this plant would be referred to *Hedeoma*. The stamens are too straight and distant for a *Calamintha*, but apparently it may be referred to that polymorphous genus.

Pogogyne tenuiflora. Glabriuscula, 2–4-pollicaris; ramis (dum adsunt) corymbosis; foliis spathulatis vel obovatis basi petioloque ciliis setiformibus perpaucis instructis; bracteis nudis; calycis puberuli lobis inæqualibus lineari-lanceolatis corollæ tubo filiformi dimidio brevioribus; filamentis sterilibus parvulis glandula capitellatis. — Guadalupe Island, off Lower California, Dr. E. Palmer. Corolla nearly half an inch long.

Scutellaria nana. Stolonibus filiformibus moniliformi-tuberiferis perennans, depressa, cinereo-puberula, foliosa; foliis obovatis ovatisve obtusissimis (semipollicaribus) integerrimis brevi-petiolatis flores brevissime pedicellatos æquantibus; corolla alba (semipollicari sat lata), labiis brevibus æquilongis. — N. W. Nevada, in Winnemucca Valley, near Pyramid Lake, J. G. Lemmon.

Monardella Benth. A study of some new materials, and a revision of the species for the Botany of California (to which they all belong), bring to view eleven species, which may be disposed as here subjoined.*

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* MONARDELLA Benth.

§ 1. *Macranthæ laxifloræ*, nempe floribus in capitulo laxiusculo sat magnis minus numerosis: corolla e calyce longe exserta: antheræ loculis ovali-oblongis divaricatis: perennes.

1. M. macrantha. Rhizomatibus repentibus cæspitosa, depressa vel procumbens, puberula vel pubescens; foliis crassiusculis ovatis obtusis (haud pollicem longis) glabratis, petioli gracili; capitulo 10–20-floro; bracteis involucrantibus

ERIOGONUM CHRYSOCEPHALUM. (*E. Kingii* var. *laxifolium* Gray, Proc. Am. Acad. 8, p. 161.) *E. pauciflоro* affinius, differt perigoniis aureis basi annulo magis prominente articulatis, involucri dentibus minus latis; foliis paullo latioribus incanis *E. multicipitis.* — Utah, in the Wahsatch Mountains, Watson, and above Spring Lake, Parry; by the latter, in full flower.

GRAYIA BRANDEGEI. Inermis, sesquipedalis, leviter furfuraceo-cinerea; foliis spathulato-linearibus; thecis minoribus flavidulis oblato-orbiculatis quandoque trialatis basi latissime retusis, alis subundulatis; ovario basilari papuloso. — Hillsides, among fragments of cretaceous sandstone, on the San Juan River, near the boundary between Colorado and Utah, T. S. Brandegee in Hayden's Exploration, August, 1875. — While pleased with an accession to this genus, and with the opportunity of associating it with the name of an excellent correspondent who discovered it, I must add that it does not much strengthen the

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ovatis oblongisve obtusis tenui-membranaceis subscariosis cum calycibus villoso-pubescentibus; corolla sesquipollicari aurantiaco-punicea, tubo calyce duplo longiore, lobis lanceolatis. — Southern part of California, on the Cuiamaca Mountains and near Julian City, D. Cleveland, E. Palmer. The calyx is three-fourths or in fruit a full inch long; the corolla sometimes two inches long. This would be very ornamental in cultivation.

2. M. NANA. Præcedenti sat similis, magis hirsuta; floribus minoribus; corolla pallida, tubo pubescente ultra calycem paullo exserta; bracteis albidis roseisve. — S. California, in the mountains behind San Diego, D. Cleveland. Calyx barely two-thirds of an inch long; the corolla-tube only a line or two longer.

§ 2. *Densifloræ et multifloræ:* calyce $\frac{1}{4}$–$\frac{1}{3}$-pollicari: antheræ loculis brevioribus minis divaricatis.

* Perennes, basi nunc lignescentes: corolla incarnata vel purpurea nunc pallidiore tubo calycem parum superante.

+ Pubescens seu villosa, foliis ovatis nunc oblongis.

3. M. VILLOSA Benth., cum varietatibus.

+ + Pube minuta canescens vel fere glabra; foliis angustioribus, venis inconspicuis.

4. M. ODORATISSIMA Benth. Humilis; foliis oblongo-lanceolatis brevi-petiolatis; bracteis villosis vel ciliatis; calycis dentibus brevibus triangulari-lanceolatis intus extusque hirsutis. — Also in Oregon.

5. M. LINOIDES. Pedalis, gracilis, pube imperceptibili cinerea; foliis lanceolatis seu linearibus sessilibus imisve oblongo-spathulatis; bracteis parum ciliatis; calycis dentibus angusto-lanceolatis tantum pubescentibus. — S. California, in the mountains east of San Diego, Dr. Palmer.

genus. The small thecæ, as far as seen only 3 lines broad, and with some furfuraceous puberulence (but they are far from mature, and mainly unfertilized), and the papulose cellular ovary too much remind us of *Atriplex* (incl. *Obione*). *A. Endolepis* of Watson, Rev. Chenop., p. 111 (of which I should like to form a distinct section), has as thin and complete a sac; but there are two minute teeth at its apex, and their position, along with the venation, shows that the sac is compressed laterally, i.e., formed of two flat bracts. I agree with Mr. Watson's view, that the sac of *Grayia* is obcompressed, or formed of a pair of conduplicate bracts, completely united to the very tip; and on this character (along with the inferior radicle) the genus actually rests. But this view demands the separation from *Atriplex* of a species which has always appeared like a stranger in the genus, and which I propose

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* * Annuæ, minus foliosæ; foliis integerrimis raro undulatis.

+– Corolla (carnea, rosea, vel purpurea) tubo e calyce sat parumve exserto, lobis linearibus vel lineari-oblongis.

++ Bracteæ muticæ, venis plerisque a basi parallelis; calycis dentibus latiusculis muticis.

6. M. UNDULATA Benth. Glabella; foliis oblongo-spathulatis vel fere linearibus obtusis margine undulatis in petiolum attenuatis; bracteis ovatis obtusis tenui-membranaceis vel scariosis nervis simplicibus percursis (nec venulosis) calycibusque villosis; corolla rosea.

7. M. LANCEOLATA. Viridis, fere glabra, brachiato-ramosa; foliis lanceolatis vel oblongo-lanceolatis haud undulatis in petiolum gracilem attenuatis; bracteis fere foliaceis ovatis oblongisve plerumque acutis inter costas reticulato-venosis; calycis parum nervosi dentibus intus crebre extus vix hirsutis; corolla roseo-purpurea sæpius maculata. — California, from Plumas to San Diego Co.; not uncommon; has been confounded both with the preceding and the succeeding.

8. M. CANDICANS Benth. Pl. Hartw. p. 330. Pube brevi molli canescens vel cinerea, nunc laxe ramosa; foliis oblongis vel lanceolatis obtusis subito in petiolum contractis; bracteis fere scariosis ovatis obtusis, venulis parcis inter costas reticulatis; calycis nervosi dentibus intus extusque villosissimis; corolla semper brevi pallida.

++ +– Bracteæ cuspidatæ, præter costas validas tenui-scariosæ vel hyalinæ.

9. M. BREWERI Gray, Proc. Am. Acad. 7, p. 386. Habit of *Monarda fistulosa*.

10. M. DOUGLASII Benth.

+– +– Corolla (alba?) parva, tubo incluso, lobis brevibus latis: bracteæ tenui-scariosæ, candidissimæ, 7–9-nerves.

11. M. LEUCOCEPHALA Gray, Proc. Am. Acad. 7, p. 385.

to establish by itself, between *Atriplex* and *Grayia*, under the name of its discoverer, Dr. George Suckley, U. S. A., one of the naturalists of the exploration across the Continent under Governor Stevens.*

APPENDIX.

CHAPMANNIA Torr. & Gray. This genus was described from imperfect materials in the Flora of North America (1, p. 355), taken up by Mr. Bentham in his paper upon *Arachis*, and then the character added to in Fl. N. Amer. 1, p. 692, — all this upon a wrong view as to two kinds of blossoms, which Mr. Bentham subsequently corrected. Good specimens, with well developed flowers, are in Rugel's collection; and I have just received others from an esteemed correspondent, Dr. Feay of Savannah, collected on Pease River, Florida. A few particulars are added to complete or slightly correct the character as given in Bentham and Hooker's Genera Plantarum, 1, p. 517, and to bring out more prominently the differences between it and *Stylosanthes*.

The broadly obovate vexillum and alæ are only slightly unguiculate, not at all auriculate at base, but the latter nearly as equal-sided as the former. In anthesis they are widely spreading, and distant from the carina. The latter is shorter and straight (only in Rugel's specimens is there an obliquity giving the appearance as of a slight curvature); its two petals are united almost completely into an oval or somewhat obovate piece, which is not auriculate at base, very obtuse and emarginate at the apex, convolute as if into a tube, one edge slightly over lapping, or slightly open in full anthesis. The andrœcium is only half the length of the carina, which encloses it or, when it opens down the upper side, allows the anthers to project from towards its base. The

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* Subtribus EUROTIEÆ. Theca, e bracteis pl. m. conduplicatis coalitis con stans, obcompressa, rarissime triptera.

1. GRAYIA. Theca nuda, integerrima, scariosa, orbiculata, plana, samaroidea, alato-marginata. Radicula infera. Flores dioici.

2. SUCKLEYA. Theca nuda, subhastata, complanata, marginibus herbacco-cristatis, apice bidentato. Radicula supera. Flores monoici. — S. PETIOLARIS. *Obione Suckleyana* Torr. *Atriplex Suckleyana* Watson, l. c.

3. EUROTIA. Theca villosissima, turgida, nec marginata nec aristata, apice bifida. Radicula infera. Flores dioici.

4. CERATOCARPUS. Theca cuneata, obcompresso-plana, biaristata. Radicula infera. Flores monoici.

very slender filiform style, however, is longer than the carina and protrudes beyond it more or less, even before the flower opens, and continues exserted. It is evidently a case of proterogyny. Although the ten anthers are nearly alike in size and shape, the alternate ones are shorter as well as somewhat differently affixed. The ovary is not "pluri-ovulatum." That is probably a misprint of "2–3-ovulatum." At least I find only three ovules; and, answering to this, the loment is at most three-jointed. Instead of "subreniform," the seed is obovate and the radicle is projecting and straight, as described by Mr. Bentham himself in Linn. Trans. 18, p. 162. There may be a slight inflection, but it seems to be in the incumbent direction. The stipules, unlike those of *Stylosanthes*, are nearly or quite free from the petiole.

VI.

BOTANICAL CONTRIBUTIONS.

By Sereno Watson.

Presented, Oct. 12, 1875.

I. On the Flora of Guadalupe Island, Lower California.

The Island of Guadalupe is in lat. 29° north, about one hundred miles from the coast of Lower California, and two hundred and thirty west of south from the town of San Diego, which is near the southern line of California. It is twenty-six miles in length in a north and south direction, with an average breadth of ten miles, and is traversed by a mountain ridge, the central peak (Mount Augusta) having an elevation of 3900 feet above the level of the sea. From this point the nearest mainland is visible. The sides of the ridge are exceedingly rough and broken, cut up by numerous deep and rocky cañons, and even the more level surfaces are described as usually covered by rocks of every size and form. The rocks are volcanic, and several extinct craters still exist.

The island lies within the great ocean current which flows from the peninsula of Alaska down our western coast, the continuation of what is known as the Japanese Gulf-stream, and in the zone of the north-west trade-winds. Fogs are very prevalent, especially in the winter months (from November to February), when they are driven by the winds over the crest of the island, covering all the northern end and filling the upper portions of the cañons, while the lower cañons and the southern extremity of the island remain clear and warm. These winter winds from the north-west are described as strong and cold, sometimes extremely so, an instance of which occurred during December, 1874, when ice an inch in thickness was formed in the middle of the island, accompanied by two inches of snow, which was followed by hail and five days of cold rain. In summer these winds have less force, though still brisk and chilly for much of the time; and the fogs, instead of being carried over the central ridge, are driven around the northern end, and by eddy-winds are borne into the lower cañons of the eastern side, which are thus made cooler than the region above them. Otherwise the summer months are intensely hot, especially in the southern portion of the island, and the soil becomes soon everywhere so dry that the effect of the temporary summer fogs upon the vegetation is slight. The difference in the seasons, however, at the two extremities of the island is remarkable, as vegetation at the southern end and in the eastern cañons is at least two months earlier than in the northern and western portions, and has for the most part reached its maturity by the close of May, under the then established heats of summer. The annual amount of actual rainfall is very variable, there being an abundance in some years, in others little or none.

Guadalupe was early known to the navigators of these seas, but it was never permanently occupied. There are evidences of its temporary occupation by shipwrecked sailors, and it was also long ago stocked with goats * for the purpose of supplying fresh meat to vessels short of provisions or suffering from scurvy, and though out of the general course of travel it has been occasionally visited on this account. Twelve years ago an expelled governor of Lower California took refuge here with his family, and remained for two years. Soon afterward a party of men from the same State lived for some months upon the island engaged in killing the goats, and during the last ten years it has been occupied by a California company, by whom it was purchased for the purpose of raising the Angora goat, and the island is now overrun by these animals. Several men are kept in continual charge of them, and regular visits are made by the vessels of the company.

With this much of preliminary remark upon those conditions which must affect the vegetation of the island, we may pass to the flora itself. As respects the probable sources from which this flora may have been derived, it is evident that there has been abundant opportunity for the introduction of some species by human agency. These should be especially expected near the usual landing-place upon the eastern side, excepting such as would be probably distributed through the island by means of the goats. Those of most recent introduction in this way would doubtless be Californian; the older might be from the nearer peninsula or from other localities. Of other recognized agencies for the distribution of plants, — the winds, ocean cur-

* It is said that this was done by Captain Cook, who, however, was never upon this part of the coast. Vancouver passed near the island in 1793, but without stopping.

rents, and birds, — the prevalent direction of the first from the north-west is adverse to the supposition that any species of phænogamous plants, at least, would be so introduced. The ocean currents might be considered as more favorable, and as likely to bring accessions from the Californian mainland, contributed from the interior by the Sacramento and other smaller streams. But the winds here again would prove an interposing agency, and by creating a surface drift toward the coast would prevent floating seeds from attaining any great distance from it. Such as did succeed in reaching the island, and in obtaining and maintaining a foothold upon it, would probably be wholly Californian. Less certain conclusions might be expected in regard to the agency of birds, but it appears, from the collection of the birds of the island made by Dr. Palmer, that they are all in some measure peculiar to the island itself, "consisting almost entirely of familiar forms of the birds of the Western United States, but showing marked peculiarities, entitling them to recognition as geographical varieties. Nothing Mexican about them in the slightest degree." * So that, though they demonstrate a connection between the island and California, yet they also indicate that that connection has only been at a remote period, and that their participation in the introduction of plants must have been slight.

It might therefore be conjectured, if the island were of comparatively recent formation and always disconnected from the mainland, that its flora would show a meagre list of species almost wholly Californian. Or if, on the other hand, it had at some time been connected with the continent, that then its vegetation would be similar to that of the adjacent peninsula, unless some counteracting influence should have been at work, as would seem to be true of the birds.

To show to what extent the flora of Lower California differs from that of California proper, reference may be made to the list of plants collected by Xantus at the lower extremity of the peninsula,† as given by Dr. Gray in the 6th volume of the Proceedings of this Academy. Of the 118 phanerogamic species there enumerated, only six are probably found even in extreme Southern California, while thirty others range northward only as far as Sonora, or eastward through Mexico to New

* Prof. Spencer F. Baird, in letter.

† The Island of Guadalupe is equally distant from San Francisco and Cape San Lucas, but three degrees of latitude nearer to the latter point; and the difference of latitude between the cape and San Diego is little greater than that between Guadalupe and San Francisco.

Mexico or Texas, the remainder being peculiar to the peninsula or exclusively Mexican. The peninsula shares in this difference with Mexico itself, the type of whose whole flora accords rather with that of the eastern portion of the continent northward, except so far as it would necessarily be affected by the more tropical character of the climate. Of this a good and sufficient illustration is seen in the fact that of the *Phaseoleæ*, a tribe which is well represented in all the Atlantic States, Texas, Southern New Mexico, Eastern Arizona, Sonora, Lower California, and all of Mexico southward, not one species is found within the limits of California, nor in the interior basin west of the Rocky Mountains.

The only collection that we have of the plants of Guadalupe is that made by Dr. Edward Palmer during the last season, from February to May, which is probably as complete as was possible, though attended with much labor and difficulty. He visited all parts of the island, often finding it necessary to reach places which the goats had found inaccessible, in order by means of ropes and poles to secure rare specimens of species which appeared to have been elsewhere completely extirpated. The entire number of species is 131, including 102 exogenous and 8 endogenous, the remaining 21 belonging to the higher cryptogamic orders, — ferns, mosses, and liverworts. Omitting a single phænogamous species (a *Heuchera*), of which the material is insufficient for a satisfactory determination, the remaining 109 may be divided into five groups: (1) Introduced species, of which there are twelve; (2) Those that range from the Pacific to the Atlantic States, of which there are nine; (3) Those that are found throughout California, or at least as far north as San Francisco, numbering forty-nine; (4) Those found only in Southern California, below Los Angeles, or in Arizona, numbering eighteen; lastly, those peculiar to the island itself, of which there are twenty-one.

The twelve species* of whose comparatively recent introduction there can be little doubt, are all of European origin, and chiefly from Southern Europe, and are all also found more or less widely naturalized in California. The original introduction of most is probably due to the Spaniards, at least upon the mainland, where the extent to which several have become distributed is something marvellous. The most remarkable is the Alfilaria (*Erodium cicutarium*), which, unlike

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* *Brassica nigra*; *Oligomeris subulata*; *Silene Gallica*; *Malva borealis*: *Erodium cicutarium* and *E. moschatum*; *Sonchus oleraceus*; *Anagallis arvensis*; *Solanum nigrum*; *Chenopodium album*; *Avena fatua*; *Bromus sterilis*.

the wild oat (*Avena fatua*), has not been limited in its range to the western side of the Sierra Nevada, but is found through much of the interior, from New Mexico to Washington Territory. On Guadalupe it is found everywhere, and is more abundant than any other plant. Another species of the same genus (*E. moschatum*), provided with the same contrivances for securing the dissemination and planting of its numerous seeds, occurs less frequently both here and in California; probably because, requiring more moisture, it is unable to maintain itself where the other will flourish. Another instance is the *Oligomeris subulata* of India, Egypt, and the Canary Islands, found also in Southern California, and common eastward through the valleys of the Lower Colorado and of the Gila to the Rio Grande, and in Northern Mexico. It is difficult to account for the wide spread of this plant, if of recent introduction, through a region so desert and sparsely inhabited.

Besides these twelve species placed in the first group, there are two others, also found in California, which are considered identical with South American forms (*Specularia biflora* and *Amblyopappus pusillus*), possibly introduced from Chili or Peru, perhaps indigenous to both regions. Their presence on Guadalupe would perhaps rather favor the belief that they are native to our western coast, especially as five other South American species, or forms of them, occur in the Guadalupe flora (*Tillæa minima*, *Gilia pusilla*, *Plantago Patagonica*, *Parietaria debilis*, and *Muhlenbergia debilis*), which are more or less frequent in California and eastward in the centre of the continent, and are generally admitted to be native.

There are, therefore, 97 phænogamous plants which may be considered as indigenous. Of these, nine have a very extended range upon the mainland;* one (*Parietaria debilis*) from Southern California across the continent; all the rest common throughout California, and ranging eastward to the Atlantic States. Two of these (*Galium Aparine* and *Juncus bufonius*) are also European, and two (*Plantago Patagonica* and *Parietaria debilis*) are found widely distributed through South America.

Far the largest group, as already stated, includes those species, 49 in number, which are common over a large part of the State of California. Many of these extend northward as far as Oregon or Washington Territory, or eastward through the Great Basin to the Rocky

* *Sisymbrium canescens; Silene antirrhina; Daucus pusillus; Galium Aparine; Dodecatheon Meadia; Linaria Canadensis; Plantago Patagonica; Parietaria debilis; Juncus bufonius.*

Mountains. To these are to be added the eighteen species * of more limited range upon the mainland, confined to Southern California or Western Arizona; very few of them, so far as their distribution is known, belonging to Lower California or Mexico, and several of rare occurrence. Among the latter is *Crossosoma Californicum*, known previously only from the Island of Santa Catalina, in the Santa Barbara Archipelago, of which genus the one other species is found in the mountains of Western Arizona. *Leptosyne gigantea* and *Stenochloe Californica* were also known only from the same island, the latter the only species of the genus; the former belonging to a small genus confined to Southern California and the region eastward to New Mexico.

It is evident, therefore, that, as regards the species common to the island and the mainland, the flora may be said to be exclusively Californian in its character. Not a single species is found that is peculiar to Lower California or Mexico. The same alliance is nearly as prominent if we look at the twenty-one new phænogamous species of the island. Fifteen of these (a *Thysanocarpus*, a *Sphæralcea*, a *Lupinus*, a *Trifolium*, an *Œnothera*, a *Megarrhiza*, a *Galium*, a *Hemizonia*, a *Perityle*, a *Bæria*, a *Mimulus*, a *Pogogyne*, a *Calamintha*, a *Phacelia*, and an *Atriplex*) all belong to genera largely or exclusively represented in California and the region east of it, and are mostly closely allied to the species of that region. The remaining six species include a *Lavatera*, a Composite, a Borraginaceous plant, a species allied to the Olive, and finally a palm. The *Lavatera* is interesting as representing a widely scattered genus, not otherwise found in America, except as a second species occurs on the more northern island of Anacapa. The genus belongs chiefly to the region of the Mediterranean, where fourteen species are native; two others are confined to the Canary Islands; another has been discovered in Central Asia, and still another in Australia. The new Composite is referred by Dr. Gray to a South American genus (*Diplostephium*), not otherwise represented in our flora, but of which there are eighteen species in the Andes from the equator southward. Of the Borraginaceous and Oleineous species, Dr. Gray forms new genera; the one (*Harpagonella*) allied to the small genus *Pectocarya*, of which there is one Chilian species, and

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* *Crossosoma Californicum; Lepidium Menziesii* and *lasiocarpum; Rhus laurina; Hosackia argophylla; Leptosyne gigantea; Filago Arizonica; Perityle Emoryi; Amblyopappus pusillus; Malacothrix Clevelandii; Antirrhinum Nuttallianum* and *A. speciosum; Lycium Californicum; Eritrichium angustifolium; Pinus insignis; Cupressus macrocarpa; Muhlenbergia debilis; Stenochloe Californica.*

two Californian, one of these also in the Guadalupe flora; the other (*Hesperelœa*) bearing no close resemblance to any other member of the Olive family. On the other hand, the palm (*Brahea* (?) *edulis*), conspicuous on the island as the only representative of a tropical flora, is probably less nearly related to the Central Mexican genus to which it is provisionally referred than to the genus *Livistona* of Australia. A congener of the Guadalupe species has recently been detected by Dr. Palmer in the cañons of the Tantillas Mountains, near San Diego.

As respects the cryptogamic vegetation, of the half a dozen ferns all are frequent in California, one peculiar to the southern part of the State, another found throughout North America and Europe. Of the eleven mosses, two are strictly Californian species, seven are common everywhere in the United States and Europe, and two are European species which had not previously been detected in America. Of the four *Hepaticæ*, three are Californian, and one is considered new.

Looking now at the relative proportions which the larger orders bear to each other in this limited flora as compared with the flora of the Great Basin (the only at all similar one of which we have the data for comparison), we find that the proportions which the *Compositæ* and *Leguminosæ* bear to the whole (17 and 7 per cent.) are identical in both; while in the next largest orders, the *Cruciferæ*, *Scrophulariaceæ*, and *Gramineæ*, the proportions in the two floras are very nearly the same. The most conspicuous discrepancies are the almost entire absence in Guadalupe of *Cyperaceæ*, *Polygonaceæ*, *Rosaceæ*, and *Liliaceæ*, and a less decided preponderance of *Solanaceæ*, *Borraginaceæ*, and *Hydrophyllaceæ*. These differences are largely due evidently to the character of the surface of the island, though the want of any representatives of the large characteristic western genera, *Eriogonum* and *Astragalus*, is remarkable.

Reference should be made to the plants which by their abundance and prominence give character to the vegetation. Among these the "sage-brush" and "grease-woods" of the valleys of the Basin are duly represented by an *Artemisia* and an *Atriplex*, which share with a *Franseria* in covering large tracts, and in protecting the soil and the smaller annuals from the winds and sun. Trees are numerous over much of the island, chiefly coniferous: a pine, belonging to a Southern Californian species, but peculiar in some of its characters; a juniper, common in California; a cypress, similar to and perhaps identical with a Mexican species which extends into California; and a small oak, which is common throughout the State. To these is to be added the palm, which is frequent in the southern cañons, growing to a height of forty feet, and bearing large clusters of edible fruit.

To conclude, it is apparent, from all that has been said, that this little flora as a whole is to be considered a part of that of California, as distinct from the flora of Mexico. It may be inferred also that it has not been to any great extent derived from California by any existing process of conveyance and selection, but that it is rather indigenous to its present locality. Moreover, while it would indicate a connection at some period between the island and the mainland to the north, yet the number and character of the peculiar species favor the opinion that they are rather a remnant of a flora similar to that of California, which once extended in this direction considerably to the southward of what is now the limit of that flora upon the mainland. And, finally, the presence of so many South American types suggests the conjecture that this, and the similar element which characterizes the flora of California, may be due to some other connection between these distant regions than any which now exists, and even that all the peculiarities of the western floras of both continents had a common origin in an ancient flora which prevailed over a wide, now submerged area, and of whose character they are the partial exponents.

II. *List of a Collection of Plants from Guadalupe Island, made by Dr. Edward Palmer, with his Notes upon them.**

1. Ranunculus hebecarpus, Hook. & Arn. Abundant on warm slopes in the middle of the island.

2. Crossosoma Californicum, Nutt. A shrub two or three feet high, in the crevices of cliffs overhanging the cañons in the middle of the island. Only nine were found, out of reach of the goats, and accessible only by the aid of a rope. In flower, February 10; petals soon falling; seed ripe, April 20.

3. Eschscholtzia Californica, Cham., var. hypecoides, Gray. Only at the south end in ravines, and in the middle of the island on level ground; apparently not eaten by goats. A form with smaller flowers has been found on rocky heights in the middle of the island.

* The determinations of the *Gamopetalæ* of the collection were made entirely by Dr. Asa Gray. The *Musci* were referred to Mr. Thomas P. James, and the *Hepaticæ* to Mr. Austin. Acknowledgment is made, in connection with a few species, of assistance received from other authorities. The numbers are those under which the collection was distributed.

4. SISYMBRIUM REFLEXUM, Nutt. (*S. deflexum*, Harv.) Abundant in the middle and at the south end, in low grounds; flowers white.

5. BRASSICA NIGRA, Koch. In considerable quantity in the middle of the island, in open spots and on the best soil; eaten by goats.

6. SISYMBRIUM CANESCENS, Nutt. In great abundance in warm sheltered localities.

7. LEPIDIUM MENZIESII, DC. Generally abundant on warm hillsides throughout the island; not much eaten by goats, as also the next.

8. LEPIDIUM LASIOCARPUM, Nutt. In ravines in the middle of the island, rarely at the south end.

9. THYSANOCARPUS ERECTUS, Watson; new species. (See page 124.) Found only between Jack's Bay on the west side and Mount Augusta, in clear level spots; succulent.

10. OLIGOMERIS SUBULATA, Boiss. In deep warm cañons and ravines in the middle of the island, and occasionally at the south end.

11. SILENE GALLICA, Linn. Occurring sparingly in the middle of the island, in level open spots.

12. SILENE ANTIRRHINA, Linn. Only in a cañon on the east side, near the beach.

13. STELLARIA NITENS, Nutt. Among rocks on hillsides, in the middle and at the north end.

14. CALANDRINIA MENZIESII, Hook. In moist spots in the open valleys all over the island, growing in masses; flowers white to rose-color or purple, opening at midday. Goats are very fond of this and the next.

15. CLAYTONIA PERFOLIATA, Donn. All over the island, in masses on the shaded side of rocks or logs, or in deep ravines; flowers pink.

16. MALVA BOREALIS, Wallm. Only on the richer open spots in the middle of the island, in dense masses; goats at first eat only the young leaves, but in summer devour the whole.

17. LAVATERA OCCIDENTALIS, Watson; new species. (See page 125.) A conspicuous plant on the cliffs in the middle of the island, only rarely, and with difficulty, accessible. In flower and immature fruit; April.

18. SPHÆRALCEA SULPHUREA, Watson; new species. (See page 125.) In large bunches, three feet high, very abundant on rocky slopes and in the crevices of the highest rocky ridges, from the middle of the island to the southern end, where it was most frequent; much relished by goats; April to May.

19. ERODIUM CICUTARIUM, L'Her. Abundant all over the island,

and the principal food for the goats, covering the rocks; usually three or four inches high by August, and producing abundance of seed.

20. Erodium moschatum, L'Her. Middle of the island, less common than the last, and starting later in the spring. In low places, the root long, large, and fleshy; leaves light green, fleshy.

21. Rhamnus crocea, Nutt. A scraggy shrub, five feet high, of a dense green hue. Only six were found, growing in the crevices of high cliffs in the middle of the island; in bloom, April 6.

22. Ceanothus crassifolius, Torr. Of rather loose habit, eight feet high; wood very hard. Only three were found alive, at the base of Mount Augusta.

—. Ceanothus cuneatus, Nutt. A small shrub almost exterminated, three nearly dead specimens alone being seen among rocks in the middle of the island; not in bloom.

—. Rhus laurina, Nutt. An irregularly growing shrub, about four feet high, in the crevices of high rocks; only four found; May 20, not in bloom.

—. Vicia exigua, Nutt. Among rocks in the centre of the island, a single specimen seen; very small.

23. Hosackia grandiflora, Benth. Among trees in the middle of the island; flowers yellow, changing the second day to bronze-red.

24. Hosackia argophylla, Gray. In the crevice of a rock; flowers yellow, changing to reddish brown.

25. Lupinus niveus, Watson; new species. (See page 126.) Only in the middle of the island, on high cliffs; one plant in bloom, March 25.

26. Trifolium Palmeri, Watson; new species. (See page 132.) Rather abundant in the middle of the island among rocks and trees on hillsides; flowers whitish with red centre, becoming redder on the edges.

27. Trifolium microcephalum, Pursh. Very abundant at the middle and north end of the island; flowers white or light pink.

28. Trifolium amplectens, Torr. & Gray. Only on the beach on the east side of the island, rare; flowers yellowish white with dark tips.

29. Alchemilla occidentalis, Nutt. Among rocks and sage-brush at the north end, and also around a spring, where it was much larger.

—. Heuchera —— ? A single plant in the crevice of a rock, not in bloom.

—. Ribes sanguineum, Pursh. Only two plants in the damp shade of cliffs at the north end; flowers rose-color, becoming white.

30. Tillæa minima, Miers, & var. (*T. leptopetala*, Benth.). In large patches in a few exposed clear spots in the middle and at the north end.

31. Epilobium minutum, Lindl., fide W. Barbey. Only at the north end, among rocks and sage-brush; flowers purplish white.

—. Œnothera Guadalupensis, Watson; new species. (See page 137.) Only two plants were found in a ravine on the east side, near the beach.

32. Mentzelia dispersa, Watson. In ravines in the middle and at the south end; flowers orange, opening after sundown. Goats are not fond of it.

33. Megarrhiza Guadalupensis, Watson; new species. (See page 138.) In crevices of high rocks in the middle of the island; flowers white; fruit green.

—. Sanicula Menziesii, Hook. & Arn.? Two plants only, without flowers or fruit, in crevices of rocks in the middle of the island.

34. Daucus pusillus, Michx. Abundant through the middle of the island, among sage-brush on the sides of cañons and in open level places; not much relished by goats.

35. Galium Aparine, Linn. Common on warm shady hillsides in the middle and more rarely at the south end.

36. Galium angulosum, Gray, Proc. Am. Acad. xi. 74; new species. A single small scrubby plant, in a crevice of a high cliff in the middle of the island; flowers greenish white; May 1.

37. Micropus Californicus, Fisch. & Mey. On dry gravelly slopes in the middle of the island.

38. Filago Arizonica, Gray. On level ground at south end.

39. Diplostephium canum, Gray, Proc. Am. Acad. xi. 75; new species. A large shrub of rather loose habit, some four feet high, in the crevices of high cliffs; flowers yellow; March 28.

40. Franseria bipinnatifida, Nutt.? One of the most conspicuous plants at the south end, especially about Jack's Bay, growing in thick roundish clumps about a foot and a half high, on level spots and among rocks, giving the country a greenish white appearance. Flower-buds red; bloom straw-color, flowering at the end of February. Not relished by goats, but asses are very fond of it.

41. Leptosyne gigantea, Kellogg. Only two plants found, in the crevices of high rocks. Five feet high, branching near the top, and the branches terminated with bright green leaves and masses of showy yellow bloom; May 10.

42. Hemizonia frutescens, Gray, Proc. Am. Acad. xi. 79; new

species. In the middle of the island, only a few small plants among bushes in the crevices of high rocks. It grows in compact bunches with abundant yellow bloom; May 1.

43. Perityle incana, Gray, l. c. 78; new species. Very common in the middle of the island, in the crevices of high rocks, hanging in massive bunches of yellow bloom; April, and through the summer.

44. Perityle Emoryi, Torr. Scattered through some of the cañons on the east side; flowers white, showy, blooming abundantly for three months, commencing in February. Much eaten by goats.

45. Bæria Palmeri, Gray, Fl. Calif. ined.; new species. Abundant in warm low spots in the middle and at the south end; flowers showy, gamboge-yellow; February 27.

—. Bahia lanata, Nutt., var. A single plant had escaped the goats, on a rocky open spot in the middle of the island; flowers light orange; May 10.

46. Amblyopappus pusillus, Hook. & Arn. In low ground at the southern end.

47. Matricaria discoidea, DC. Around springs in the middle of the island.

48. Artemisia Californica, Less. In considerable abundance at the south end, in rocky spots, giving character to the vegetation; about a foot and a half high, of rather loose habit. Also in the middle of the island in crevices of the highest cliffs.

49. Senecio Palmeri, Gray, Proc. Am. Acad. xi. 80; a new species. "White sage;" very abundant on many warm slopes, from the middle to the north end. About three feet high, of diffuse habit, a very free and showy bloomer; beginning to flower early in February and maturing in May, when the air is filled with its downy seeds.

—. Gnaphalium Sprengelii, Hook. & Arn. With the next.

50. Microseris linearifolia, Gray. Only in the middle of the island, on stony ridges; eaten close by goats.

51. Malacothrix Clevelandii, Gray. Abundant among rocks and trees in the middle of the island; flowers deep yellow.

52. Sonchus oleraceus, Linn. Very rare, on warm slopes in the middle of the island.

—. Specularia biflora, Gray. Rare, in the shade of rocks and sage-brush on hillsides in the middle of the island.

53. Githopsis specularioides, Nutt. Abundant at the middle and north end, under sage-brush and dead branches; flowers white, turning to blue after gathering.

54. Plantago Patagonica, Jacq. In level spots at the south end.

—. Anagallis arvensis, Linn. Only three plants found in a gravelly place near the beach on the east side.

55. Dodecatheon Meadia, Linn. Very abundant on moist rocky slopes at the south end and middle. Goats are very fond of it, and birds eat the buds and flowers.

—. Linaria Canadensis, Spreng. Rare on the sides of cañons in the middle of the island.

56. Antirrhinum Nuttallianum, Benth. Rather rare, in deep warm cañons in the middle of the island; succulent, with small violet flowers, white in the centre and dotted with violet; March 21.

57. Antirrhinum speciosum, Gray. Frequent in the crevices of high rocks in the middle of the island. Very ornamental, the bright scarlet flowers continuing all summer.

58. Mimulus latifolius, Gray, Proc. Am. Acad. xi. 95; new species. Only in the middle, scattered in warm rather moist spots; flowers velvety red, yellow at base, with a musky odor.

59. Castilleia foliolosa, Hook. & Arn. Only in the middle of the island, rare, among fallen branches.

60. Solanum nigrum, Linn., var. Rare in the middle of the island and in a cañon near the beach on the east side, in rich level spots; flowers white or purple; fruit black.

61. Solanum nigrum, Linn., var. Douglasii, Gray. Only two plants in a cañon near the beach on the east side; flowers white, small.

62. Solanum Xanti, Gray, l. c. 70. Only in the middle of the island. A very showy shrubby plant, in large bunches, about two feet high, in the crevices of rocks, blooming all the year. Flowers numerous, lilac or purple; fruit small, changing from green to yellow, mottled, and at length very dark plum-color, maturing very slowly.

63. Lycium Californicum, Nutt.; Gray in Fl. Calif. ined. At the extreme south end, on rocky bluffs, not abundant. A loose shrub, about two feet high; flowers creamy white, tinged with lilac.

64. Nicotiana Bigelovii, Watson. Only in a few places in the centre of the island, in open spots and good soil; flowers greenish yellow, bronzy below. The leaves stick to the goats' hair and do much damage.

65. Pogogyne tenuiflora, Gray, Proc. Am. Acad. xi. 100; new species. Very rare, among sage-brush, on the eastern side.

66. Calamintha Palmeri, Gray, l. c.; new species. Abundant among trees and sage-brush in the middle of the island; strong-scented and not eaten by goats.

67. Eritrichium angustifolium, Torr. On level spots at the south end, and also near the beach on the eastern side.

68. Eritrichium muriculatum, Torr. In warm clear places in the cañons of the middle of the island.

69. Amsinckia vernicosa, Hook. & Arn. Very abundant on level ground at the south end; flowers orange.

69 *a*. Pectocarya penicillata, DC. With the next.

70. Harpagonella Palmeri, Gray, Proc. Am. Acad. xi. 88; new genus. Only at the south end, in low valleys; often prostrate.

71. Phacelia phyllomanica, Gray, l. c. 87; new species. In large compact masses in the crevices of high rocks in the middle of the island; rare.

72. Same, var. interrupta, Gray, l. c. Frequent in warm nooks in rocky ravines in the middle and at south end; February to May.

73. Emmenanthe penduliflora, Benth. Rocky ravines in the middle of the island; refused by goats, but asses are fond of it.

74. Ellisia chrysanthemifolia, Benth. Abundant under sage-brush on warm hillsides from the middle to the north end, and also rarely at the south end; flowers lilac.

75. Same, with narrower calyx-lobes and larger corolla.

76. Nemophila aurita, Lindl. On warm slopes in the middle of the island, rarely at the south end; much relished by goats, like the last.

77. Collomia gilioides, Benth., var. glutinosa, Gray. Abundant under brush and in protected places in the middle of the island.

78. Gilia multicaulis, Benth., var. millefolia, Gray. Very abundant in similar localities; flowers blue and showy, or cream-colored with a violet base.

79. Gilia pusilla, Benth., var. Californica, Gray. Abundant in similar localities.

80. Convolvulus occidentalis, Gray, Proc. Am. Acad. xi. 89. In the crevices of high rocks, hanging down six feet or more; continuing in bloom from March through the summer. A thousand flowers were seen on a single plant.

81. Hesperelæa Palmeri, Gray, Proc. Am. Acad. xi. 83; new genus. A rather compact tree, twenty to twenty-five feet high; flowers lemon-color. Only three live trees were found, in a cañon on the east side; no young trees seen, but many dead ones.

82. Mirabilis Californica, Gray. Of compact branching habit, growing in crevices in the walls of cañons on the east side; color lilac-purple.

—. CHENOPODIUM ALBUM, Linn. Only one plant near the sea on the east side.

83. ATRIPLEX PALMERI, Watson; new species. (See page 146.) Only at the south end, in roundish bunches, about a foot and a half high. One of the three characteristic perennials of the island, much more frequent than *Artemisia Californica*, but scarcely half so abundant as *Franseria bipinnatifida*. In flower at the end of February.

84. PTEROSTEGIA DRYMARIOIDES, Fisch. & Mey. In the shade of rocks in the middle and more rarely at the south end.

85. PHORADENDRON BOLLEANUM, Seem. Near the south end, on *Juniperus* and *Cupressus*, more frequently the former.

86. HESPEROCNIDE TENELLA, Torr. In damp shady places, among high rocks, in the middle of the island.

87. PARIETARIA DEBILIS, Forst. Abundant in similar localities.

88 and 89. QUERCUS CHRYSOLEPIS, Liebm.; fide Dr. Engelmann. Frequent at the north end, and occasionally found in the cañons on both sides of the island. Often large, sometimes forty feet high, and wide-spreading; timber good and durable, though knotty.

90. PINUS INSIGNIS, Dougl., var.; fide Dr. Engelmann; with leaves in twos. At the north end, at high elevations. Very vigorous and handsome trees, usually spreading widely, the largest seven and a half feet in circumference and averaging seventy feet high. The wood is very knotty and soon decays. At the extreme northern end, facing Espaza Bay, the trees assume a hedge-like form, owing to the force of the winds.

91. JUNIPERUS CALIFORNICA, Carr., fide Dr. Engelmann. All over the middle of the island and occasionally at the south end, in the ravines and low valleys, forming groves about fifteen feet high. It is exceedingly crooked, the timber small but very durable. As soon as dead the ants take possession of it.

92. CUPRESSUS MACROCARPA, Hartw.? A fine widely spreading tree, though varying much in habit, growing in irregular clusters in the middle of the island. It averages about forty feet in height. A tree thirty-eight feet high and seven in circumference numbered 236 annual rings. The largest is at the head of Landrum's Cañon, twenty-five feet in circumference, dividing into seven branches at the height of two or three feet, the main limb at ten feet above the forks being thirteen feet around. The bark is claret-brown, shining when wet, at length cracking irregularly and curling up in thin plates. An abundance of resin is exuded, especially as the bark is eaten off by the goats. The wood

is white, very knotty and liable to crack, when dry impervious to nails, and decaying rapidly if exposed to wet. Fruit is abundant.

—. Brahea edulis, Wendland; new species. (See page 146.) Frequent in deep warm ravines, from the northern end to Jack's Bay; the only thing on the island having a tropical look. It attains a height of about forty feet, averaging fifteen inches in diameter. Each tree bears one to four clusters of fruit, four feet in length, and each weighing forty or fifty pounds. The fruit is eaten by man, goats, birds, and mice. In flower near the end of March.

93. Juncus bufonius, Linn. From the middle to the north end of the island, growing abundantly in very springy places and a sure indication of water; not much eaten by goats.

94 and 94 *a*. Avena fatua, Linn., and var. Several small patches were found in open places and on the best soil.

95. Muhlenbergia debilis, Trin. Identical with Arizona specimens so referred. Growing in abundance on warm slopes in the middle of the island, more rare at the south end; not much eaten by goats till dried in summer.

96. Stenochloe Californica, Nutt. in Pl. Gambel. 189, fide Professor Thurber. On warm rocky slopes in the middle of the island; not very abundant; very succulent, and the goats are very fond of it. Known previously only from Nuttall's specimens.

97. Festuca microstachys, Nutt. In bunches on warm slopes and in open places in the middle of the island.

98. Melica imperfecta, Trin. In tufts in the crevices of high rocks in the middle of the island.

99. Bromus sterilis, Linn. On warm hillsides, sometimes in large patches as if sown, at the south end and middle.

100. Pellæa ornithopus, Hook., fide Professor Eaton. Rare, in the crevices of the highest cliffs.

101. Gymnogramme triangularis, Kaulf. In similar places in the middle and at the south end of the island.

102. Aspidium munitum, Kaulf. In large bunches; only two seen at the northern end in a rocky place inaccessible to goats, and constantly damp from the prevalent fogs.

103. Polypodium Californicum, Kaulf., fide Professor Eaton. Abundant at the north end in the cracks of rocks, in damp localities, sometimes covering large surfaces.

104. Polypodium Scouleri, Hook. Encircling the trunk of a single oak, in a thick mat of moss and constantly wet by the fogs,

covering the tree with a network of its strong tough roots to the height of ten feet.

105. NOTHOLÆNA NEWBERRYI, Eaton. Throughout the island on rocks in dry exposed places.

106. WEISSIA VIRIDULA, Brid.

107. CERATODON PURPUREUS, Brid.

108. BARBULA RIGIDA, Schultz, var. PILIFERA. Not before collected in America.

109. BARBULA ATROVIRENS, Smith. Also new to America.

110. BARBULA VINEALIS, Brid.

111. BARBULA RURALIS, Hedw.

112. ORTHOTRICHUM LYELLII, Hook.

113. GRIMMIA PULVINATA, Hook. & Tayl.

114. GRIMMIA TRICHOPHYLLA, Grev.

115. HYPNUM MYOSUROIDES, Linn.

——. ALSIA CALIFORNICA, Sulliv.

116. MADOTHECA NAVICULARIS, Nees.

117. FOSSOMBRONIA LONGISETA, Austin.

118. FIMBRIARIA CALIFORNICA, Austin.

119. FIMBRIARIA PALMERI, Austin, Bulletin Torrey Botanical Club, 6. 47; new species.

III. *Descriptions of New Species of Plants, chiefly Californian, with Revisions of certain Genera.*

ANEMONE (PULSATILLA) OCCIDENTALIS. Alpine, more or less villous, stout and often tall: leaves large, long-petioled, biternate and pinnate; lateral primary divisions nearly sessile; segments pinnatifid with narrow laciniately toothed lobes; involucral leaves similar, nearly sessile upon the middle of the stem: flower solitary, white or purplish, an inch broad or more: sepals six or seven: receptacle conical, becoming much elongated: tails of the linear-oblong akenes at length an inch and a half long, reflexed. — *A. alpina*, Hook. Fl. Bor.-Am.; Torr. & Gray, Flora; &c., not Linn. In the mountains, from British Columbia southward to Mt. Shasta and Lassen's Peak; perhaps also the *A. alpina* of arctic collectors from Kotzebue Sound, &c., of which specimens are not at hand. It differs from *A. alpina* of Europe and the Caucasus in its more finely and narrowly dissected leaves, which have also the primary divisions much more shortly petiolulate, and in the lengthened receptacle (sometimes an inch and a half long), which in the other is small and hemispherical.

CROSSOSOMA BIGELOVII. A low shrub, more slender than *C. Californicum*, and all the parts much smaller: leaves glaucous, three to six lines long, oblong, somewhat fascicled: pedicels slender, terminating very short branchlets: petals oblong, three lines long: stamens about fifteen: carpels 10–12-ovuled. — *C. Californicum*, Torrey in Pacif. R. Rep. iv. 63, t. 1, excl. fig. 1, 2. Collected by Dr. Bigelow, on Lieut. Whipple's Expedition, in cañons near the mouth of Bill Williams River, W. Arizona; in flower only. The petals are narrower and the stamens and ovules much less numerous than in the island species. Of the latter, fine fruiting specimens were for the first time obtained by Dr. Palmer on Guadalupe Island; but the characters of the embryo, which is found to be nearly as long as the thick fleshy albumen and strongly curved, with narrowly oblong cotyledons longer than the radicle, do not confirm the reference of the genus either to the *Pæonieæ* or to the *Dilleniaceæ*.

ESCHSCHOLTZIA MINUTIFLORA. Slender, and about a foot high: flowers very small (three lines or less in diameter), orange; torus cylindrical, without border: capsule very narrow, an inch and a half long: seeds nearly smooth, scarcely half a line broad. — *E. Californica*, var. *tenuifolia*, Gray in Bot. Ives's Rep. 5, in part. *E. Californica*, var. *hypecoides*, Watson, Bot. King's Rep. 14. From Northwestern Nevada to Arizona and Southern Utah (Parry), apparently confined to the inner basin. It has smaller and smoother seeds, smaller flowers, and narrower capsules than any other form.

ARABIS LYALLII. Perennial and alpine or subalpine, glabrous and bright green or glaucous, or somewhat villous below with spreading hairs, especially on the margins of the petioles; rarely more or less canescent with stellate hairs: stems slender, from a branching base, two to fifteen inches high, often dwarf: radical leaves oblanceolate, on slender petioles, acute, entire; the cauline oblong-lanceolate, clasping and sagittate at base: petals light pink, about three lines long, twice longer than the sepals: style none: pods straight, narrow, erect or ascending, one to three inches long: seeds in two rows, narrowly winged. — *A. Drummondii*, var. *alpina*, Watson, Bot. King's Rep. 18. In the mountains from Washington Territory to Mono Pass in the Sierra Nevada, and eastward to W. Wyoming and Utah. Resembling some forms of *A. Drummondii*, but distinguished by its perennial root.

ARABIS REPANDA. Biennial, pubescent with loose branched hairs, especially below: stem rather stout and coarse, two feet high, the spreading branches somewhat flexuous: leaves oblanceolate, three or four inches long, obtuse, coarsely sinuate-toothed, attenuate to a broad petiole; those on the branches narrower and acutish: calyx pubescent, a line and a half long or less, a little shorter than the pinkish petals: pods somewhat pubescent, ascending, falcate, three inches long and a line wide: style very short: seeds in one row, broadly winged. — Yosemite Valley, n. 4881 Bolander. A strongly marked species.

Arabis Breweri. Perennial, cespitose, canescent with a dense stellate pubescence and villous above with spreading nearly simple hairs: stems simple from a branching base, two to ten inches high: radical leaves spatulate, an inch long or less, shortly petioled, entire; the cauline ovate-oblong, sessile but not sagittate, acute: petals deep rose-color, from one to four lines long, twice longer than the purplish sepals: pods spreading or recurved, about two inches long, a line wide: style none: seeds in one or two rows, narrowly winged. — In the Coast Ranges from Mt. Diablo (Brewer, Bolander) to Lake County (Greene) and Mendocino County (Bolander). Most like *A. arcuata*, Gray, of the Sierra Nevada and mountains of S. California, which is a taller species, with larger flowers, longer pods, and different pubescence, the leaves mostly toothed and the cauline ones sagittate.

Smelowskia (?) Fremontii. A dwarf alpine perennial, pubescent with scattered short spreading hairs, the branching somewhat woody base covered with a few remnants of old leaves: stems two to four inches high: leaves less than half an inch long, pinnate with one to three pairs of linear leaflets, which are strongly nerved and slightly revolute: sepals glabrous, broad, less than a line long; petals white, twice longer: immature pods two to three lines long, somewhat obcompressed, obtuse at base and scarcely attenuate above, beaked with a short thick style; valves faintly nerved: seeds small, ten or more in each cell; cotyledons obliquely incumbent. — Collected by Fremont on hills near Klamath Lake, and by Lemmon in the northern Sierra Nevada. It much resembles *S. calycina* in habit, but the characters of the fruit do not fully accord with those of the genus.

Lyrocarpa Palmeri. Pod reniform-obcordate, rounded at the base, four or five lines wide, broader than high: cells 2-seeded, the upper seed horizontal, the lower pendulous: petals linear, purplish, six lines long, twice longer than the calyx. — It otherwise resembles the original *L. Coulteri*, Hook. & Harv. The peculiarities of the fruit require a modification of the received generic character. From the Big Cañon of the Tantillas Mountains, below San Diego; collected by Dr. Edward Palmer.

Thysanocarpus erectus. Smooth and leafy: leaves oblong to oblanceolate, an inch or two long, auricled at base, somewhat sinuate-dentate: flowers purple or rose-colored: fruiting pedicels erect: pod minutely pubescent, the wing of the fruit (still immature) without indication of nervation or perforation: style very short — Collected by Dr. E. Palmer on the western side of Guadalupe Island. Distinguished especially by its erect pedicels.

Frankenia Palmeri. A rather slender diffuse shrub, a foot high, with short straight divaricate branchlets: leaves numerous, fascicled, a line or two long, thick and strongly revolute so as to be nearly terete, canescent with a white papillose and furfuraceous encrustation: calyx a line and a half long: petals linear, a little exserted: stamens four: style bifid: capsule 2-seeded. — Lower California, upon the gulf side, Dr. E. Palmer.

Silene Palmeri. Puberulent with short spreading hairs, glandular above: stems a foot high, slender, from a branching base: leaves oblanceolate, an inch long: flowers purplish, on slender pedicels, in an open panicle: calyx four lines long; teeth short: petals very narrow, half an inch long; blade 4-parted with linear entire or bifid lobes; appendages linear; claw not auricled, and with the filaments very villous: styles and stamens much exserted: capsule oblong, exceeding the calyx; stipe scarcely a line long: seeds tubercular, not crested. — In the Cuyamaca Mountains, San Diego County; Dr. Edward Palmer, August, 1875.

Calandrinia Breweri. Much resembling *C. Menziesii*, from which it is distinguished by its divaricately spreading or deflexed pedicels; by a longer conical blunt capsule, 4 to 5 lines long, and exceeding the triangular-ovate sepals; and by the rather smaller (half a line broad) seeds, which are more strongly tuberculate, and not shining. — *C. Menziesii*, var. *macrocarpa*, Gray in Proc. Am. Acad. 3. 102. Collected by Professor W. H. Brewer, in the Santa Inez Mountains, near Santa Barbara; the only specimens are a foot tall or more, with elongated racemes.

Lavatera occidentalis. A close shrub, three or four feet high, leafy at the ends of the short branches: leaves stellate-puberulent, round-cordate, 7-lobed to the middle, three to five inches broad, on long petioles; lobes acutish, coarsely toothed: flowers axillary, solitary, on short deflexed pedicels: calyx over an inch long, twice longer than the involucre, cleft to the middle into broad foliaceous lobes: petals narrowly spatulate with a broad naked claw, emarginate, two inches long, straw-colored with violet stripes: fruit half an inch broad, finely pubescent; carpels six to ten, about equalling the short conical summit of the axis. — Collected by Dr. E. Palmer on the cliffs of Guadalupe Island. An interesting discovery as confirming the American habitat of the genus.

Malvastrum Coulteri. Perennial, somewhat pubescent, with slender branches: leaves small, ovate or somewhat cordate, 3–5-lobed, acutely toothed, equalling or exceeding the slender petioles; flowers small, in a rather loose raceme: calyx-lobes acuminate: petals rose-colored, 4 or 5 lines long: carpels rounded, less than a line in diameter, with a thin horizontal oblong projection inward at base, very strongly reticulated, pubescent below. — Collected probably in South-eastern California by Coulter (n. 96), and in the valley of the Gila by Schott, on the Mexican Boundary survey. Very peculiar in the character of its carpels.

Sphæralcea sulphurea. Perennial, resembling *S. Emoryi* in habit, but more tomentose, and the inflorescence usually much more paniculate and diffuse: leaves ovate, two to four inches long, exceeding the petioles, more or less distinctly 3–5-lobed, acutish, crenately toothed, cordate to abruptly cuneate at base: flowers sulphur-yellow or whitish, usually tinged with pink: calyx two or three lines long, with broad acute lobes: petals twice longer, villous at the base of the claw: fruit globose; carpels semicircular, a line and a half long, reticulate on the sides. — On Guadalupe Island, Dr. E. Palmer; growing abundantly among rocks, in large bunches three feet high.

Abutilon Newberryi. Woody at base, often four to five feet high, densely tomentose; branches short and stout: leaves thick, oblong-lanceolate, acutish, cordate at base, one or two inches long, on short petioles: pedicels fascicled in the axils, much shorter than the leaves: flowers deep yellow, three lines long: carpels about eight, somewhat membranaceous, three lines long, narrower but rounded above, 2-valved to the base, 3-seeded. — *Sphæralcea incana,* Gray, Bot. Ives's Exp. 8. At Canebrake Cañon on the Lower Colorado by Newberry, on the Lower Gila by Emory, and in the Big Cañon of the Tantillas Mountains, below San Diego, by Palmer.

Tribulus Californicus. Small, hoary-pubescent and hairy: leaflets about six pairs, oblong-elliptical, two or three lines long: flowers yellow, very small, the petals little longer than the narrow sepals: fruit deeply 5-lobed, two lines or less in diameter, short-beaked; the carpels with four or five stout obtuse tubercles upon the back; pedicels shorter than the leaves. — Collected by Dr. E. Palmer, in Lower California (1870), on the eastern side of the peninsula.

Adolphia Californica. A shrub of rigid and compact habit, about two feet high; the branches terete, with spreading spiny branchlets, puberulent: leaves orbicular to oblong-ovate, one or two lines long, mucronate or often retuse, abruptly attenuate to a slender petiole: flowers greenish, on pedicels about equalling the leaves: petals rather deeply hooded: fruit two lines in diameter; the short style deciduous from the very base. — *A. infesta*, Torrey, Bot. Mex. Bound. 45, in part. At Solidad and Chollas Valley, near San Diego, and near Monterey; collected by Parry, Cleveland, and Palmer. The more eastern *A. infesta*, Meisner, is distinguished by its larger linear or oblong-lanceolate leaves, attenuate to a short petiole; petals less deeply hooded; and longer style, jointed above the base, and leaving the capsule apiculate.

Thermopsis Californica. Woolly-tomentose throughout: stipules lanceolate; leaflets obovate to oblanceolate, 1 or 2 inches long, acute or obtuse, equally tomentose on both sides: bracts mostly ovate, broad and clasping at base: pod on a short glabrous stipe, very pubescent, linear, 6–8-ovuled; mature fruit not known. — *T. macrophylla*, Torrey, Pacif. R. Rep. 4. 81; &c. *T. fabacea*, Torrey, Bot. Mex. Bound. 58. Marin and Napa counties, California, and probably southward. *T. macrophylla*, H. & A., is distinguished by its villous spreading pubescence, its large leaves glabrous above, and broad 4–5-seeded pod. The more northern and eastern species, *T. montana*, Nutt. (usually referred to *T. fabacea*, DC.), is much more glabrous, the linear pods 10–12-seeded.

Lupinus niveus. White throughout with a short dense tomentum, without villousness: stems a foot high, branching, leafy: leaflets nine, broadly oblanceolate, acutish, an inch long or more, shorter than the petioles: flowers subverticillate, in a shortly peduncled loose raceme; pedicels two or three lines long; bracts short, deciduous: calyx-lips equal; the lower narrow, nearly entire; the upper bifid: petals equal, broad, all naked, four or five lines long, deep blue, the banner greenish yellow in the centre: pod 5-ovuled. — Collected by Dr. E. Palmer, on Guadalupe Island, on rocks. Allied to *L. leucophyllus*.

Lupinus Grayi. A span high, densely hoary-tomentose throughout, usually with some silky hairs: leaflets five to nine, cuneate-oblong or oblanceolate, obtuse or acutish, shorter than the petioles: racemes peduncled, short and loosely flowered, with rather slender pedicels a line or two long; bracts subulate, equalling the calyx, deciduous: flowers subverticillate, light blue, rather large (six to seven lines long), with broad wings and broad naked banner; keel ciliate: pod 5–6-seeded, an inch long or more. — In the Sierra Nevada; near Clark's Ranch, Mariposa Co., Dr. Asa Gray; Indian Valley, Plumas Co., Mrs. M. E. Pulsifer Ames. With the large flowers and loose raceme of *L. ornatus*, but otherwise more nearly allied to the *L. leucophyllus* group.

LUPINUS ONUSTUS. A span high or less, with a decumbent and somewhat woody base, rather sparingly silky-villous: leaflets five to eight, oblanceolate, acute or acutish, glabrous above, about an inch long, the petioles two or three times longer: flowers deep blue, small (four lines long), scattered in a loose short and shortly peduncled raceme; bracts short, deciduous; pedicels slender: calyx slightly gibbous: banner naked; keel strongly ciliate: pod half an inch broad, an inch and a half long, 6-ovuled: seeds brown, over three lines broad. — Indian Valley, Plumas Co., by Mrs. M. E. Pulsifer Ames; Sierra County, Lemmon. Most nearly resembling *L. parviflorus* on a reduced scale, but very distinct in its fruit.

TRIFOLIUM (LUPINASTER) LEMMONI.* Dwarf and cespitose, alpine, sparingly appressed-pubescent, the short rather slender stems from a stout thick perennial root: stipules ovate, acuminate, toothed;

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* We give the following revision of the North American species of this genus: —

§ 1. Leaflets 5 to 7: heads not involucrate, terminal and axillary: flowers sessile: calyx-teeth filiform, plumose: low or dwarf perennials. — Western species.

1. T. MEGACEPHALUM, Nutt. Stout, somewhat villous: stipules ovate-oblong; leaflets obtuse, nearly an inch long: flowers in very large spicate heads: pod smooth, 6-ovuled. — North-eastern California and Northern Nevada to Washington Territory.

2. T. ANDERSONII, Gray. Cespitose, densely villous: stipules lanceolate; leaflets smaller, acute, nearly entire: flowers smaller, umbellate: pod tomentose, about 5-ovuled. — Proc. Am. Acad. 6. 522. North-eastern California and Northern Nevada.

3. T. LEMMONI, Watson. See above.

§ 2. Leaflets 3: heads not involucrate, terminal: perennial or biennial.

* Flowers on slender pedicels, large. — Eastern species.

4. T. REFLEXUM, L. Not stoloniferous: leaflets obovate to cuneate-oblong: flowers numerous, umbellate on the summit of the peduncle: pod stipitate, 4-ovuled. — *T. platycephalum*, Bisch. in Linnæa, 14. 132 (Litt.-Bericht.). From Canada West to Florida and Texas.

5. T. STOLONIFERUM, Muhl. Stoloniferous: leaflets broadly obovate, retuse: flowers fewer, on an evident rhachis: pod nearly sessile, 2-ovuled. — Ohio and Kentucky to Missouri.

leaflets three to five, thick, obovate, obtuse, coarsely toothed, half an inch long or less: peduncles mostly terminal, equalling the leaves: flowers numerous, spicate upon a short rhachis (only two lines long),

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* * Flowers sessile or nearly so. — Western species.

+ Caulescent, often tall.

++ More or less pubescent: calyx-teeth very narrow, much longer than the tube, plumose or hairy: stipules lanceolate, acuminate.

6. T. ERIOCEPHALUM, Nutt. Usually spreading-villous: leaflets oblong: flowers in dense ovate heads, at length reflexed: teeth filiform, lax, very plumose: ovary hairy. — N. California to Oregon and Idaho.

7. T. PLUMOSUM, Dougl. Somewhat appressed-villous: leaflets elongated, narrowly oblong to linear: heads oblong or ovate; flowers not reflexed: teeth straight, plumose: ovary smooth. — Oregon, Idaho.

8. T. LONGIPES, Nutt. Stem usually glabrous: leaflets shorter, narrowly oblong, mostly very acute: heads ovate, smaller and looser: teeth straight, more or less hairy. — Var. LATIFOLIUM, Hook. Often low: leaflets broader: flowers pedicellate in loose heads. — From the Rocky Mountains to the Pacific.

++ ++ Glabrous throughout: calyx-teeth subulate, rigid, contorted, twice longer than the tube: flowers sessile: stipules lanceolate, acuminate.

9. T. ALTISSIMUM, Dougl. Stout: leaflets narrowly oblanceolate, acute. — Oregon, Idaho.

++ ++ ++ Glabrous throughout: calyx-teeth straight, scarcely longer than the tube: stipules mostly ovate, acute, entire: flowers on very short pedicels, at length reflexed.

10. T. BECKWITHII, Brewer, ined. Stout: leaflets oblong to oblanceolate, obtuse or acute, 1 or 2 inches long, coarsely veined and toothed: flowers 7 to 9 lines long, in dense globose heads: teeth linear-subulate: ovary 2–6-ovuled. — *T. altissimum*, Torr. & Gray, Pacif. R. Rep. 2. 120. N. E. California to S. Idaho.

11. T. KINGII, Watson. Smaller and more slender: leaflets usually narrow and acuminate: flowers 4 to 7 lines long, in looser heads. — Bot. King's Rep. 59. *T. Haydeni*, Porter, Hayden's Rep. 1871, 480. N. E. California to Montana and Utah.

12. T. BOLANDERI, Gray. Cespitose, decumbent: leaflets small, broad and obtuse, very finely reticulated, slightly serrulate: flowers few, 3 or 4 lines long: teeth lanceolate, scarcely as long as the tube: ovules 2. — Proc. Am. Acad. 7. 335. Yosemite Valley.

+ + Dwarf, cespitose, acaulescent or nearly so. — Rocky Mountains to Utah.

++ Glabrous: flowers large: ovary smooth, linear, 8-ovuled.

13. T. NANUM, Torr. Leaflets small, oblanceolate, serrulate: flowers 1 to 3, 6 to 9 lines long: calyx-teeth broad, acute.

14. T. BRANDEGEI, Watson. See p. 132.

very small (so far as known): calyx villous, two lines long, the filiform plumose teeth exceeding the purplish petals: banner deeply hooded: ovary smooth, 2-ovuled. — From Lassen's Peak, by J. G. Lemmon,

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++ ++ Pubescent: flowers small: ovary obovate, densely villous, 2-ovuled, at length exserted from the calyx.

15. T. GYMNOCARPON, Nutt. Leaflets ovate-oblong to oblanceolate: flowers 3 to 5 lines long, in rather close heads. — *T. subcaulescens*, Gray, Bot. Ives's Rep. 10.

§ 3. Leaflets 3: heads not involucrate, axillary or rarely terminal: annuals.

* Pubescent: heads mostly terminal: flowers sessile, not reflexed: calyx-teeth long-filiform, very plumose: ovules 2. — Western.

16. T. MACRÆI, H. & A. Flowers dark-purple, 3 lines long, in dense ovate long-peduncled heads. — Var. DICHOTOMUM, Brewer. Taller and stouter, with larger flowers: corolla more conspicuous, tipped with white. *T. dichotomum*, H. & A. — From the Columbia River to S. California. The typical Chilian form appears to have nearly sessile heads and stouter calyx-teeth.

* * Mostly glabrous: heads axillary, small: flowers shortly pedicellate, at length reflexed: calyx-teeth subulate or short.

+ Calyx-teeth subulate: ovules 2. — Western species. (*T. depauperatum* might be looked for here.)

17. T. CILIATUM, Nutt. Glabrous: leaflets obtuse or retuse: calyx campanulate; teeth lanceolate, rigid, the scarious margin rough-ciliate. — Pl. Gambel. 152. *T. ciliolatum*, Benth. Pl. Hartw. 304. From the Columbia to S. California.

18. T. GRACILENTUM, Torr. & Gray. Slender: peduncles rarely villous with spreading hairs: leaflets retuse: heads rather dense: calyx campanulate; teeth subulate, equalling the corolla. — *T. denudatum*, Nutt. Pl. Gambel. 152, t. 24. From the Columbia to S. California.

19. T. BIFIDUM, Gray. Leaflets narrow, deeply notched or cleft, the sides sparingly toothed or entire: otherwise as the last. — Proc. Am. Acad. 6. 522.

20. T. AMABILE, HBK. Similar to *T. gracilentum*, but more decumbent, pubescent: calyx-teeth linear-setaceous, somewhat villous. — Mexico and Western South America.

21. T. BREWERI, Watson. See p. 132.

22. T. PALMERI, Watson. See p. 132.

+ + Ovules 4 or more: low, decumbent: leaflets obcordate or obovate. — Eastern species.

23. T. CAROLINIANUM, Michx. More or less pubescent: corolla 2 lines long, scarcely exceeding the green subulate calyx-teeth. — Pennsylvania to Florida and Texas.

24. T. AMPHIANTHUM, Torr. & Gray. Stoloniferous, very slender, nearly glabrous: flowers few, 4 lines long: calyx-teeth slender, much shorter, equalling

1875. The few specimens are imperfect, only a few perhaps undeveloped flowers remaining on the receptacles.

TRIFOLIUM BRANDEGEI. Dwarf, perennial, cespitose and acau-

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the tube: small solitary fertile flowers often borne under ground. — Louisiana to Texas.

25. T. BEJARIENSE, Moricand. Slightly hairy: calyx herbaceous, unequally lobed, nearly equalling the corolla; upper tooth nearly distinct, narrow; the rest broad, acute, reticulated: standard and wings broad, toothed, 3 lines long. — Pl. Nouv. 2, t. 2. *T. macrocalyx*, Hook. Ic. Pl. t. 275. Texas.

§ 4. Leaflets 3: heads subtended by a mostly monophyllous usually many-cleft involucre, axillary: flowers in whorls, sessile or nearly so, not reflexed.

* Low or dwarf perennials, acaulescent or nearly so: flowers rather large: involucre parted, somewhat scarious. — Rocky Mountains.

26. T. PARRYI, Gray. Glabrous, often stout: leaflets oblong to oblanceolate: flowers large, in close heads: bracts 5 to 7, oblong, obtuse: calyx-teeth broadly subulate, equalling the tube. — Am. Jour. Sci. 2. 33. 409.

27. T. DASYPHYLLUM, Torr. & Gray. Cespitose, silky: leaflets linear-lanceolate, entire: bracts very small, unequal, lanceolate: teeth linear, much longer than the tube.

28. T. ANDINUM, Nutt. Cespitose, silky: leaflets cuneate-oblong, entire: involucre of 2 broadly stipuled 3-foliolate leaves: teeth subulate, nearly equalling the smaller flowers. — Watson, Bot. King's Rep. 60, t. 8.

* * Slender annuals: corolla not becoming inflated. — Western.

+ Involucre not membranaceous, deeply lobed: lobes laciniately and sharply toothed.

29. T. INVOLUCRATUM, Willd. Glabrous: leaflets mostly oblanceolate, acute at each end: flowers ½ inch long, in close heads: teeth thin, long and narrow, entire: ovules several. — *T. Wormskioldii*, Lehm. *T. fimbriatum*, Lindl. *T. spinulosum*, Dougl. From British America to Mexico.

Var. HETERODON. Heads mostly larger and leaflets broader: some of the teeth setaceously cleft. — *T. heterodon*, Torr. & Gray. Washington Territory to New Mexico.

30. T. TRIDENTATUM, Lindl. Smooth or glandular-puberulent: leaflets linear to narrowly lanceolate: flowers 6 to 8 lines long in close heads: teeth rigid, rather abruptly narrowed from a broad base into the spinulose apex, entire or shortly toothed: ovules 2. — *T. involucratum*, Torr. & Gray. *T. aciculare* & *polyphyllum*, Nutt. From Washington Territory to S. California.

Var. OBTUSIFLORUM. Stouter, often glandular: leaflets usually broader and heads large: teeth entire. — *T. obtusiflorum*, Hook. Central California.

Var. MELANANTHUM. Smooth, often low: flowers smaller, dark-purple: teeth entire or toothed. — *T. melananthum*, Hook. & Arn. *T. variegatum*, β., Torr. & Gray. S. California to Arizona.

31. T. PAUCIFLORUM, Nutt. Smooth, very slender: involucre small: flowers little exceeding the calyx, rather few: teeth rigid, setosely acuminate, entire. —

lescent, glabrous, the inflorescence slightly villous: stipules scarious; leaflets elliptic-oblong, thin, acutish, entire, a half to an inch long: peduncles about equalling the leaves: flowers spicate in a loose naked head, purplish, seven lines long: calyx-teeth lanceolate, acuminate, a little longer than the campanulate tube: ovary stipitate, 7-ovuled. — On the north-western border of New Mexico; collected by T. S. Brandegee, on Hayden's Survey. A strongly marked and peculiar species.

TRIFOLIUM BREWERI. Annual, very slender and diffuse, somewhat pubescent throughout, a span high or more: stipules lanceolate, short; leaflets obcordate or obovate, rarely oblong, toothed or serru-

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T. variegatum, Nutt. *T. oliganthum*, Steud. Washington Territory to S. California and Utah.

32. T. MONANTHUM, Gray. Often villous, small, very slender: involucre very small: flowers 1 to 4, much exceeding the short calyx: teeth thin, shortly acuminate. — Proc. Am. Acad. 6. 523. Sierra Nevada.

+ + Involucre membranaceous, at least at base, less deeply lobed; lobes entire or serrate.

33. T. MICROCEPHALUM, Pursh. Villous: heads small: lobes of involucre acuminate, 3-nerved, entire: calyx-teeth long-subulate, with broad scarious margin. — Washington Territory to S. California, and N. Nevada.

34. T. MICRODON, H. & A. Villous: involucre broader; lobes 3-toothed: calyx smooth, angled; teeth rigid, triangular, acute, with a narrow serrulate scarious margin. — Washington Territory to San Francisco; Chili.

35. T. CYATHIFERUM, Lindl. Smooth: heads larger: involucre very broad; lobes short, toothed, many-nerved: calyx-teeth setosely many-branched. — From the Columbia River to N. California and N. Nevada.

* * * Slender annuals: standard becoming conspicuously inflated. — California.

+ Heads mostly large: involucre conspicuous.

36. T. BARBIGERUM, Torr. Somewhat villous: involucre shortly lobed, setaceously many-toothed: calyx-teeth filiform, plumose, sometimes 2–3-parted. — Pacif. R. Rep. 4. 79. Monterey to Mendocino County.

37. T. FUCATUM, Lindl. Smooth, stout: stipules large and scarious: heads large: involucre deeply lobed or parted; lobes entire, acuminate: teeth narrowly subulate, entire or 2–3-cleft. — *T. Gambellii*, Nutt. Pl. Gamb. 151.

+ + Heads small, few-flowered: involucre small or none: calyx-teeth narrowly subulate: small.

38. T. DEPAUPERATUM, Desvaux. Involucre a very small toothed or truncate often scarious ring. — *T. stenophyllum*, Nutt. l. c. Also Chilian.

39. T. AMPLECTENS, Torr. & Gray. Involucre 4–5-parted or cleft, the segments oblong, usually obtuse, entire or nearly so, equalling the calyx. — *T. diversifolium*, Nutt. l. c. 152.

late, three to nine lines long: flowers few, in axillary naked very loose heads, nearly white, two to four lines long, on slender pedicels often half as long, at length reflexed: calyx very narrow, the slender teeth much shorter than the corolla. — In the Sierra Nevada, from the Yosemite Valley, at Clark's, to Sierra County, from several collectors. Of the *T. gracilentum* group, which is otherwise confined chiefly to the Coast Ranges.

TRIFOLIUM PALMERI. A glabrous and diffuse annual, the stems ascending, about a foot high or less: stipules elongated, narrowly acuminate; leaflets oblong to narrowly lanceolate, acute or acutish at each end, serrulate, a half to an inch long: peduncles axillary: heads naked, 10–20-flowered; flowers sessile, at length reflexed: calyx three lines long, deeply cleft into narrow acuminate entire lobes: petals purplish, scarcely exceeding the calyx: pod 2-seeded. — Guadalupe Island; Dr. E. Palmer.

DALEA CALIFORNICA. Shrubby, with the leaves and younger branches canescent with a fine appressed pubescence: glands mostly obscure, but upon the peduncles sometimes prominent and prickle-like: leaflets one or two pairs, linear-oblong, not two lines long, decurrent upon the short rhachis: flowers on short pedicels in a loose raceme, purple, four lines long: calyx half as long, finely pubescent, the ovate acute teeth shorter than the tube: ovules two. — Known as yet only from scanty specimens recently collected by Dr. Parry in the San Bernardino Mountains, California. It adds another to a group of more or less woody or shrubby species, which may be separated as a section *Xylodalea*, characterized by having the claws of the petals adnate to the stamineal tube only at the very base, the flowers spreading or reflexed, mostly in loose spikes or racemes, and the ovules in a few of the species four or six. It includes a dozen species, some with calyx very pubescent and teeth mostly slender (*D. scoparia* Gray; *D. frutescens*, Gray; *D. Emoryi*, Gray; *D. arborescens*, Torr.; *D. polyadenia*, Torr.; *D. amœna*, Watson), others with the calyx sparingly pubescent and broadly toothed (*D. Fremontii*, Torr.; *D. Californica*, Watson; *D. Johnsoni*, Watson; *D. Kingii*, Watson; *D. Schottii*, Torr.; and *D. spinosa*, Gray). The species *D. argyræa*, *D. Parryi*, and *D. leucostachys* are intermediate between this section and the true Daleas. The genus *Asagræa* of Baillon, founded on *D. spinosa* and characterized by the several ovules and simple leaves, can hardly be maintained, as *D. Schottii* likewise has simple leaves but only two ovules, while in *D. scoparia* at least the ovules are four.

LATHYRUS NEVADENSIS.* Slender, usually a span high, finely pubescent or nearly glabrous: stipules semi-sagittate, the lobes narrowly acuminate; leaflets thin, two to four pairs, ovate to ovate-

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* The North American species of this genus may be arranged as follows: —

§ 1. Rhachis of the leaves tendril-bearing: peduncles mostly equalling or exceeding the leaves: pod sessile.

* Annual: racemes 1–2-flowered.

1. L. PUSILLUS, Ell. Glabrous; stems winged: leaflets 2, narrow: flowers small, purple: pod linear: seeds minutely tuberculate. — S. Carolina to Texas.

The *L. Engelmanni*, Bischof in Linnæa, 14. 132 (Litt.-Bericht), from near Fort Gibson, Arkansas, may be distinct. It is described as with oblong leaves, ciliate stipules, and seeds "ruguloso-exsculptis."

* * Perennials: racemes several-flowered.

+ Stipules large, ovate or somewhat semi-hastate with broad lobes: stout and glabrous, excepting forms of *L. maritimus*.

2. L. MARITIMUS, Bigel. Stipules broadly ovate, acute: leaflets 6 to 10, thick, ovate-oblong, obtuse or acutish, 1 or 2 inches long, nearly sessile: flowers large (9 lines long), purple: calyx-teeth sparingly ciliate. — Seashore, from New Jersey and Oregon northward, and on the Great Lakes. The high northern and arctic form is low and more slender, and more or less densely pubescent.

3. L. POLYPHYLLUS, Nutt. Stipules smaller, triangular, scarcely longer than broad, acute or acuminate; leaflets 12 to 20, thin, oblong, distinctly petiolulate: otherwise like the last. — N. California and Oregon, near the coast.

4. L. OCHROLEUCUS, Hook. Stipules semi-cordate; leaflets 6 to 8, thin, ovate, obtuse or acutish: flowers smaller, ochroleucous. — Northern United States from New England to Washington Territory, and north to Lake Winnipeg.

5. L. SULPHUREUS, Brewer. Glaucous: stipules semi-cordate or semi-sagittate; leaflets 6 to 20, oblong-ovate to linear-lanceolate, about an inch long, acute: flowers sulphur-yellow, 6 lines long. — In the Sierra Nevada.

+ + Stipules narrower, semi-sagittate, the lobes usually lanceolate, acuminate: flowers purple or purplish.

++ Leaflets 8 to 12: peduncles rather many-flowered.

6. L. VENOSUS, Muhl. Stout, climbing, usually somewhat downy: stipules mostly narrow and short; leaflets oblong-ovate, mostly obtuse, about 2 inches long: flowers 6 to 8 lines long: calyx densely pubescent to nearly glabrous: ovary smooth. — Through the Atlantic States to the Saskatchawan, and thence to Washington Territory.

Var. CALIFORNICUS. Stems very stout, often strongly winged: stipules broader; leaflets acute and narrower: flowers larger. — Sonoma County to Monterey, California, and in the foothills of the Sierra Nevada; near water. Intermediate forms occur.

oblong, an inch or two long, obtuse or acute; rhachis rarely developing a short tendril at the extremity: flowers ochroleucous or sometimes purplish (?), large (7 to 12 lines long): calyx-teeth shorter than the

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7. L. VESTITUS, Nutt. Slender, often tall, usually more or less downy: stipules narrow, often small; leaflets ovate-oblong to linear, ½ to 1 inch long, acute: flowers pale, 7 to 10 lines long: ovary appressed-pubescent. — *L. strictus*, Nutt. Coast Ranges of California, from Sonoma County to San Diego; very variable.

++ ++ Leaflets 4 to 8: peduncles 2–6-flowered.

8. L. PALUSTER, Linn. Slender, glabrous or somewhat pubescent: stem often winged: stipules mostly narrow, often small; leaflets narrowly oblong to linear, acute, an inch or two long: flowers smaller, 6 lines long. — *L. Lanszwertii*, Kellogg, Proc. Calif. Acad. 2. 105, fig. 44.

Var. MYRTIFOLIUS, Gray. Stipules usually broader and larger; leaflets ovate to oblong, an inch long or less. — *L. venosus*, var. δ., Torr. & Gray, Fl. 1. 274. *L. polyphyllus*, Watson, Bot. King's Rep. 78. — Very variable: found throughout the northern part of the continent, ranging southward in the mountains to New Mexico, Arizona, and S. California. What appears to be merely a low form with the tendrils undeveloped is found in the Rocky Mountains and westward.

§ 2. Rhachis not tendril-bearing or rarely so: pod shortly stipitate.

* Peduncles long, 2–6-flowered.

9. L. LITTORALIS, Endl. Densely silky-villous: stipules ovate-oblong, acute, entire; leaflets 2 to 6, with a small terminal one, cuneate-oblong, 4 to 6 lines long: flowers purple, 6 to 8 lines long: pod oblong, villous. — On the coast, from Washington Territory to San Francisco.

10. L. NEVADENSIS, Watson. See above.

11. L. POLYMORPHUS, Nutt. Usually low, finely pubescent or glabrous, glaucous: stipules narrowly acuminate; leaflets 6 to 12, thick and strongly nerved, narrowly oblong, acute, 1 or 2 inches long: flowers very large, purple: pod 3 or 4 lines broad: funiculus remarkably narrow and hilum short. — New Mexico and Colorado to Central Arizona.

12. L. ORNATUS, Nutt. Leaves narrower and shorter: pod somewhat broader: funiculus broader: otherwise resembling the last. — Mountains of Colorado and Utah.

* * Peduncles very short, 1-flowered.

13. L. TORREYI, Gray. Very slender, low, sparingly villous: stipules narrow; leaflets thin, 8 to 12, with occasionally a similar terminal one, ovate to oblong, acute, ½ inch long: flowers rather small, purplish: pod pubescent. — Washington Territory to N. California, near the coast.

Species excluded.

L. LINEARIS, Nutt. and others, including *L. dissitifolius*, Nutt., is only a western form of *Vicia Americana*, with narrow leaflets, = *V. Americana*, var. *linearis*.

tube: fruit not seen. — *L. venosus*, var. *obovatus*, Torrey in Pacif. R. Rep. 4. 77. In the Sierra Nevada, in Calaveras County, where it has been collected by Bigelow, Brewer (n. 1602, 1612), Dr. G. L. Goodale, and H. Mann. Other specimens from the Blue Mountains, Oregon (Rev. R. D. Nevius), and from Northern Idaho (Geyer, n. 312; *L. polymorphus*, Hook. Jour. Bot. 6. 207), are probably the same, with rather narrower and acuter leaflets.

Sophora Arizonica. An evergreen shrub, somewhat canescent with short appressed silky hairs: leaflets two or three pairs, narrowly oblong, acutish, about an inch long; stipules small, subulate: racemes very short (half an inch long), and few-flowered; bracts deciduous: pedicels bracteolate, about three lines long: calyx narrowed at base: pods smooth, coriaceous, compressed, reticulated and with nerve-like margins, three or four inches long, more or less contracted between the thick oblong (half inch long) seeds; stipe exceeding the calyx. — *S. speciosa*, Torrey in Pacif. R. Rep. 4. 82. At Cactus Pass and on White Cliff Creek in W. Arizona, by Dr. Bigelow; only fruiting specimens found, January. The pod is thinner and more compressed than is usual in the genus and the seed less globose. The more eastern *S. speciosa*, Benth., has very thick and terete silky pods, with ovate seeds, and larger obtuse or emarginate cuneate-obovate or broadly spatulate leaves.

Parkinsonia Torreyana. A small tree, twenty or thirty feet high, with smooth light green bark; younger branches and leaves sparingly pubescent: leaflets two or three pairs in each pinna, oblong, obtuse, narrower toward the somewhat oblique base, two or three lines long, glaucous: flowers on long pedicels in racemes terminating the branches; pedicels jointed near the middle, the joint not evident until in fruit: petals apparently bright yellow, four lines long; claw of the upper petal with a thick prominent gland: ovary glabrous: pod with a double groove along the broad ventral suture, usually two inches long or more, 2–8-seeded, straight or somewhat contracted between the seeds: seeds very thick. — *Cercidium floridum*, Torrey in Pacif. R. Rep. 5. 360, t. 3. Abundant on the Lower Colorado River and in the valleys of Western and Southern Arizona, and known as *Palo Verde* or Green-barked Acacia. It has been always mistaken for *P. florida* (*Cercidium floridum*, Benth.), of the Rio Grande Valley, which has sessile axillary racemes, pods with a narrow acute margin on the ventral side, thinner seeds, and somewhat smaller leaflets.

The characters which have been relied upon to separate *Cercidium*, Tulasne, from *Parkinsonia*, do not hold good in regard to our western species, and it becomes necessary to unite the two genera. The *P. microphylla* of Torrey, from W. Arizona (republished by Bentham under the same name in Martius' Flora Brasil.), is certainly rightly referred, the pod being in every respect that of *Parkinsonia*, though the habit and characters of the flowers are those of *Cercidium*. Both genera are alike in the jointed pedicels of the flowers, in the more or less thickened glandular and pubescent claw of the upper petal, in the strongly gibbous filament of the corresponding upper stamen, in the indoubling of the style in the bud, and in the more or less oblique longitudinal veining of the pod. The valvate or slightly imbricate æstivation of the calyx, the straight or torulose and more or less coriaceous pods, and the differences in foliage, cannot be relied upon to distinguish the genera. In addition to the three species already mentioned and the eastern *P. Texana* (*Cercidium Texanum*, Gray), there is perhaps another undescribed species from near Camp Grant in Arizona, and Botteri's n. 994 from Orizaba, Mexico, appears also to be distinct, but the material in both cases is insufficient for a satisfactory description.

Cassia (Chamæsenna) armata. Herbaceous, about three feet high, minutely puberulent, light green: leaflets two or three pairs, thick, round-ovate, acutish, a line or two in diameter, the margin slightly revolute, distant upon an elongated (two inches long) rigid flattened spinulose rhachis; stipules and glands wanting: flowers in a short terminal raceme, yellow, on slender pedicels and with rigid aculeate-tipped bracts: petals two or three lines long: ovary slightly pubescent; the numerous ovules obliquely transverse: young pod glabrate, stipitate, linear, acuminate, compressed, the sutures thick and nerve-like. — A remarkable species, found by Dr. J. G. Cooper in the mountains of S. California, between Fort Mohave and Cajon Pass, and also by Lieut. Wheeler in W. Arizona.

Neillia Torreyi. A small shrub, differing from *N. opulifolia* in its smaller leaves, which are an inch long or often less, its finer pubescence and the leaves sometimes densely white-tomentose beneath, its fewer and smaller flowers (only half as large) on shorter pedicels, the fewer (15 or 20) stamens, and especially the densely tomentose ovaries, which are fewer (usually 1 or 2) and become less inflated. — *Spiræa monogyna*, Torrey, Ann. N. Y. Lyc. 2. 194. *S. opulifolia*, var. *pauciflora*, Torr. & Gray. In the mountains of Colorado and westward to Nevada. Very distinct from *N. opulifolia*, though by no means always monogynous as originally described, and of interest as being a strictly American species of this chiefly Asiatic genus.

Sedum variegatum. Glabrous, slender; stems simple, from underground rootstocks (?), erect, an inch or two high: radical leaves none; cauline lanceolate with a broad base, two lines long or less: flowers few (three to six) in a close cyme: sepals broadly ovate, acute, short and purplish: petals twice as long (about two lines), ovate-lanceolate, yellowish with purple midvein: stamens 10, included. — A diminutive species, sent by D. Cleveland, from San Diego.

Œnothera (Sphærostigma) Guadalupensis. A low erect annual (three inches high), branching, finely pubescent: leaves oblanceolate, sessile or the lowest attenuate to a petiole, obtuse or acutish, obscurely sinuate-toothed, an inch long: flowers few, axillary, yellow, very small: calyx-tube obconical, a line long; the lobes as long, close in the bud: capsule oblong-pyramidal, nearly straight, strongly angled, half an inch long: seeds brown, smooth. — Found by Dr. E. Palmer on Guadalupe Island; a peculiar species in the section as respects its capsule, in which it most resembles *Œ. andina.*

Mentzelia dispersa. A slender annual, usually about a foot high: leaves narrowly lanceolate, sinuate-toothed or sometimes entire, rarely pinnatifid, the uppermost often ovate: flowers small, mostly approximate near the ends of the branches; calyx-lobes a line long, little shorter than the five spatulate or obovate petals: filaments not dilated: capsule narrowly linear-clavate, six to nine lines long: seeds very often in a single row, angular and somewhat rhombohedral, more or less grooved upon the angles, very nearly smooth, half a line long. — *M. albicaulis*, var. *integrifolia*, Watson, Bot. King's Rep. 114. From Washington Territory to Colorado and southward, frequent; Yosemite Valley, Bolander; Guadalupe Island, Palmer. Much resembling *M. albicaulis*, Dougl., with which it has been confounded almost from the first, but which is distinguished by its more pinnatifid leaves and slightly larger flowers, and especially by its rather strongly tuberculate seeds, irregularly angled with obtuse margins. The rarer allied species *M. micrantha* differs in its more leafy habit and small ovate leaves, and in its shorter, broader and few-seeded capsules, the seeds a line long.

Cucurbita palmata. Canescent with a short rough pubescence, which is appressed upon the leaves; stems leafy: leaves thick, cordate, two or three inches broad, usually exceeding the petioles, palmately 5-cleft to the middle with lanceolate acuminate lobes, which are often obtusely toothed near the base: flowers three inches long, on stout pedicels: calyx-tube an inch long, the lanceolate teeth three lines long or more: fruit globose; seeds five lines long, rather smaller than in *C. digitata.* — San Diego County: collected in Cajon Valley by D. Cleveland, and at Larken's Station near the Jacumba Mountains by Dr. E. Palmer.

Cucurbita Californica, Torrey MS. in herb. Imperfect specimens of this species were collected by Dr. E. Pickering on the Wilkes Exploring Expedition, at some locality in the Sacramento Valley. The foliage is much like that of the last, but the flowers are smaller, scarcely more than an inch long, exceeding the slender pedicels; calyx-teeth short and linear.

Megarrhiza Guadalupensis.* Nearly glabrous, the inflorescence somewhat pubescent: leaves thin, 3–5-lobed to the middle;

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* MEGARRHIZA, Torrey. The species of this genus have been imperfectly studied, owing to want of material, and the only one at all well known has been the original *M. Californica*, the *Echinocystis fabacea* of Naudin. As already pointed out by Dr. Gray and Dr. Torrey, the genus is separated from the eastern *Echinocystis* by its thick perennial roots, its large turgid immarginate seeds, and its thickened fleshy cotyledons, which remain subterranean in germination, — characters which hold good in all the species, and may be considered as sufficiently distinctive. The following are the species at present known, the characters subject to modification as fuller material may require. Considerable diversity is shown in the internal structure of the fruit, which may perhaps be found to vary to some extent even in the same species.

1. M. Californica, Torrey. Nearly glabrous; stems very long: leaves 5–7-lobed, rarely to the middle; lobes broadly triangular, abruptly acute: fertile flowers without abortive stamens: ovary globose, densely echinate, 2 celled (rarely 3–4-celled), the cells 1–2-ovuled; ovules attached to the outer side, the lower ascending, the upper horizontal: fruit globose or ovoid, two inches long, beset with stout almost pungent spines (a half to an inch long), 1–4-seeded: seed obovoid, ten lines long, surrounded lengthwise by a shallow groove or darker line, the hilum at the end. — Pacif. R. Rep. 6. 74. *Echinocystis fabacea*, Naudin, Ann. Sci. Nat. 4. 12. 154, t. 9, and 16. 188. Near the coast from Punta de los Reyes to San Diego.

2. M. Marah. Scabrous or nearly smooth; stems very long: leaves nearly as in the last: fertile flowers with abortive stamens: ovary oblong-ovate, more or less covered with soft spines, 2–3-celled: ovules 1 to 4 or more in each cell, ascending or horizontal, attached to the outer side of the cell: fruit ovate-oblong, four inches long, somewhat attenuate at each end, more or less beset with weak spines: seeds horizontally imposed, flattish, suborbicular or irregularly elliptical, an inch in diameter, about half as thick, with an obscure marginal furrow and prominent lateral hilum. — *Marah muricatus*, Kellogg, Proc. Calif. Acad. 1. 38. Near San Francisco Bay, at Bolinas, Saucelito, Alameda, Redwood, Corte Madera, &c.

3. M. Oregona, Torrey. Much like the last: fertile flowers without abortive stamens: young fruit similar in shape, sparingly muricate with soft spines,

lower lobes quadrangular, the upper acuminate, with a few short teeth: flowers in subsimple racemes, six to eight lines broad; calyx-teeth filiform: ovary ovoid, densely covered with short soft spines, on a slender pedicel an inch long, 2-celled; ovules one or two in each cell: fruit ovoid, about two inches long, acute above, somewhat pubescent, and with scattered short stiff spines, usually 2-seeded: seeds subglobose, an inch in diameter, attached to the inner side of the cell, smooth upon the margin. — From Guadalupe Island, by Dr. E. Palmer; growing on high rocks.

Sanicula Nevadensis. Low, the peduncles mostly from the base of the stem: leaves ternate with decurrent oblong-ovate 3–5-lobed divisions, the segments lobed or toothed: involucre pinnatifid and toothed: rays about 5, sometimes branched, about an inch long in fruit; involucels somewhat unilateral, of several oblong acute more or less united bracts: flowers yellow: fruit sessile, covered with stout prickles. — In Plumas County, California; collected by Mrs. M. E. P. Ames, and by Lemmon.

Cicuta Bolanderi. Leaves bipinnate; leaflets narrowly lanceolate, narrowly and sharply acuminate, two inches long, very acutely serrate, the veinlets passing to the sinuses; lower leaflets petiolulate, often deeply lobed: involucre of several linear leaflets: fruit two lines long, nearly orbicular, strongly ribbed and with broad vittæ, which are sunk in the channelled seed. — At Suisun, California, in salt-marshes; Bolander.

Œnanthe Californica. Stems succulent: leaves ternate and bipinnate, the pinnæ nearly sessile; leaflets approximate, ovate, about an inch long, acute or acutish, toothed, often lobed at base: involucre

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3–4-celled: cells imbricated above each other, 1-seeded: seeds obovoid, ascending, attached to the outer side of the cell. — Pacif. R. Rep. 6. 74. Common in Washington Territory and Oregon. The ripe fruit has not been collected.

4. M. muricata. Nearly glabrous and often glaucous; stems six to eight feet long: leaves usually smaller, deeply 5-lobed, the divisions broader above and sharply toothed or lobed: fertile flowers without abortive stamens, on slender pedicels: ovary oblong, acute at each end, smooth or sparingly muricate: fruit nearly globose, an inch in diameter, naked or with a few short weak spines near the base, 2-celled (or perhaps sometimes 3- or 4-celled), 2-seeded: seed nearly globose, half an inch in diameter, ascending, attached to the outer side of the cell near the base, the margin smooth. — *Echinocystis muricata*, Kellogg, Proc. Calif. Acad. 1. 57. On the lower slopes of the Sierra Nevada, in Calaveras and Placer Counties.

5. M. Guadalupensis, Watson. See above.

of one or two linear bracts or none: fruit crowded, oblong, obtuse at each end; ribs and commissure very corky: seed somewhat dorsally compressed, usually angled; vittæ at the angles. — Found in marshes at Point Lobos and Merced Lake, and southward to San Diego County. — *Œ. sarmentosa*, Nutt., of Washington Territory, differs especially in its more diffuse leaves, the leaflets acuminate and smaller.

LIGUSTICUM FILICINUM. Rather slender, erect, a foot and a half high: leaves broadly triangular in outline, ternate, the divisions bipinnate, and the segments deeply pinnatifid with linear acute lobes: rays 10 to 15, an inch or two long; involucre none; involucels of one or few small linear bracts; pedicels slender: fruit oblong, three lines long, with dilated crenate disk but obscure stylophore, strongly ribbed on the back, the lateral ribs narrow; vittæ obscure: seed flattened, concave on the face, obscurely ridged on the back. — *L. apiifolium*, Watson, Bot. King's Rep. 125. *L. scopulorum*, Parry in Am. Naturalist, 9. 271. In the Wahsatch and Uintah Mountains (n. 454 Watson; n. 82 Parry, S. Utah collection), and northward to Wyoming (n. 121 Parry, N. W. Wyoming collection). Both *L. apiifolium*, of Oregon and California, and *L. scopulorum*, of Colorado, have much less dissected foliage, and different fruit, which is shorter and more oval, with conical stylophore, less flattened carpels, and a medial longitudinal ridge upon the face of the seed. These two species are very similar, but the latter has the more broadly winged ovate fruit, and the more depressed seed. There are indications of one or two other species, but fruit is needed for their confirmation.

SELINUM PACIFICUM. Leaves ternate and bipinnate, the ovate acutish segments an inch long, laciniately toothed and lobed: umbels on stout peduncles, about 15-rayed, with a conspicuous involucre of two or three lobed and toothed leaflets, an inch long and equalling the rays; involucels of several narrowly linear entire or 3-toothed bracts, equalling the flowers; pedicels slender: fruit smooth, oblong, three or four lines long; wings thin, rather narrow; stylopodium slightly prominent above the disk: vittæ conspicuous, very rarely in pairs, the dorsal ones sunk in the body of the seed. — On the Saucelito hills, near San Francisco; Kellogg & Harford, n. 315. This closely resembles a plant of Unalaschka, one of the two northwestern and arctic species which have been referred to the Siberian *Conioselinum Fischeri*, but which are rightly separated from it by Benth. & Hook. in Gen. Pl. 1. 915. The Alaskan species differs in having narrower and acute leaflets, the fruit shorter and more ovate (only two lines long), with often a single prominent calyx-tooth; stylopodium somewhat more prominent, and (in the still immature fruit) the vittæ obscure and seed not grooved beneath the dorsal ones.

Angelica tomentosa. Very stout, hoary-tomentose throughout or the stem glabrous: leaves quinate and bipinnate, the leaflets thick, ovate, acute, very oblique at base, unequally serrate with acutish teeth, the lower sometimes lobed, two to four inches long: umbels naked, often dense; rays one to three inches long: fruit broad-elliptical (three lines long by two or more broad), the lateral wings thin and the dorsal acutish: seed thin, flat on the face, channelled on the back under the solitary vittæ. — In the Coast Ranges from San Francisco to Mendocino County; the only species near the coast.

Cymopterus globosus. Nearly acaulescent: leaves clustered upon the very short stem, smooth and glaucous, pinnate or bipinnate with broadly oblong pinnatifid segments, the ultimate divisions oblong, obtuse, entire or toothed: involucre and involucels apparently none, and the rays and pedicels obsolete, the flowers and fruit being in dense globose heads a half to an inch in diameter: flowers white: fruit three to four lines long, the thin flat wings a line broad, narrower at base: vittæ solitary in the intervals, two on the commissure; seed slightly concave on the face. — Northern Nevada, collected in the valleys near Carson City by Stretch and Watson, and in the Goshoot Mountains by Beckwith. Referred to by Dr. Torrey in Whipple's Report under *C. montanus* as an abnormal form, and made a variety of the same species in Bot. King's Rep. 124, the fruit of the two having been confounded and the real fruit not examined.

Peucedanum Hallii.* Glabrous, shortly caulescent, the elongated

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* The western North American species of this confused and rather difficult genus form a group usually readily recognizable. They are found frequenting hillsides or dry valleys, low-stemmed or acaulescent, with thick fleshy roots, the stems rarely solitary, involucres wanting; stylophore nearly obsolete, and disk not dilated. The following characters may serve to distinguish them.

§ 1. Leaves not finely dissected (rarely bipinnate), the segments large or broad or elongated: flowers yellow: calyx-teeth mostly obsolete: fruit glabrous.

* Acaulescent, glabrous: fruit oblong to ovate.

+ Leaves biternate or ternate-quinate; leaflets orbicular to lanceolate: involucels none.

1. P. leiocarpum, Nutt. Often stout and tall: leaflets thickish, narrowly lanceolate to ovate, acute, 1 or 2 inches long, entire or often few-toothed at the apex: rays usually few, elongated: fruit oblong, narrower below, 4 or 5 lines

peduncles six to fifteen inches high : leaves pinnate, oblong in outline, the ovate segments half an inch long, deeply toothed or pinnatifid or pinnate with narrow divisions : involucels small : flowers yellow : calyx-

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long, narrowly winged : vittæ distinct, solitary, 4 on the commissure. — Washington Territory and Idaho to the Sacramento.

2. P. Nuttallii, Watson. Very similar : leaflets orbicular or ovate, obtuse : fruit shorter and more ovate, very narrowly winged ; vittæ obscure, 3 or 4 in the intervals and 4 to 6 on the commissure. — Bot. King's Rep. 128. *P. latifolium*, Nutt. Oregon and N. Nevada.

+- +- Leaves pinnate or bipinnate ; leaflets narrowly linear : involucels present.

3. P. graveolens, Watson, l. c. Scape 6 to 18 inches high, a little exceeding the leaves : fruit oblong, 4 or 5 lines long, narrowly margined ; calyx-teeth evident ; vittæ about 2 in the intervals, 4 on the commissure. — *Musenium tenuifolium*, Hook. in Lond. Jour. Bot. 6. 237, not Nutt. Mountains of Utah and Colorado ; subalpine.

* * Caulescent (often acaulescent in n. 4) : involucels mostly present : vittæ solitary, except in n. 8.

+- Leaflets linear, entire.

4. P. triternatum, Nutt. Finely puberulent, often tall : leaves biternate or ternate-quinate ; segments acute : fruit oblong, narrower below, 3 or 4 lines long, very narrowly winged, distinctly ribbed, rarely pubescent ; vittæ distinct, 2 on the commissure. — *P. leptocarpum*, Nutt., the acaulescent form. Washington Territory and Idaho to Northern California.

5. P. simplex, Nutt. Similar : leaves ternate or biternate : fruit orbicular, 3 to 6 lines long, emarginate at each end ; wings broader than the body ; ribs prominent. — Watson, l. c. 129. *P. triternatum*, var. *platycarpum*, Torr. in Stansb. Rep. 389. Montana to N. Arizona.

6. P. ambiguum, Nutt. Glabrous, often low : petioles much dilated at base ; leaves 1–2-pinnate with long linear leaflets, the upper often more dissected : involucels very small or none : fruit narrowly oblong, 4 lines long, narrowly winged ; 2 vittæ on the commissure, broad and thin. — *P. lævigatum* and *P. abrotanifolium* of Nutt. ; *P. farinosum* and *P. tenuissimum* of Geyer. Washington Territory and Oregon to W. Montana ; the root much used by the Indians. There is one other imperfectly known allied acaulescent species in the same region, and probably more.

+- +- Leaflets ovate, toothed or sometimes pinnatifid : fruit orbicular or elliptical : glabrous.

7. P. Euryptera, Gray. Low : leaves ternate ; leaflets broadly cordate, coarsely toothed, an inch long or less : fruit 5 lines in diameter, emarginate at each end, broadly winged ; 2 vittæ on the commissure. — Proc. Am. Acad. 7. 348. *Euryptera lucida*, Nutt. ; Torrey, Bot. Mex. Bound. t. 27.

8. P. parvifolium, Torr. & Gray. Low, slender : leaves deltoid in outline, biternate, 2 inches long ; leaflets ovate, laciniately lobed and toothed or pinnati-

teeth obsolete: fruit glabrous, broadly elliptical, three lines long, the wing half as broad as the body; vittæ three in the intervals, four or six on the commissure. — *P. nudicaule*, Gray, Proc. Am. Acad. 8. 385. Collected in Northern Oregon by Hall (n. 211).

PEUCEDANUM PARRYI. Acaulescent, glabrous: leaves lanceolate in outline, bipinnate, the short segments laciniately pinnatifid: peduncles six inches high: involucels small: flowers yellow; calyx-teeth evident: fruit oblong, glabrous, four lines long, narrowly winged; ribs filiform; vittæ undetermined. — *P. macrocarpum*, Parry, Am. Naturalist, 9. 271. In Southern Utah, by Parry (n. 85).

PEUCEDANUM NEVADENSE. Glaucous, puberulent, shortly caulescent, the peduncles three to fifteen inches high: leaves compoundly dissected with small oblong segments: rays often unequal, an inch or two long: involucels small, of several linear-lanceolate bractlets, usually

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fid: calyx-teeth somewhat prominent: fruit about 3 lines long, broadly winged, scarcely emarginate; 4 vittæ on the commissure. — Coast Ranges south of San Francisco.

9. P. HALLII, Watson. See above.

§ 2. Leaves decompound; segments narrowly linear; petioles very broadly dilated: involucels conspicuous, of usually scariously margined bractlets: flowers yellow: calyx-teeth obsolete: fruit broadly elliptical, glabrous: caulescent, puberulent.

10. P. CARUIFOLIUM, Torr. & Gray. Shortly caulescent: leaf-segments ½ to 2 inches long: bractlets often lanceolate: fruit 3 or 4 lines long; ribs obsolete; vittæ indistinct, 2 or 3 in the intervals, none on the commissure. — *P. marginatum*, Benth. Pl. Hartw. 312. Central California.

11. P. UTRICULATUM, Nutt. More caulescent: leaves more finely divided; segments half an inch long or less: bractlets usually much dilated: fruit distinctly ribbed; vittæ broad, solitary in the intervals, 4 to 6 on the commissure. — Washington Territory and Idaho to S. California.

§ 3. Leaves ample, very finely dissected with short filiform segments: flowers yellow: involucels present: calyx-teeth obsolete: fruit glabrous.

* Fruit orbicular or broadly elliptical: acaulescent.

12. P. FŒNICULACEUM, Nutt. Tomentose, sometimes glabrous: involucels gamophyllous, 5–7-cleft: fruit 2 or 3 lines in diameter, winged; ribs prominent; vittæ 1 to 3 in the intervals, 2 to 4 on the commissure. — From the Saskatchawan to Nebraska and the Indian Territory.

13. P. MILLEFOLIUM, Watson. Glabrous, taller: involucels of distinct linear bractlets: fruit 4 or 5 lines long, 3 or 4 broad, broadly winged: vittæ solitary, 2 on the commissure. — Bot. King's Rep. 129. Northern Utah to Washington Territory.

distinct: flowers white: calyx-teeth obsolete: fruit somewhat pubescent, rounded to ovate, three to five lines long, two to four wide; ribs prominent; vittæ two or three in the intervals (sometimes four in the lateral ones, perhaps sometimes solitary), four to six on the commissure. — *P. nudicaule*, Watson, Bot. King's Rep. 130, and others; not Nutt. Eastward of the Sierra Nevada from N. E. California to Sonora and New Mexico.

ARALIA CALIFORNICA. Herbaceous, unarmed and nearly glabrous, eight to ten feet high, from a deep thickened root: leaves bipinnate, or the upper pinnate with one or two pairs of leaflets; leaflets cordate-ovate, four to eight inches long, shortly acuminate, simply or doubly serrate with short acute teeth; terminal leaflets ovate-lanceolate: umbels in loose terminal and axillary compound or simple racemose panicles, which are more or less glandular-tomentose; rays numerous, four to

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* * Fruit oblong: caulescent, glabrous.

14. P. BICOLOR, Watson, l. c. Stem short; peduncle elongated: rays few, very unequal: involucel of a few linear bractlets: fruit on short pedicels, 5 to 6 lines long, narrowing from near the base, narrowly winged; ribs filiform; vittæ obscure. — Wahsatch Mountains.

§ 4. Leaves smaller, much or finely dissected with small segments: flowers yellow: involucels present: low, acaulescent.

15. P. VILLOSUM, Nutt. More or less densely pubescent: leaves of very numerous crowded narrow segments: umbels dense in flower: involucels small: fruit oval, pubescent, 3 or 4 lines long; vittæ several in the intervals. — W. Nevada to Nebraska and S. Utah.

16. P. PARRYI, Watson. See above.

§ 5. Leaves much dissected with small segments: flowers white; involucels present: usually low, somewhat caulescent or scarcely so, more or less pubescent.

* Fruit glabrous, oblong or broadly elliptical; vittæ usually solitary.

17. P. MACROCARPUM, Nutt. More or less pubescent: involucels conspicuous, somewhat foliaceous: fruit 4 to 10 lines long, 2 or 3 wide; calyx-teeth evident; ribs filiform; vittæ rarely 2 or 3 in the intervals, 2 to 4 on the commissure. — Var. EURYCARPUM, Gray. Fruit broader: leaves rather more coarsely divided. — Washington Territory to N. California and east to the Saskatchawan; the variety from Oregon to the Sacramento.

18. P. NUDICAULE, Nutt. Nearly glabrous: involucels small: fruit elliptical, 2 or 3 lines long; calyx-teeth obsolete; ribs prominent; vittæ always solitary, 2 to 4 on the commissure. — Nebraska and N. Colorado to Idaho.

* * Fruit tomentose or puberulent, oval-orbicular; vittæ usually several in the intervals.

six lines long; involucres of several linear bractlets: flowers a line and a half to two lines long; disk and stylopodium obsolete; styles united to the middle: fruit (still immature) a line and a half long. — Northern California, in shaded mountain ravines and moist places. Much resembling *A. racemosa*, but with larger flowers and involucres, and fewer umbels, larger and with more numerous rays.

CORNUS TORREYI. A shrub: leaves obovate or oblanceolate, abruptly acute or shortly acuminate, on rather long slender petioles, lighter colored and somewhat pubescent beneath with loose silky hairs: cyme loose and spreading: fruit white; stone obovoid, somewhat compressed, acute at base, ridged on the edges, tubercled at the summit, two and a half to three and a half lines long. — Collected by Dr. Torrey in Central California, but locality not noted. It is very peculiar in the characters of the fruit.

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19. P. DASYCARPUM, Torr. & Gray. Villous-tomentose: leaves finely dissected: involucels of several linear to oval bractlets: fruit often acutish, tomentose, 4 to 7 lines long; ribs prominent; vittæ usually 3 (rarely solitary) in the intervals, 4 on the commissure. — *P. tomentosum*, Benth. Pl. Hartw. 312. California.

20. P. NEVADENSE, Watson. See above.

Excluded Species.

P. NEWBERRYI, Watson, Am. Naturalist, 7. 301. Fine fruiting specimens of this were collected in Southern Utah by Dr. C. C. Parry. The wing of the fruit is found to have a thick corky margin, which requires the reference of the species to *Ferula* (*Leptotænia*, Nutt.), a genus separated by only this character from *Peucedanum*. The habit of the plant is very unlike that of our other species of *Ferula*.

TIEDEMANNIA TERETIFOLIA, DC., referred to *Peucedanum* by Benth. & Hook. As compared with our own species of *Peucedanum*, and without reference to foreign forms which may be included in it, this genus appears sufficiently well marked, differing in the distinct marginal nerve of the wings, in the prominent conical stylopodium, in the presence of an involucre, and in the very remarkable habit.

ARCHEMORA, DC., another small genus of the Atlantic States reduced to *Peucedanum* by the same authorities, though less distinctly marked than the last, may still conveniently be retained. It differs from the western species in its tall-stemmed erect aquatic habit, thick and short conical stylopodia with short spreading styles, the commissural vittæ in part often shorter than the seed, and the habit of foliage and inflorescence somewhat peculiar. *A. Fendleri*, Gray, of New Mexico and Colorado, is less clearly marked than the two more eastern species.

Atriplex Palmeri. Stout, shrubby at base, diffusely branched, a foot or two high, white appressed-scurfy: leaves obovate or oblanceolate, rounded or acutish at the apex, attenuate to a short petiole, alternate, entire, a half to one and a half inches long: flowers diœcious, in close naked panicled spikes: calyx 5-cleft: bracts compressed, cuneate-orbicular, free, the margin above the middle herbaceous and irregularly laciniately toothed, in fruit somewhat indurated and convex, a line and a half broad, the sides rarely sparingly muricate. — Collected by Dr. E. Palmer on Guadalupe Island. Very nearly allied to *A. Nuttallii*, Watson, of Colorado and northward.

Brahea edulis, H. Wendland, in letter. Stem sometimes thirty feet high and fifteen inches in diameter: leaves flabelliform, tomentose on the folded edges when young, three feet long, deeply parted into numerous (70 to 80) bifid segments which are lacerately fibrous at the apex; petiole very stout (an inch broad at the top), unarmed, somewhat fibrous-pubescent on the upper side, and terminated by a densely silky-tomentose ligule two inches long: tubular spathes and much-branched spadix densely tomentose: flowers sessile, in clusters of three or more, a line and a half long: calyx 3-parted, shorter than the thick valvate 3-cleft corolla: filaments broad, adnate below to the corolla-tube: ovaries oblong, nearly free; the short styles united: berry solitary, globose, an inch in diameter when dry, the flesh somewhat fibrous: seed globular, 7 or 8 lines in diameter, smooth: albumen horny, not ruminate, with a broad and deep ventral cavity filled by the intruded testa; embryo near the base. — On Guadalupe Island, collected by Dr. E. Palmer; fruiting clusters four feet long and weighing 40 or 50 pounds. The characters above given differ from those of *Brahea*, as described and figured by Martius, especially in the perigynous instead of hypogynous stamens, in the less coherent ovaries and stigmas, and in the form of the albumen, which in *Brahea* has a narrow longitudinal cavity, filled by the testa, extending from the apex nearly to the base; the embryo is also dorsal. In most of these respects it accords more nearly with *Livistona*, but with some discrepancies in other directions.

Brahea (?) armata. A second species very similar in its fruit to the last, and evidently of the same genus, was recently collected by Dr. E. Palmer in the Big Cañon of the Tantillas Mountains, about eighty miles southeastward from San Diego. It is described as a tree forty feet high: the leaves are glaucous, nearly glabrous even when young, two and a half feet long, similarly cleft into fewer (30 to 40) entire segments; the large ligule glabrous; petiole a foot and a half long, somewhat brown-hairy on the upper side, margined with a continuous white thickened border which is irregularly toothed; teeth approximate, broad and thick, three or four lines long, pointing upward or often cleft and pointing both ways: fruit rather smaller.

With this was found growing a third species, which from the foliage appears to be the same as the palm found in San Diego county, and recently introduced into cultivation under the name of "*Brahea filamentosa.*" Its fruit, however, is very different from that of the preceding, much smaller, black and pulpy with a somewhat crustaceous integument, the seed very small (three lines long), and the albumen scarcely at all excavated. It is also peculiar in other respects. The tree is spoken of as taller and much more handsome than the last.

Cypripedium occidentale. More or less roughly and glandular-pubescent, a foot and a half high, leafy, usually 2-flowered: leaves ovate, the uppermost broadly lanceolate, acuminate: the brownish narrowly lanceolate sepals and linear-lanceolate petals acuminate, nearly two inches long; lip oblong, an inch long, dull white, veined with purple: sterile stamen oblong-lanceolate, acute, yellow dotted with purple. — *C. parviflorum*, Hook. Fl. Bor.-Am. 2. 205, in part, and Kew Jour. Bot. 7. 376. *C. passerinum*, Gray, Proc. Am. Acad. 8. 403. In the mountains of California from Santa Cruz and Mariposa counties northward to the Columbia River. Frequently collected (Tolmie, Burke, Spalding, n. 334 Geyer, n. 513 Torrey, n. 513 Hall, Bolander, n. 970 Kellogg & Harford, Gray, Nevius), and very similar in habit to *C. parviflorum.*

Cardamine Gambellii. Perennial, glabrous throughout, erect, a foot and a half high: leaflets four to six pairs, ovate-oblong to linear, sessile, entire or sparingly toothed, acute, three to twelve lines long: flowers white on slender pedicels: petals four lines long, twice longer than the calyx: pods narrowly linear, ascending, an inch long, equalling the strongly reflexed pedicel; beak a line long, slender. — Collected by Gambell near Santa Barbara, and recently by Dr. J. T. Rothrock, of Lieut. G. M. Wheeler's Exploring Expedition, in the same locality. Resembling *C. pratensis.* A very similar form, but somewhat pubescent, has been found by Bourgeau near the city of Mexico.

Vauquelinia Torreyi. Shrub or small tree: leaves coriaceous, narrowly lanceolate, acuminate, acute at base and shortly petioled, acutely serrate, white-tomentose beneath, smooth above, pinnately nerved with reticulated veinlets, about an inch and a half long: flowers in small terminal tomentose panicles: petals white, oblong: stamens 25, on the margin of the hairy disk; filaments slender: fruit tomentose, two lines long; cells 2-seeded: seeds oblong, terminated above by a wing as long as the seed. — *Spiræa Californica*, Torr. in Emory's Rep. 140. *V. corymbosa*, Torr. in Bot. Mex. Bound. 64. On the Sierra Verde, near the southern boundary of Arizona, by Schott on the Mexican Boundary Survey, and probably the same as that collected previously by Emory on high mountains near the Gila. The original species, *V. corymbosa*, Correa in Humb. & Bonpl. Pl. Œquin. 1. 140, t. 40, from Central Mexico, differs according to the description and figure in its larger and more deeply serrate nearly glabrous leaves, which are on petioles as long as the blade and with numerous fine parallel nerves, in its calyx naked within, and its 15 to 20 stamens. The embryo in the present species is without albumen, the cotyledons flat, radicle straight and inferior.

Potentilla Wheeleri. Small and subalpine, decumbent, silky-villous: stems short, branched and flowering from near the base, leafy: leaves digitate, 3–5-foliolate; leaflets cuneate, 3–5-toothed at the rounded summit, half an inch long or less; stipules entire or nearly so: lower flowers axillary: calyx with obtusish bractlets a little smaller than the lobes: petals obcordate, nearly two lines long, slightly exceeding the calyx: stamens 20: carpels 20: styles filiform. — Collected by Dr. J. T. Rothrock, in the southern Sierra Nevada, about the head-waters of Kern River, at 8,200 feet altitude.

Horkelia purpurascens. Pubescent and somewhat villous, six inches high: leaflets numerous, approximate, 2–4-parted; segments oblong to obovate, two or three lines long or less; flowers few, rather large, in an open cyme: calyx purplish, about four lines long; bractlets small and narrow: petals rose-colored, broadly cuneate-oblong, nearly equalling the calyx-lobes: stamens 20, in two rows; the filaments opposite to the calyx-lobes and bractlets subulate, the alternate ones filiform: carpels 25, on a nearly naked receptacle. — Collected by Dr. J. T. Rothrock, on the head-waters of Kern River, at 9,000 feet altitude. An unmistakable *Horkelia*, but like *H. tridentata* intermediate between the typical species and those of *Ivesia*, leaving it almost impossible to preserve the latter genus distinct. Specimens of *H. tridentata* have been recently found with decidedly deltoid filaments, showing that this character may fail even to be specific.

VII.

SPECIMENS OF MILK FROM THE VICINITY OF BOSTON.

By S. P. Sharples, S.B.

Presented, Dec. 14, 1875.

In 1873, Dr. Arthur H. Nichols of this city made a report to the State Board of Health in regard to adulteration of milk. In this report, certain analyses of milk made by Prof. J. F. Babcock were quoted: these specimens were seven in number, and of the following average composition: —

Specific gravity	1.033
Cream volume, per cent	8 to 9
Total solids, weight per cent	14.55
Sugar, weight per cent	5.08
Ash	.86
Water	85.45

These samples were not selected, but were bought from regular dealers who were known to be honest. In view of the fact that the 14.55 is much above the average amount of solids as given by most European chemists, it becomes a matter of interest to ascertain if the milk produced in this vicinity is better than the average, or whether this was a mere accidental occurrence.

During the last summer I had an opportunity of procuring from Stoneham some twenty specimens of milk. These were brought to me by my assistant, Arthur Steele, who was present during the milking of the cows, and who asserts they were not tampered with in any manner. The milk was produced by cows belonging to different owners, the owner's name in each case being given in connection with the description of the cow.

The method of analysis was as follows: —

For specific gravity one hundred cubic centimetres of the milk were poured into a flask that held this amount of water at 15 °5 C., the temperature was observed by the thermometer, and the milk was cooled or warmed until it stood at 15 °5; it was then weighed. This same portion of milk was placed in a graduated cylinder, and allowed to stand in a cool place until next morning, when the amount of cream was read off. A pipette was then introduced into the cylinder in such a manner that it reached to the bottom of the vessel, and fifty centimetres were drawn off; this was weighed, and gave the specific gravity of the skim milk. After weighing, the milk was poured into a beaker, one or two drops of acetic acid added, the milk gently warmed until it coagulated, and then allowed to cool again. It was then thrown on a filter, and the first fifty centimetres that ran through were weighed as before: this gave the specific gravity of the whey.

These two last determinations were made because many authors assert that the specific gravity of skim milk and whey are much more constant than the specific gravity of whole milk.

Von Baumhauer asserts in his monograph on Dutch cow's milk that he has been unable to obtain clear filtrates when the curd was precipitated with acetic acid. I have rarely found any difficulty on this score, when the precaution of heating the milk only a little hotter than from 40° to 50° C. was taken, provided the milk was allowed to become cold before it was filtered. If the milk is allowed to cool completely after coagulation, before it is filtered, it generally filters without any trouble; but, if poured on the filter before it becomes cold, the fat fills the pores of the filter, and it is almost impossible to do any thing with it.

Total Solids. Five cubic centimetres were poured into a tared platinum dish and weighed: this latter precaution is necessary, for a pipette cannot be relied upon to always deliver the same quantity of milk, as it will deliver more than enough of a poor milk and not enough of a rich one. This was evaporated to dryness on a water bath, and then dried for an hour in an oven at the temperature of 105° C. I found that treated in this way the weight became constant at the end of two and a half to three hours from the time the milk was placed on the bath.

The dishes used have a considerable influence over this result. The size I found to work best were about 65 mm. in diameter and 15 mm. in depth, with the bottom almost perfectly flat, the sides being nearly perpendicular, the angle between the sides and the bottom being rounded. Five centimetres form a layer over the bottom of this dish but little more than ·2 mm. thick. When dry, it does not greatly exceed one-eighth of this amount, and thus forms a film that is very readily dried.

Fat. After weighing, the dried film is treated with either benzine or ether, which in the course of an hour or two completely removes all the fat; the benzine is decanted, a fresh portion poured on and allowed to stand half an hour; this is poured off, the dish rinsed with a little fresh benzine, allowed to stand a few minutes until it has all evaporated, again dried in the air bath at 105°, and weighed; the loss gives the fat. The residue remaining on the dish is of course the *solids not fat.*

Ash. The dish is then ignited over a Bunsen burner, and again weighed, the residue in this case being the ash. With a dish of the size spoken of, all the carbon burns off quickly and readily, and leaves the ash perfectly white.

The above determinations are all that are essential to determine the purity of a sample of milk, and, as will be seen, consume but little over 100 cc. of milk: 150 cc. are ample for the full analysis as followed. In order to determine the cheese and sugar, 25 cc. of milk were taken and diluted with about 50 cc. of water, the mixture was gently warmed, and a drop or two of acetic acid added with gentle stirring; it was allowed to cool and then filtered on a weighed filter, and washed with about 200 cc. of cold water. The filtrate was made up to 500 cc., and this solution was titrated with a normal solution of cupric sulphate made by dissolving 34.65 grammes of crystallized cupric sulphate in 200 cc. of water, adding to this solution a solution made by dissolving 173 grammes of sodio-potassic tartrate in 480 cc. of caustic soda solution of 1.14 specific gravity. The whole is then made up to a litre; 10 cc. of this solution were then placed in a flask diluted with 40 cc. of water, and brought to the boiling point; the diluted whey was then allowed to flow into the solution until it no longer gave a brown color, when filtered, acidified with acetic acid and tested with potassic ferrocyanide. The following table gives the per cent of milk sugar, when 25 cc. of the milk are taken, and the whey diluted to 500 cc. 10 cc. of the copper solution, which equals .067 grammes of milk sugar, are employed.

PER CENT OF SUGAR.

CC. of whey used.	0	1	2	3	4	5	6	7	8	9
10	13.40	12.17	11.17	10.30	9.57	8.92	8.38	7.91	7.44	7.05
20	6.70	6.39	6.09	5.83	5.58	5.36	5.15	4.96	4.78	4.62
30	4.46	4.32	4.19	4.06	3.94	3.83	3.72	3.62	3.53	3.44
40	3.35	3.27	3.19	3.11	3.04	2.98	2.91	2.85	2.79	2.74
50	2.68	2.63	2.58	2.53	2.48	2.44	2.39	2.35	2.31	2.27
60	2.23	2.19	2.16	2.13	2.09	2.06	2.03	2.00	1.97	1.94
70	1.91	1.88	1.86	1.84	1.81	1.79	1.76	1.74	1.72	1.69
80	1.67	1.65	1.63	1.61	1.59	1.57	1.56	1.54	1.52	1.51
90	1.49	1.47	1.46	1.44	1.43	1.41	1.39	1.38	1.37	1.35
100	1.34	1.32	1.31	1.30	1.29	1.28	1.26	1.25	1.24	1.23

The curd remaining on the filter is removed from the funnel and placed on a watch glass, dried at 105°, and weighed; it is then treated with benzine in a funnel which has a stopper in it, and is covered with a tight fitting watch glass; one or two soakings serve to completely remove the fat. It is again dried and weighed. I have not as a rule found this determination of fat very satisfactory; it is apt to be too high, from the great difficulty of drying the greasy curd and filter; after the fat is removed, the caseine is very easily dried. The object in this set of analysis being rather to endeavor to find a series of constants which might be relied upon for determining the question of adulteration, no further examination of the caseine was made for ash, but the portion remaining on the filter after the removal of the fat was regarded as pure caseine. In all my determinations, I found that there was invariably a discrepancy between the sums of the caseine, fat, sugar, and ash, and the total solids as determined by evaporation. This varied from .43 per cent to 1.92 per cent, with an average of .87; this is owing most likely to the albumen of the milk in part, which is not precipitated by the acetic acid at 45°–50° C., and in part to the solubility of the caseine in acetic acid. As will be seen from the table annexed, the sugar seems to be the most constant constituent. The fat varies very much; the specific gravity is not to be relied upon. Wanklin's test of solids not fat is departed from in a number of instances, and the total solids fall as low as 11.64, while according to the English authorities they should never in pure milk be below 9 per cent for the solids not fat, and 12 per cent for total solids.

In summing up, I must call attention to the remarkably high average of this milk, 14.49 per cent of total solids, but .06 short of Professor Babcock's result, with three times the number of specimens which he examined. For purposes of comparison, I annex two other tables, one giving all the average results I have been able to collect up to the present time, and the other giving the extreme variations that have been observed.

SPECIMENS EXAMINED.

A. Milk supplied me by a resident of Cambridge, said to be pure Alderney.

B. Milk from an Alderney cow kept by Dr. James R. Nichols for the supply of his family.

C. Grade cow, Herford and Ayrshire. Four years old, had been milking twelve weeks and gave sixteen quarts per day. Feed, two quarts corn meal and four quarts shorts, with all the upland hay she would eat.

D. Native cow, eight years old, had been milking three weeks, and gave eighteen quarts per day. Feed, three quarts of corn meal and three quarts of shorts, with hay; same as C.

E. Native cow, four years old, had been milking fourteen weeks, and gave eight quarts milk per day. Feed, one quart meal, seven quarts shorts per day, with hay.

F. Native cow, six years old, had been milking one week, gave sixteen quarts milk per day. Feed, six quarts shorts per day, and hay.

Cows C, D, E, and F, were owned by John Steele of Stoneham, and the milk was sold.

G. Native cow, ten years old, had been milking six months, gave seven quarts per day. Feed, four quarts corn meal and meadow hay.

H. Grade cow, half native, quarter Ayrshire, quarter Jersey, had been milking fifteen months, gave eight quarts milk per day. Feed, four quarts of corn meal and four quarts of shorts per day, with meadow hay.

I. Native cow, four years old, had been milking twelve weeks, gave thirteen quarts of milk per day. Feed, four quarts of corn meal and eight quarts of shorts per day, and meadow hay.

J. Native cow, nine years old, had been milking seven and a half months, gave eleven quarts of milk per day. Feed, six quarts of meal and eight quarts of shorts and meadow hay.

K. Native cow, nine years old, had been milking four months, gave fourteen quarts of milk per day. Feed, four quarts of meal and eight quarts of shorts and meadow hay.

L. Native cow, five years old, had been milking five and one half months, gave eleven quarts of milk per day. Feed, four quarts of corn meal and eight quarts of shorts per day, and meadow hay.

M. Native cow, seven years old, had been milking four months, gave fourteen quarts of milk per day. Feed, five quarts of corn meal and eight quarts of shorts per day, and meadow hay.

N. Grade cow, half native, half Dutch, three years old, had been milking two weeks, gave fourteen quarts of milk per day. Feed, two quarts meal, four quarts of shorts, and grass.

Cows G to N were owned by Frank Steele of Stoneham, and the milk was sold.

O. Native cow, five years old, had been milking ten weeks, gave five quarts of milk per day. Feed, one and a half quarts of meal per day and hay. The first sample of this cow's milk procured was of such an extraordinary character that two other samples were afterwards obtained: these did not equal the first, but were rather better than the average. The cow had been turned out to grass before the second was obtained. She was owned by William Buckman of Stoneham, and the milk was used at home.

P. Native cow, eight years old, gave twelve quarts of milk per day. Feed, one quart of meal, grass and hay. Owned by C. S. Wiley.

Q. Grade cow, native and Devon, nine years old, had been milking seven weeks, gave nine quarts of milk per day. Feed, grass and hay. Owned by C. Wiley. A second sample of this milk was obtained a few days afterwards: it had improved somewhat. The cow had been kept in poor condition all winter, and had not had grass long enough at the time of the first trial to feel its beneficial effects. The milk was used at home.

R. Native cow, eight years old, milking one week, gave sixteen quarts of milk per day. Feed, two quarts of shorts and grass.

S. Jersey cow, five years old, milking six months, gave eight quarts of milk per day. Feed, one quart of meal and four quarts of shorts.

R and S were owned by E. Thorpe of Stoneham, and the milk was sold.

Cow.	Sp. Gr.			Cream val. per cent.	Ash.	Caseine	Sugar.	Fat.	Total solids.	Solids not fat.	Water.
	Whole milk.	Skim milk.	Whey.								
A	1.030			16	.63				13.66		86.34
B	1.031			18	.65	3.40	5.29	6.62	15.96	9 34	84.04
C	1.033	1.031		6.5	.63	2.98	5.40	4.07	14.13	10.06	85.87
D	1 033	1 034	1.030	11	.72	3.01	5.19	4.10	13 87	9.77	86 13
E	1.031	1 030	1.029	9	.65	3.50	4 81	4.41	13.98	9 57	86.02
F	1 027	1.035	1.028	12	.67	3.38	4 47	6.01	14.99	8.98	85.01
G	1 033			9	.71	4 00	4 99	3.95	15.37	11.42	84.63
H	1.031	1.035	1 031	11	.79	5.23	4.80	4.36	15.61	11.25	84.39
I	1.031	1.034	1.030	7	.64	3.46	4.64	4 23	14.18	9.85	85 82
J	1.032	1.034	1 029	12	.74	4.49	4.63	5.95	16.26	10.31	83.74
K	1.029	1.030	1.028	9	.59	3.21	4.82	5.71	14.95	9 24	85.05
L	1.033	1.033	1.030	10	.64	3 00	4.80	4.04	14.05	10 01	85.95
M	1.030	1.029	1.028	4	.60	3 59	4.81	3 07	12.63	9.56	87.37
N	1.028	1.032	1.029	9.5	.64			4.38	13.81	9.13	86.19
O	1.018	1.030	1.024	54	61	2.35	5.06	11 46	19.34	7.88	80 66
	1.030	1.031	1.020	18	.65	2.91		5.09	15 11	10 02	84.89
	1.028	1 029	1.026	12	.60	2.34	5.02	6.32	14.91	8 59	85 09
P	1 028	1.031	1 028	10	.66	2.57	5.21	4.11	13.43	9.32	86 57
Q	1.028	1.028	1.025	5	.57	2.25	4.82	2.71	11.64	8.93	88.36
	1 029	1.031	1.024	5	61	2.67	5.11	4 08	13.03	8.94	86.97
R	1.033	1.034	1.026	5.5	.71	3.66	4.73	1.61	11 91	10.33	
S	1.030	1.033	1.026	11	.74	3.58	5.11	5.69	15.88	10 19	84.12
Av'rages.	1.030	1.032	1.027	12.0 10.0	.66	3.27	4.94	4.86 4.53*	14.49	9.66	85.51
Highest.	1.033	1.035	1.031	54	.79	5.23	5.40	11.46	19 31	11.42	80.66
Lowest.	1.018	1.028	1 020	5	.57	2,25	4.47	1 61	11 64	7.88	88.36

* Omitting the 15th.

SPECIMENS OF MILK SUSPECTED TO BE ADULTERATED.

Whole milk.	Cream vat. per cent.	Ash.	Caseine.	Sugar.	Fat.	Total solids.	Solids not fat.	Water.
1.028	7	.51			3.33	11.42	8.09	88.58
1.023	7	.45	2.94	3.36	2.46	9.21	6.75	90.79
1.020	6	.45	3.11	3.37	2.26	9.19	6.93	90.81
1.021	7	.40	2.77	3.00	2.00	8.17	6.17	91.83

The last four specimens were all retailed by milk dealers in the vicinity of Boston, and well serve to indicate the danger of relying on any single determination for deciding whether a milk is adulterated or not. Taking all the determinations as they stand, they leave no doubt as to the fact that the milk has been watered, yet any one determination taken separately might be successfully disputed.

The following table, recently compiled by myself from various sources, is of considerable interest in this connection, as showing the great variation in this most important product. It will be observed that the specimens from this vicinity head the list, while those reported by Mr. Vaughan of Providence, R. I., are not far behind. I think that this in part may be owing to the use of corn meal as feed, since this substance is well known as a butter or fat producer.

		No. of specimens.	Solids.	Not fat.	Caseine.	Ash.
J. F. Babcock . .	Boston	8	14.55			.88
S. P. Sharples . . .	Boston	22	14.49	9.61	4.13	.66
Vernois & Becquerel	France	46	14.24	9.73	4.86	.65
Goppelstoder . . .	Switzerland	60	14.13			
H. W. Vaughan . .	Rhode Island	58	14.08	10.07	4.99	.75
Lebert	France		14.00	9.75	5.50	.75
Letheby	England		14.00	10.10	4.10	.80
Playfair	Scotland	9	13.49	8.61	4.17	.55
Phipson	England		13.33	8.46	3.76	
Chevalier	France	2	13.23	10.31	3.98	.78
Wanklin	England	3	13.12	9.36	4.56	.72
Cameron	Ireland	40	13.00	9.00	4.10	
Chevalier & Henry .	France		12.98	9.75	4.48	.60
A. Muller	Sweden		12.85	9.43	3.42	.72
Boussingalt	France	9	12.71	8.80	3.47	.25
Haiden			12.70	9.70	4.82	.49
Chandler	New York	1700 qts	12.55	8.72	3.88	.76
MacAdam	England	66	12.27	9.69		.71
Voelcker	England	22	12.10	9.15	2.93	.83
Von Baumhauer . .	Holland	162	11.30	8.45		.72

The limits of variation as observed by some of the above observers were as follows: —

	Total Solids.		Solids not Fat.	
	Highest.	Lowest.	Highest.	Lowest.
Dr. Voelcker . .	14.00	9.30	9.88	7 51
Dr. MacAdam .	15.54	10.57	11 23	8.74
Von Baumhauer .	13.23	10.18	8.93	8 08
Vernois & Becquerel	19.68	11.70	10.56	7.73
Vaughan	16.96	12.85	11.14	8.79
Sharples	19 34	11.64	11.42	7.88

It should be remarked, in this connection, that Dr. Voelcker's results should be received with a good deal of caution, since he acknowledges the cows were half starved; and, further, he refuses to give the methods employed in his analyses. Von Baumhauer, on the other hand, has given the fullest information in regard to the methods he employed, the feed of the cows, time milking, &c.

The benzine used was the ordinary commercial article distilled from Pennsylvania petroleum of a specific gravity of about 70° B. Gasoline of the specific gravity of 90° B. was at first used; but it was found on trial that the heavier article was just as efficient in removing the fat, and that it left no residue on evaporation, while it was much safer to have in the laboratory.

VIII.

ON PORTABLE ASTRONOMICAL INSTRUMENTS AND THEIR USE.

By Truman Henry Safford.

Presented, Oct. 12, 1875.

In determining time, latitude, and the azimuth of a meridian-mark, which are the principal operations of geodetic astronomy, the only instrument now much used in America (besides the sextant) is the portable transit, with added apparatus for speedy reversal, and a micrometer for differences of zenith distance, according to Talcott's method. A portable transit so constructed affords a speedy determination of all three elements mentioned above; but its practical handling is a little difficult to an astronomer used only to large fixed instruments, and the determination is not always the most economical in time and labor of observation and reduction.

The present paper is intended to give a few practical hints derived from actual experience with portable instruments of all grades, from an ancient transit by a forgotten maker, with an object-glass which would not come to a focus, up to the latest productions of the best workshops of America, England, and Russia.

The beginner will do well to practise with an instrument which is not quite perfect: he thus learns in an exaggerated form all the faults to which instruments are liable.

I need not describe these instruments, but will simply refer to Chauvenet's admirable Manual of Practical and Spherical Astronomy, also to the Report of the Coast Survey for 1866. I will suppose a latitude-and-longitude campaign to be planned. The first matter to be settled is, what instruments are to be used? If the work be simply geographical, without special requirements of extreme precision, like the boundaries established by the United-States Land Office, and especially if the country be rough and transportation very difficult, a small transit instrument will suffice. I am inclined to think a focal length of 14 to 16 inches, and aperture of the object-glass of $1\frac{3}{4}$ inches, are the best dimensions. The frame should be rather light, but solidly put together; the setting circle plainly divided; the striding level delicate ($2''$ to one division); and, above all, the apparatus for illuminating the field as perfect as can be made.

Such an instrument ought to show a star of the sixth magnitude with full illumination, if the observer's eye be accustomed to not too bright a light, and especially if he use Mr. Rogers's rulings on glass in place of spider-lines: indeed, he will hardly fail to do so, for other reasons. The instrument of this size with which I am acquainted, belonging to the Canadian government, was planned as an alt-azimuth by Lindsay Russell, Esq., Deputy Surveyor-General, and made by Simms of London. The star λ Ursæ minoris of the 6.7 magnitude could be readily observed with it. It is not too heavy, with all the attachments, to be carried on a strong man's back; nor too large to accompany the observer in a sleeping-car. A somewhat larger transit, by Temple of Boston, did excellent service on the south boundary of Wyoming. This has a two-inch aperture, a pretty long focal distance, but a short axis and a light frame. It looks ill-proportioned, owing to the length of its telescope; but has a very excellent object-glass. Its greatest fault is instability in collimation; the telescope tube seems weakly put together; and the mounting, as I used it, was unstable too, probably because it was fastened to a plank on a wooden post.

To mount such an instrument away from civilization requires a good deal of trouble and expense. Brick is, of course, the best material for the foundation, but cannot always be obtained; and, at one of my stations, the only two brick-masons in town were intoxicated, and the pier was built by a civil engineer who accompanied me, with a sergeant of the United-States Engineers to mix the mortar. At Duluth the ground itself furnished rough stone in place.

At Santa Fé an unfinished and abandoned state-house furnished a pier of cut stone. At Fort Union, the sun-dial of the fort, removing the gnomon, was an excellent pillar for the instrument. Chauvenet's suggestion to use a tree-stump is impractical, on account of the roots: the instrument is kept in constant tremor by persons walking about.

When circumstances compel the use of a wooden post, great care must be taken to shield it from the sun, and the observations must be so distributed that the changes in azimuth and level are harmless. The level requires constant watching, but ought not to be changed during a group of stars, lest the azimuth be disturbed too. To eliminate changes in the latter, the groups of four or five stars must take but little time.

All these things considered, it is best to use the ephemerides of 529 stars yearly published at Berlin, originally intended for the reduction of the great zones now in progress. I think it altogether likely that this will be eventually the standard time-list for astronomers generally in this hemisphere: at any rate, these places will be kept accurate by continual observation for a good many years to come. They include all stars north of 10° of *south* declination down to the fourth magnitude, and a selected list of fainter ones to fill gaps. Many of these same stars are also given in the Connaissance des Temps, the Nautical Almanac, and the American Ephemeris; but these latter have not quite enough of them for rapid work.

To illustrate how azimuth and collimation are to be determined and eliminated, I give a scheme of observations actually used at Pueblo, C. T., May 11, 1873, by Lieut. E. H. Ruffner of the United-States Engineers. The scheme was, in general, agreed upon between him and myself.

Star.	Position of instrument.	A. R.	Decl.
		h. m. s.	
γ Ursæ majoris .	I.	11 47 10	+54°24′
o Virginis . . .	I.	58 45	9 26
4 H. Draconis . .	I.	12 6 19	78 20
η Virginis . . .	I.	13 26	0 2
6 Canum . . .	II.	19 37	39 43
20 Comæ . . .	II.	23 22	21 36
κ Draconis . . .	II.	28 7	+70 29
γ Virginis . . .	II.	35 15	— 0 45
ε Ursæ majoris .	II.	48 29	+56 39

On comparing this with other similar schemes, it will be noticed that here are no stars observed below the pole, and but one south of the equator; in other words, all are as near the zenith as practicable. Moreover, every pair of consecutive stars include the zenith between them (this is not absolutely essential, but yet very well), and hence give a definite value of the clock correction if the collimation be known.

My own scheme corresponding to the above was as follows: —

Denver, May 11.

Star's name.	Position of instrument.	A. R.	Decl.
		h. m. s.	
ξ Ursæ majoris . .	I.	11 11 25	32°15′
ι Leonis	I.	17 19	11 14
λ Draconis . . .	I.	23 53	70 2
υ Leonis	I.	30 28	— 0 7
3 Draconis . . .	I.	35 25	67 27
χ Ursæ majoris .	I.	39 22	48 29
γ Ursæ majoris .	II.	47 10	54 24
ο Virginis . . .	II.	58 45	9 26
4 H. Draconis . .	II.	12 6 19	78 20
2 Canum . . .	II.	9 47	41 22
η Virginis . . .	II.	13 26	0 2

In determining latitude with an instrument of small size, Talcott's method is subject to some inconveniences, which may sometimes be better avoided by using Bessel's method; that is, by establishing the transit in the prime vertical.

But here the same principle (immediate elimination of azimuth error) ought to be carried out; that is, the same stars should not, in general, be used east and west of the meridian. This process is Bessel's own, as distinguished from Struve's.

I annex a scheme of observation (from the Report for 1873–74

Star's name.	E. or W. transit.	Position of instrument.	Time of transit.	A. R.	Decl.
			h. m.	h. m. s.	
ρ Herculis . . .	W.	I.	20 17	17 19 19	37°16′
6 Lacertæ . . .	E.	I.	22	22 25 3	42 29
ο Andromedæ . .	E.	I.	43	22 56 7	41 39
θ Herculis . . .	W.	I.	50	17 51 54	37 16
ζ Andromedæ . .	E.	II.	21 19	0 10 30	37 59
ι Andromedæ . .	E.	II.	30	23 31 57	42 34
ζ Lyræ	W.	II.	36	18 40 25	37 29
η Lyræ	W.	II.	52	19 9 27	38 56
μ Andromedæ . .	E.	II.	56	0 49 45	37 49
θ Lyræ	W.	II.	22 4	19 11 59	37 55
γ Cygni	W.	II.	51	20 17 42	39 51
τ Andromedæ . .	E.	II.	23 1	1 33 9	39 56
υ Andromedæ . .	E.	II.	6	1 29 24	40 46
ν Cygni	W.	II.	17	20 52 28	40 41
75 Cygni . . .	W.	I.	35	21 35 14	42 42
γ Andromedæ . .	E.	I.	44	1 56 10	41 43
16 Persei . . .	E.	I.	50	2 42 38	37 48
σ Cygni . . .	W.	I.	56	21 12 47	38 52

of the Chief Engineer of General Sheridan's staff) which I used for this purpose at Bismarck, D. T., Oct. 9, 1873. It was my first fair trial of the method. The stars were selected from my catalogue of 981 stars, published in that year by the War Department, and are all thoroughly well determined, — an advantage which Bessel's method has had over Talcott's.

This scheme requires four hours observing. If I recollect rightly, it was somewhat interfered with by clouds, and would otherwise have been sooner finished. I was anxious to succeed that evening, as time pressed; and I therefore did not attempt to accumulate as many observations as possible, but preferred to make sure of a few. The result was sufficiently accurate for geographical purposes, having a probable error of $\pm$ 0″31. The instrument was quite indifferent in its optical portion. The Land Office at that time required a probable error of less than 3″; and does still, so far as I know. There are Land Office determinations extant which are far more than this in error.

In more precise latitude and longitude work, the instruments used have generally 3 inches aperture, and 30 to 36 inches focal length. Such an instrument should be very solidly built and set up. The one with which I am most familiar is Brigham Young's, in the Temple yard at Salt Lake City: it is by Würdemann, and was originally placed there at the time of the Coast Survey determination of longitude at that place. I found it very firm and strong: its level, collimation, and azimuth errors were constant, though not very small, as the Mormon astronomers seem not quite expert in adjusting. But I did not for this reason neglect to make the full number of observations, nor to distribute them precisely as if I were observing with a smaller and worse instrument, partly from habit, and partly because the instrument at Evanston, W. T., with which I was comparing time, was the instrument by J. H. Temple, mentioned above; and the observers were exchanged in the middle of the series.

There are two essentially different patterns of large portable transits. The one, the German or Russian, has a prism between the object-glass and the eye-piece; and the eye-piece itself is at one end of the horizontal axis. I have used such instruments only for trials of personal equation. There is one such at the Harvard College Observatory, and others were made for the American Transit of Venus expeditions. These transits are very convenient. The level is always upon the axis. The observer sits in one position between reversals, and has not the troublesome necessity of bending his body into inconvenient postures. His setting circle is directly before him, his working list at one side, and his chronometer or telegraph-key at the other. But he is liable to a troublesome personal equation; and I am told that the collimation cannot easily be made steady, owing to the great prism between objective and ocular. The instruments are also very costly; so that, in this country, a construction is preferred which is nearer like the ordinary observatory transit. Here the prismatic or diagonal eye-piece takes the place of the "broken telescope," as the other construction is technically called in German. The observer has to change position, and is liable to a variety of petty annoyances thence arising. Upon the whole, I think one construction is as good as the other for practical purposes.

The distribution of stars to be observed for time may often be improved by employing one star within 10° of the pole to every group of four or five time-stars. The latter will then be predominately south of the zenith, but not exclusively so. Where the instrument is known to be very firm and solidly mounted, and has a reversing apparatus, the collimation may be determined by the pole-stars alone. The double-group for Denver, as previously given, would be modified by introducing the polars 39 Cephei Hevelii and 6 Ursæ minoris Bode, as follows: —

Star's name.	A. R.	Decl.
ξ Ursæ majoris } as before.		
ι Leonis } as before.	h. m. s.	
58 Ursæ majoris	11 23 38	+43°52′
39 Cephei H. sub-polo . .	23 27 47	86 37
χ Ursæ majoris	11 39 22	48 29

INSTRUMENT REVERSED.

Star's name.	A. R.	Decl.
	h. m. s.	
β Virginis	11 44 5	2 29
γ Ursæ majoris } as before		
o Virginis } as before		
2 Canum } as before		
6 Ursæ minoris B.	12 14 23	88 24

The single polar in the first position (39 Cephei H.) is probably quite sufficient to give equal accuracy in azimuth with the two (λ and 3 Draconis) in the former list, especially as 4 Draconis H. is now replaced by a close polar. The intervals are now a little closer in some cases than before, as the instrument is expected to be easier reversed by a machine, and the lines in the focus to be nearer together.

Additional time-stars may also be inserted, namely: —

Star's name.	A. R.	Decl.
	h. m. s.	
τ Leonis	11 21 23	3°33′
ω Virginis	11 31 53	8 50
π Virginis	11 54 33	7 19
4 Comæ Ber.	12 5 24	26 35

But this would involve (as indeed the close polars do) much extra computation.

The fashion in Germany has been, lately, to select a list of stars to be observed regularly, night after night, at both stations; thus freeing the results more exactly from errors in the star-places, and, indeed, supplying observed right ascensions of great accuracy. This plan would be excellently well adapted for such observations as those between Denver and Pueblo, which are not far apart in longitude; but in much American work the distances are too great, and the use of the telegraph-lines too precarious. Good star-places are common enough, if we have them all collected in a convenient place; and this is done in the German catalogue mentioned, and, when that has not enough, in my own catalogue of 981 stars, which is soon to be doubled in extent, so as to include the zone between 10° and 70° of declination, instead of 30° to 60° only.

The young observer should by no means fail to accustom himself to the eye-and-ear method of observing. It is, as Leverrier has remarked, a better discipline than the chronographic. It is somewhat less accurate: but one who can use it skilfully can always adapt himself to a chronograph with ease; and, on the other hand, if the chronograph breaks down, or any trouble with it occurs where help cannot be got, the eye-and-ear observer is more independent than the mere chronographist. For this reason, I have never allowed a pupil to use a chronograph till he had mastered the elementary practice of the other method. In my own experience at Chicago upon the great zones I had no chronograph, but did not find that a serious drawback. Argelander was on this point ultra-conservative; but I do not think there are many observers by the new method whose work I would take in exchange for his by the older. The temptation with mechanical methods of observing is to undertake more work than can be reduced; which is a bad practice.

In determination of time, Döllen has suggested using the transit in the vertical of Polaris. I have often used this method on a first night's work, but, when the chronometer error is roughly known, can never resist the temptation to bring the instrument at once pretty close to the meridian. The pupil should be thoroughly practised in the minutiæ of this process; for I have seen even a good observer badly vexed with it, when an instrument new to him, especially a poor one, was employed.

In the determination of latitude by Talcott's method, I think a device of Mr. Rogers is likely to be useful. He replaces the micrometer by a system of parallel lines oblique to the meridian, so that each star must pass two sets of three each in its transit. The lines are very beautifully and exactly ruled by his process, and they save the time required to turn the micrometer screw. If this has to be moved largely, a star might often be lost; which is the more troublesome, as in doubtful weather, when there are flying clouds, the pairs are often spoilt by losing one of the stars. It is quite probable that Mr. Rogers's improvement will enable us to go farther from the centre of the field, and thus help the choice of star-places.

The stars should always be so chosen that the positive and negative distances from the centre of the field $[\frac{1}{2}(\delta + \delta') - \varphi]$ may pretty nearly balance, so as to give the means of determining the micrometer-values from the latitude observations themselves; otherwise the resulting latitudes could not be as accurate as the star-places and observations would permit.

The foreign astronomers use Talcott's method very little. Their objection to it is, that the star-places must necessarily be worse than for Bessel's or Struve's, or for the employment of a vertical circle or portable meridian circle. These latter instruments, however, are not used in America, principally because our methods were formed independently of the modern Germans, partly because we have no very good dividing-engines, and because they are too delicate to stand transportation over our frightful Western roads. On the other hand, Talcott's method has greatly helped our astronomers by furnishing a definite aim for their meridian observations and compilations of star-catalogues, and will thus contribute largely to the knowledge of stellar proper motions, as I shall show elsewhere. I may here say, that the probable error of a star's declination, as compiled from the best authorities, can be so estimated, classified according to the quantity and goodness of the materials, and allowing enough to cover all defects.

Class of Star.	Probable Error of Declination.
A A.	0″18
A.	0 28
B.	0 43
C.	0 70

Within 30° of the zenith, there are now stars enough of the classes AA, A, and B, for any American latitude, using Talcott's method; and the probable error of declination of a single pair of stars will vary from 0″. 13 to 0″.31. Allowing, then, a p. e. of 0″. 43 to each observation, we have the final probable error of latitude from a pair of stars, observed thrice, —

$$= \sqrt{\overline{0''.13^2} + \frac{\overline{0.43^2}}{3}} \text{ or } \sqrt{\overline{0.31^2} + \frac{\overline{0.43^2}}{3}};$$

that is, from ± 0″.28 to ± 0″.40; which only requires from eight to sixteen (say twelve) pairs to give a probable error of 0″.1.

Moreover, observations now in progress, both general and special, will in a year or two raise all the stars of the British Association's catalogue now classed as C (within our latitude-limits) to the class B, and will doubtless transfer many of this class to a higher. On the other hand, the portable meridian circle, or the prime vertical transit, needs only stars of the two highest classes, and, if other practical difficulties do not intervene, can probably secure this same degree of accuracy with fewer observations; not necessarily, however, with a less amount of time and trouble. I am inclined to think that the extravagant praises of Talcott's method to which our officials give utterance are about balanced by the steady adherence of the French and Germans to the other way, and that the practical difference between them is one rather of habit than essential. It is quite certain that both give excellent results.

The reduction of the observations for time and latitude is simple enough, and the methods are given in the ordinary books. Some discretion, however, is desirable in applying them.

The application of least squares to time reductions is considered by Struve often unnecessary; nor is it generally practised in Germany and Russia. Where it is applied, weights should be given to the observations depending upon the star's declinations. I am inclined, in case the observations are fairly complete, and depend on about the same number of wires, to consider the expression

$$\varepsilon^\circ \sqrt{1 + \sec\delta^2}$$

as a fair representation of the probable error in different declinations. Hence the weight will be expressed by

$$\omega = \frac{2}{1 + \sec\delta^2},$$

that at the equator being taken as unity. If azimuth, collimation, and clock-error, or rather small corrections of their adopted values, are the unknown quantities, their co-efficients, multiplied by $\sqrt{\omega}$, will be

$$A\sqrt{\omega} = \sin(\varphi - \delta)\sec\delta\sqrt{\frac{2}{1 + \sec\delta^2}} = \sin(\varphi - \delta)\sqrt{\frac{2}{1 + \cos\delta^2}}$$

$$C\sqrt{\omega} = \sqrt{\frac{2}{1 + \cos\delta^2}}$$

$$\sqrt{\omega} = \sqrt{\frac{2}{1 + \sec\delta^2}}$$

and their required squares and products

$$A^2\,\omega = \sin^2(\varphi - \delta)\; C^2\omega$$

$$A\,C\omega = \sin(\varphi - \delta)\; C^2\omega$$

$$C^2\omega = \frac{2}{1 + \cos\delta^2}$$

$$A\omega = \sin(\varphi - \delta)\; C\omega$$

$$C\omega = \frac{2}{\sec\delta + \cos\delta}$$

$$\omega = \frac{2}{1 + \sec\delta^2}.$$

I have tabulated the values of $C^2\omega$, $C\omega$, and ω, together with their logarithms, according to these formulæ, and give them in Table I. For any station, the preparation of $A^2\omega$, $A\,C\omega$, $A\omega$, is at once very simple.

The best results are not obtained from poor observations by *cooking* them, but by letting them pass for what they are worth. Of course, an observation must now and then be rejected. Argelander's method was to scrutinize doubtful cases with much care, adopting or rejecting them, and giving the results of both methods. His experience in his own line was so great, that he rarely missed assigning the probable cause for any large discrepancy, whether it arose from errors in reading off mistakes in wires, miscounting time, or imperfect hearing by the recorder, where one was employed, as in the Histoire Céleste; and, if he was at fault, he would suspend judgment on the case, and note it down for further observation. In geographical work, where the observer must finish each problem in a given time, and is comparatively thrown upon his own resources for little repairs to his instruments, and the means of avoiding their occasional great defects, natural or acquired, he must proceed with double caution in making his observations, checking them in every way, and making enough to get his result in spite of any abnormal discrepancies. This is the great advantage of simplicity in the field-work, and reliance upon the star-catalogues (which can always be improved afterwards), for what they will give.

The reduction of latitude observations by the zenith telescope needs but little remark. The process is a simple one: the usual form (see United-States Coast Survey Report for 1866) unnecessarily complicated.

The half-sum of declinations of the two stars can be at once computed; first, the mean value for the beginning of the year, $\frac{1}{2}(\delta_1 + \delta_2)$, and then the half-sum of apparent declinations for the date: thus from

$$\delta'_1 = \delta_1 + Aa'_1 + Bb'_1 + Cc'_1 + Dd'_1 + \tau\mu'_1$$
$$\delta'_2 = \delta_2 + Aa'_2 + Bb'_2 + Cc'_2 + Dd'_2 + \tau\mu'_2$$

it follows that

$$\begin{aligned} \tfrac{1}{2}(\delta'_1 + \delta'_2) = & \tfrac{1}{2}(\delta_1 + \delta_2) \\ & + A \frac{a'_1 + a'_2}{2} \\ & + B \frac{b'_1 + b'_2}{2} \\ & + C \frac{c'_1 + c'_2}{2} \\ & + D \frac{d'_1 + d'_2}{2} \\ & + \tau \frac{\mu'_1 + \mu'_2}{2} \end{aligned}$$

That a'_1, a'_2, and the rest, are only given by their *logarithms*, is no objection to the use of this formula. The computer has simply to employ the Gaussian logarithms. The best four-place table I know (J. H. Traugott Müller's, 2d edition, Halle, 1860) has them in excellent shape for this purpose. The micrometrical and refraction corrections should be placed in one column, and computed together by a small table of the value of one division or its logarithm, as affected by refraction at various altitudes. A very trifling correction from the usual table is necessary in Rocky Mountain work, as the barometer may stand at 23 or 24 inches instead of 30.

The form of reduction which I suggest will be found in Lieut. Wheeler's report on the geographical positions of Cheyenne and Colorado Springs.

In my catalogue of 981 stars, the logarithms of a' b' c' d' are given for 1875, and will serve for some years to come. The trifle of error introduced by their use after the lapse of a few years can best be corrected by selecting some few stars, and computing their reductions to mean place, say for 1975, thus getting the correction for 100 years; or by differential formulæ. These will be

$$\frac{da'}{dt} = \frac{\text{Secular variation}}{100}$$

$$\frac{db'}{dt} = -\cos\alpha\frac{d\alpha}{dt} = -aa'\frac{15}{n}\sin 1''$$

$$\frac{dc'}{dt} = [-\tan\omega\sin\delta - \sin\alpha\cos\delta]\frac{d\delta}{dt} - \cos\alpha\sin\delta\frac{d\alpha}{dt}$$

$$= -[15\,ad' + a'c'\tan\delta + 15\,a'd]\sin 1''$$

$$\frac{dd'}{dt} = -\sin\alpha\sin\delta\frac{d\alpha}{dt} + \cos\alpha\cos\delta\frac{d\delta}{dt} = [15\,ab'\sin\delta$$

$$+\frac{a'^2}{n}\cos\delta]\sin 1''$$

In computing the probable error of the latitude determinations, I should proceed as follows: —

The stars should be classified, and the probable error of the catalogue declination of each class estimated, as suggested above. The comparison of observations of the same pair will give the probable error of observation. The mean *reciprocal* of the number of observations on each pair should be taken: its reciprocal will give the average weight of a pair as depending on this circumstance only.

The pairs should now be classified by computing the probable error to be expected, owing to both causes: those pairs which are once or twice observed, or whose stars are both doubtful (Class C), will give a large *à priori* probable error. These probable errors should now be compared with the actual ones, to ascertain if any error constant to each pair exists; which ought not to be, but is often. The weights to each pair being now roughly assigned, the observations should be treated by least squares (if they can be improved in this way), considering the latitude and the value of one micrometer revolution as the unknown quantities.

A weak point in the zenith telescope is the connection of the level readings with the actual position of the vertical axis; arising from the fact that the level has to be much handled, and to be tilted in observing. It might be well, therefore, to employ the delicate level only for the reading off, and have a separate rougher one for the setting circle; placing the former in direct connection with the vertical axis. The instrument ought to be so constructed, that the two delicate levels used for time and latitude respectively could replace one another; saving one spare level, or else diminishing the chance of loss from their breakage. Some of the earliest as well as of the latest meridian and equal altitude instruments are reversed by a machine, instead of being turned around a vertical axis. I think this is an improvement in solidity, if not in rapidity of observing.

I will give, as an example of a method of discussing latitude observations, the latitude of Colorado Springs as observed by Dr. Kampf. (See Lieut. Wheeler's Report on Cheyenne and Colorado Springs, pp. 70ff.) The stars are taken either from my catalogue of 981 stars, or computed by myself on similar principles: the quantities $\Delta\varphi$ are here added from a completer discussion of the declinations than given in the Report.

PAIRS ONCE OBSERVED.

Pairs No.	$\Delta\ \phi$	ϕ	Class of stars.	Probable error. (1)	Probable error. (2)
1	+0″76	38°49′43″21	BA	±0″49	
4		41. 22	AB	±0. 49	
8	+0. 90	40. 59	AB	±0. 49	
9	—0. 20	41. 22	BA	±0. 49	
10	—0. 20	40. 84	AB	±0. 49	
11	+0. 25	40. 05	AA	±0. 46	
12		40. 08	CA	±0. 57	
13	—1. 68	41. 23	AB	±0. 49	
		Mean 41. 06		Mean ±0″50	±0″60

All these observations except those of pair 4 were taken on one day, August 2d, on which a constant difference of about — 0″.7 from the final result is exhibited, save for the first pair. The probable errors (1) are derived from the estimated values as derived from the separate stars, and the probable error of one observation ±0″428 as given by Dr. Kampf.

PAIRS TWICE OBSERVED.

Pairs No.	Δ φ	φ	Class of stars.	Probable error. (1)	Probable error. (2)
2	— 0″76	38°49′41″60	AC	0″48	
3	— 0. 15	41. 29	AA	0. 35	
5	+ 1. 18	41. 38	AB	0. 39	
6	+ 0. 24	41. 04	AA	0. 35	
7	+ 0. 09	40. 90	AA	0. 35	
14	+ 0. 25	41. 00	BC	0. 45	
15		41. 36	AC	0. 48	
16	— 0. 05	43. 04	CA	0. 48	
17	— 0. 40	41. 41	AA	0. 35	
18	+ 0. 25	41. 56	CB	0. 45	
19	+ 0. 43	41. 75	CA	0. 48	
20		41. 42	BA	0. 39	
21		41. 25	AA	0. 35	
22	— 0. 10	41. 72	AC	0. 48	
23	+ 0. 45	41. 67	AC	0. 48	
24	— 0. 24	41. 17	BA	0. 39	
49	— 0. 10	41. 92	AB	0. 39	
50	0. 00	42. 52	AA	0. 35	
		Mean 41. 56	Mean	±0. 42	±0″323

PAIRS THREE TO SIX TIMES OBSERVED.

AVERAGE NUMBER, FOUR.*

Pairs No.	Δ φ	φ	Class of stars.	Probable error. (1)	Probable error. (2)
25	— 0″15	38°49′42″04	AA	±0″27	
26	+ 0. 04	40. 91	BB	±0. 37	
27	+ 0. 90	41. 78	AC	±0. 43	
28	— 0. 35	41. 87	AA	±0. 27	
29		41. 21	BA	±0. 33	
30	— 0. 45	40. 35	CA	±0. 43	
31	+ 0. 42	42. 38	BA	±0. 33	
32	+ 0. 10	42. 36	BC	±0. 46	
33		41. 52	BB	±0. 37	
34		40. 96	BB	±0. 37	
35		42. 40	AC	±0. 43	

* The number of observations now makes but a trifling difference in the probable errors.

Pairs No.	Δ φ	φ	Class of stars.	Probable error. (1)	Probable error. (2)
36		38°59′42″00	BB	±0″37	
37	−0″19	42. 62	AA	±0. 27	
38	−0. 14	42. 31	AA	±0. 27	
39	+0. 08	41. 84	AB	±0. 33	
40	+0. 08	41. 06	AC	±0. 43	
41	−0. 46	41. 60	AA	±0. 27	
42	−0. 46	41. 27	AA	±0. 27	
43	−0. 29	41. 35	BA	±0. 33	
44	0.	42. 69	AA	±0. 27	
45	0.	42. 46	BC	±0. 46	
46	−0. 38	40. 78	BA	±0. 33	
47	−0. 91	40. 92	BA	±0. 33	
48	−0. 91	40. 12	CA	±0. 43	
51	+0. 38	40. 99	AA	±0. 27	
		38 59 41 63		±0. 357	±0. 527

Classifying according to magnitude of probable error (1), —

Class (α). All stars AA more than once observed.
All stars AB more than twice observed.

20 pairs of class (α) . . . . 38°59′41″61
PE of 1 pair (1) . . . . ±0. 31
(2) . . . . ±0. 463

Class (β). All stars AB twice observed.
All stars BB more than twice observed.

8 pairs of class (β) . . . . 38°59′41″41
PE of 1 pair (1) . . . . ±0. 38
(2) . . . . ±0. 28

Class (γ) All stars once observed . . . . 38°59′41″46
All stars AC, BC.

23 pairs of class (γ)
PE of 1 pair (1) . . . . ±0. 46
(2) . . . . ±0. 605

The probable errors (1) and (2) do not agree very well, owing to the small number of observations; but those denoted by (2) are the larger, upon the whole, owing to errors constant either for all the observations of a night, or upon a pair of stars. The three results will be thus: —

		Probable Error. (1)	(2)
Class (α)	38°59′41″61	±0″069	±0″101
„ (β)	41.41	±0.134	±0.099
„ (γ)	41.46	±0.096	±0.126

I think no considerable uncertainty will be left if the stars of Class (β) have a weight of $\frac{3}{4}$ each, and those of Class (γ) $\frac{1}{2}$ each. This will give the total probable error for weight 1, a thoroughly good pair sufficiently observed; as, —

	(1)	(2)	
From Class (α)	±0″31	±0″46	20 pairs.
„ „ (β)	±0.33	±0.24	8 „
„ „ (γ)	±0.33	±0.43	23 „
	Mean ±0.32	±0.41	51 „

and the final latitude

38°59′41″47 ±0″067

including errors of all kinds.

The latitude is manifestly determined with all the precision necessary for an arc of the meridian; the instrument being of the largest class, the observer excellent, and the star-places the result of a careful investigation.

TABLE I.

Decl.	Log. $C^2\omega$	Log. $C\omega$	$C^2\omega$	$C\omega$	ω
0°	0.0000	0.0000	1.000	1.000	1.000
2	0.0003	0.0000	1.001	1.000	0.999
4	0.0010	0.0000	1.002	1.000	0.998
6	0.0024	0.0000	1.005	1.000	0.995
8	0.0042	0.0000	1.010	1.000	0.990
10	0.0066	9.9999	1.015	1.000	0.985
12	0.0095	9.9999	1.022	1.000	0.978
14	0.0129	9.9998	1.030	1.000	0.970
16	0.0168	9.9997	1.040	0.999	0.961
18	0.0212	9.9995	1.050	0.999	0.950
20	0.0262	9.9992	1.062	0.998	0.938
22	0.0316	9.9988	1.075	0.997	0.925
24	0.0375	9.9982	1.090	0.996	0.910
26	0.0439	9.9975	1.106	0.994	0.894
28	0.0507	9.9966	1.124	0.992	0.876
30	0.0580	9.9955	1.143	0.990	0.857
32	0.0657	9.9941	1.163	0.987	0.837
34	0.0738	9.9924	1.185	0.983	0.815
36	0.0824	9.9903	1.209	0.978	0.791
38	0.0912	9.9878	1.234	0.972	0.766
40	0.1005	9.9848	1.260	0.965	0.740
42	0.1101	9.9811	1.288	0.958	0.712
44	0.1199	9.9769	1.318	0.948	0.682
46	0.1300	9.9718	1.349	0.937	0.651
48	0.1403	9.9658	1.381	0.924	0.619
50	0.1508	9.9589	1.415	0.910	0.585
52	0.1614	9.9508	1.450	0.893	0.550
54	0.1722	9.9414	1.486	0.874	0.514
56	0.1829	9.9304	1.524	0.852	0.476
58	0.1936	9.9178	1.562	0.827	0.439
60	0.2041	9.9031	1.600	0.800	0.400
62	0.2145	9.8861	1.639	0.769	0.361
64	0.2247	9.8665	1.678	0.734	0.322
66	0.2346	9.8439	1.716	0.698	0.284
68	0.2440	9.8176	1.754	0.657	0.246
70	0.2530	9.7870	1.791	0.612	0.209
72	0.2614	9.7514	1.826	0.564	0.174
74	0.2692	9.7096	1.859	0.512	0.141
76	0.2763	9.6600	1.889	0.457	0.111
78	0.2826	9.6005	1.917	0.399	0.083
80	0.2881	9.5278	1.941	0.337	0.059
82	0.2927	9.4363	1.962	0.273	0.038
84	0.2963	9.3155	1.978	0.207	0.022
86	0.2989	9.1425	1.990	0.139	0.010
88	0.3005	8.8433	1.998	0.070	0.002
90	0.3010	———	2.000	0.000	0.000

IX.

ON SOME PHYSICAL OBSERVATIONS OF THE PLANET SATURN.

By L. Trouvelot.

Read by William A. Rogers, Dec. 14, 1875.

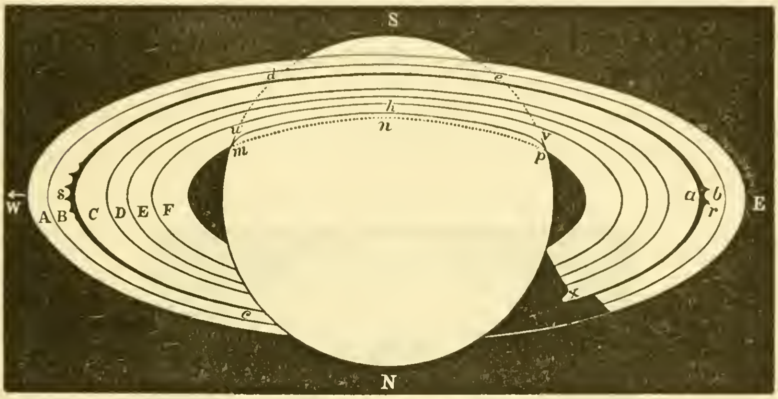
During the last four years I have had many occasions to observe the planet Saturn, and to study its physical constitution under very favorable circumstances. My series of observations extends over more than a hundred nights, many of which were as good as could possibly be desired, both for the steadiness of the image, and for the amount of light.

The observations on which this communication is based were made: 1°. With the fifteen-inch refractor of the Harvard College Observatory, while I was employed by Professor Winlock in making the sketches for the series of the astronomical engravings published by him. By his kind permission I have availed myself of considerable of the data thus obtained. 2°. With the twenty-six-inch refractor of the Washington Observatory while it was still in the hands of Messrs. Alvan Clark & Sons. 3°. With the six-and-one-quarter-inch refractor of my own Physical Observatory at Cambridge. During the past summer, I was honored with an invitation from Admiral C. H. Davis, Superintendent of the Naval Observatory, to visit Washington and make some sketches with the magnificent instrument of this establishment. I thus had an excellent opportunity to confirm all my previous observations. The powers used ranged, according to the amount of light and the steadiness of the atmosphere, from 140 to 700. On good nights, however, higher powers have been tried, but never with advantage, as the light lost by the use of high powers is generally of more importance for good vision than a superior enlargement with a reduced amount of light.

Numerous observers, among whom are such eminent astronomers as Sir William and Sir John Herschel, Otto Struve, Daws, Bond, &c., have made careful studies of this planet; and it is not, therefore, to be expected that very important discoveries remain to be made by later observers. As I have had the opportunity of observing with the same instrument many of the celestial objects previously studied with so much success by Professor George P. Bond, it gives me the greatest pleasure to express my admiration for the accuracy and fidelity of his observations.

The following diagram, representing the outlines of Saturn and its rings, will facilitate my explanations, and give clearness to the subject: —

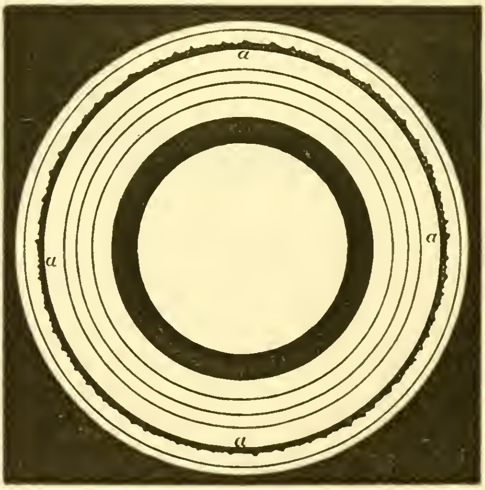
Fig. 1.



By looking at the rings, attention is at once attracted to a conspicuous dark line, apparently concentric with the outer margin of the rings, and boldly surrounding the planet, and adorning it by its sharp contrast. This dark line is known as "the principal division of the rings," and is shown at *a*, Fig. 1. Owing to the effect of perspective, it always appears widest at the two extremities of its major axis, on that portion called "the ansæ," as there only, it is seen without foreshortening. I have carefully compared the intensity of this dark line with the sky outside of the rings, and inside of the ansæ; and I have always found it to be slightly lighter. All my observations also agree in showing this line as appearing a little narrower on the side farther from the observer, at *c*, Fig. 1, than it appears on the opposite side, at *d*. This phenomenon could readily be explained by supposing that the outside margin of the ring *C* is on a plane higher than the ring *B*, and may, consequently, conceal a narrow portion of the dark line. The assumption of such an hypothesis seems to be fully supported by the observations, as will be shown hereafter. It is furthermore to be remarked, that the outside margin of the ring *C* has always appeared to me to be more sharply defined on that part of the ellipse farther from the observer than on the side nearest. The case is the same for the outer border of the ring *A*, which appears sharper on its northern than on its southern side. In both cases, the northern portion of the ellipse is limited by the matter composing the surface of the rings on their flat and illuminated side; while for the southern portion it is seen a little edgeways, and this may account for the vagueness of its outlines on this side.

Soon after the beginning of my observations, in October, 1872, my attention was called to a singular appearance not heretofore noticed, as far as I am aware. Two small, dark, angular forms, *r*, Fig. 1, were seen near the summit of the principal division of the rings on the following side, and apparently projected upon the ring *B*. After an interval of three hours, no sensible change could be detected in the position of these forms; and on the following day they were seen

Fig. 2.



occupying about the same position. This phenomenon could easily be explained by supposing there were some sort of protuberances on the external edge of the ring *C*, casting their shadow under the oblique rays of the sun, which occupied then a proper position to answer to this hypothesis. But, some days later, another of these singular forms was observed 180° from the first, on the preceding side, at *s*. This at once overthrew the supposition that they were shadows cast by protuberances existing on the ring *C*; since in this case the shadows would have been projected opposite the sun on the ring *C*, and not on the ring *B*. Since that time, I have rarely observed the planet without seeing some of these singular appearances, either on one side or the other, but generally on both sides. The number of these dark forms is variable. One, two, three, four, and even five, have been seen at the same moment, and on the same side. Though these forms are variable, and appear and disappear, I have never been able to detect in one night any change of position which could be ascribed to the rotation of the rings.

The most plausible explanation of the phenomenon which I can conceive is, that the inner margin of the ring *B*, which forms the outer limit of the principal division, is irregular, jagged, and deeply indented, as shown at *A*, Fig. 2, which represents Saturn as it would appear to an observer placed above one of its poles.

As Bond speaks of the principal division of the rings as "not being perfectly elliptical," and as in one instance he has suspected that it "was narrower in some places," it is to be inferred that he had some faint glimpses of the phenomenon which I have observed, and which possibly may be more conspicuous now than twenty years ago.

But the fact that this phenomenon has not been observed earlier does not necessarily prove that it had no existence before; as it is well known, by those who have had experience with the telescope, that one may look for a long while at a celestial object, and miss perceiving what he will readily see when once he is told where to look, and what to look for. Seeing what is new and unsuspected is quite different from seeing what has been observed before.

Though no noticeable changes in the position of the dark angular forms could be observed in the course of two or three hours, it does not follow that the system of rings does not rotate upon an axis, as theory indicates; since the supposed indentations seen on the ansæ would be placed in the most unfavorable position for showing their motion, if they have any, because it would be accomplished almost in a line with the visual ray, either approaching or receding from the observer.

Next to this division, but much less conspicuous, and to be seen only on very good nights, is a narrow, grayish, and somewhat diffused line, called "the pencil line," shown at *b*, Fig. 1. I have never been able to trace this line all around the planet, as it diminishes very rapidly with the foreshortening, and is soon lost. Probably I have never traced it more than 30° or 40° on each side of the major axis of the rings. The pencil line has never appeared to me black and well defined, but rather grayish and diffused. Sometimes I have had the impression that it was irregular in width and in depth of tint.

These two lines are the only ones I have observed, which could, with a certain amount of probability, be said to be a separation of the rings; though they might just as well be depressions, or dark belts, especially the outer one. But the fact that they have been observed on both surfaces north and south, apparently corresponding in position, is in favor of their being real separations of the rings. Though I have repeatedly endeavored to see the planet through the principal division between *d* and *e*, Fig. 1, I have never seen the faintest traces of it; and I am not aware that others have been more successful.

If the principal division of the rings is, in fact, what it is said to be, — viz., a space free from matter, and entirely disconnecting the rings *B* and *C*, — I do not see why the planet has never been seen through it. If the planet could be seen through that space, the dark line forming the principal division would be invisible from *d* to *e*, as the bright light of the planet would shine through in its place, and be undistinguishable from that of the rings. It may be objected that the invisibility of the planet through the principal division is due to the thickness of the ring *C*; but, in this case, why should the black sky be seen, if the planet is invisible?

Besides the two dark gaps or divisions of which I have just spoken, the rings are subdivided by concentric zones or belts, which reflect light of different hues and intensity. Though only three of these belts are conspicuous, I have found by careful examination that there are six which I can always recognize whenever the illumination is good, and the image steady. These zones are represented on the diagram, Fig. 1, at *A*, *B*, *C*, *D*, *E*, *F*. On several occasions, I have had a pretty distinct impression of seeing the whole surface, from *C* to *E* inclusive, grooved, as it were, by numerous narrow concentric belts. These impressions may have been illusory, as they were almost instantaneous; but I have since learned by experience, that, after all, rapid impressions are not so much to be discarded, as, quite often, even more fugitive impressions have proved in the end to be real. A striking instance in my own experience may be worth recording. This Summer I made a study of the Horse-shoe Nebula in Sagittarius with my 6¼-inch refractor. During the course of my observations, I was much annoyed by what appeared to me as faint ghost-like reticulated shadows projected upon the nebula. I at first thought I had left the reticule of squares ruled on glass in the eye-piece; but having convinced myself that this was not so, and the same appearance again presenting itself, I wiped my eye, but with no better result. As I experienced the same thing on other nights, I paid no more attention to it, thinking the trouble was in my sight. Some time afterwards, while in Washington, I had an opportunity of studying the same nebula with the great twenty-six-inch refractor of the Naval Observatory. I was not a little surprised to see that the ghost-like reticule which I wanted so much to rub out of my eye while at home, was caused by dark channels in the nebula itself, which is divided on the preceding side by bright luminous patches, separated by dark intervals.

In order of brightness, the zones or belts composing the system of rings run as follows: *C*, *D*, *B*, *E*, *A*, *F*; *C* being by far the brightest, and *F* by far the darkest. The zones *A* and *B* have a bluish cast, or light slate-color; *C* is of a bright luminous white; *D* is slightly grayish; *E* is at little darker; while *F*, which is very dark, is tinged with bluish purple.

A is separated from *B* by the pencil line; *B* from *C* by the principal division; while the others do not show any separation whatever, and are only limited by the contrast of their different colors and shades, and seem to be in immediate contact. However, the different zones do not terminate abruptly where they come in contact, but seem somewhat blended into each other. This is especially the case between *E* and *F*. Though at that point the contrast between the two internal rings is very great, yet it is impossible to see any line of division, so much do they mingle at their point of contact.

On good nights, I have often observed on that part of the rings *A*, *B*, and *C*, seen on the ansæ, an unmistakable mottled or cloudy appearance such as is represented on Plate 1. This appearance was always more characteristic and better seen on the ring *C*, especially near its outer margin, close to the principal division. It would seem, as has been already remarked, that the ring *C* is on a higher level than that of the rest of the rings, and that the cloudy appearances observed there form by their accumulation some kind of protuberances of different heights and breadths. The bright spots resembling satellites, so often observed by Bond in 1848, when the plane of the rings was parallel with that of the ecliptic, were probably caused by the crests of some protuberances similar to those now seen on the ansæ. The form of the shadow thrown by the planet on the rings on Nov. 30, 1874, as shown at *x*, Fig. 1, seems also to agree with this hypothesis. The curious and deep indentation of the shadow at x, in that part where it is projected on the outer border of the ring C, is perfectly explained on the supposition that this part of the ring is on a higher level. The same shadow, as it appeared projected on the rings B and A, also clearly indicates that the plane of these zones is on a lower level.

In order to find the shape of the surface of the rings from the observation of the form of the shadow thrown by the planet. I have experimented on a miniature representation of Saturn, illuminated by a lamp occupying the position of the sun, while my eye occupied the position of the earth. By successive trials in altering the shape of the miniature rings, I have soon found what must be the form of the rings in order to give to the shadow the same appearance which had been observed on the planet; and the result agrees with the explanation already given.

From the form of the shadow as it has appeared at different times during the last four years, and from the experiment just mentioned, it seems pretty clear to me, that, from the inner margin of the dusky ring F, the thickness gradually increases until it reaches the extreme border of the ring C, where it gently decreases, as indicated by the rounding of the shadow at this point; after which it sinks perpendicularly down, until it comes even with the general level of the rings B and A. The slightly curved appearance of the shadow of the planet during the present year, with its concavity turned towards its globe, also supports this hypothesis.

Though, in general, the level of the ring C is always higher than that of the rest of the system, it does not seem, however, to be uniform and permanent, but varies, either by the rotation of the rings upon an axis, or by some local changes in the cloud-forms themselves; as in several instances I have observed quite rapid and striking changes taking place during the course of one evening in the indentation of the shadow shown at x, Fig. 1. Sometimes the indentation appeared to increase, indicating a higher level; and sometimes to decrease, indicating a lower level.

That the thickness of the rings is increasing from the interior margin of the dusky ring to the outer border of the bright ring C, seems to be corroborated by the phenomena which I have observed on the dusky ring, and of which I shall speak presently.

On all favorable occasions, I have made careful searches on the dusky ring for the divisions suspected by Bond; but I never had the faintest glimpses of them. The dusky ring appears to me to be continuous, though it is certainly not of the same thickness throughout. Whatever may be the material of which this ring is composed, it is quite rarefied; and it becomes more and more so as it approaches its inner margin. There, it seems to be composed of discrete particles, each of which reflects the light separately; and, by applying high powers to telescopes of large aperture, I have had the impression that the supposed particles were more widely separated by the increase of magnifying power. I do not pretend to have seen distinct and isolated particles in the dusky ring; but by instants my impressions have been so decided, that it seemed as if only a little more favorable conditions were required to enable me to see separate corpuscles of matter. The appearance was somewhat like fine particles of dust floating in a ray of light traversing a dark chamber.

The inner border of the dusky ring, notwithstanding its dark appearance, is sharply defined on the dark sky within the ansæ; but it loses this sharpness of outline in that part which is seen projected upon the disk of the planet. There it appears very diffused and ill defined.

The inner border of the dusky ring, as seen within the ansæ, forms a part of a perfect ellipse concentric with the other rings; but these graceful curves are remarkably and quite abruptly distorted where they enter upon the disk of the planet at *m* and *p*, Fig. 1. At these points, they are seen turning up rapidly, describing a short curve; after which they continue parallel with the curves of the other rings until they meet at *h*. If the ellipse described within the ansæ should cross the planet without any deflection, it would be seen along the dotted line, Fig. 1, and pass through *n*; while, on the contrary, it is seen above at *h*.

I was quite surprised, at first, by this singular phenomenon; but I at last satisfied myself with the following explanation: If we conceive the dusky ring to be made up either of vapors or of numerous small independent solid bodies, and, moreover, if we conceive the thickness of this ring as increasing from its interior margin to its outer limit, we shall have an easy explanation of the observed phenomena. When the matter composing this ring, whether solid or gaseous, is seen projected upon the disk of the planet brilliantly illuminated, it will be lost, and will individually disappear, absorbed by the irradiation of the bright light surrounding it, and it will remain visible only at that part where it forms a stratum thick enough to overpower the effect of irradiation.

The fact that the distortion of the inner margin of the dusky ring is not abrupt at *m* and *p*, where it enters upon the disk, but is gradual, seems to prove that the planet is less luminous on its border than elsewhere, providing the above explanation holds good; and this may be owing to the absorption caused by an atmosphere surrounding the planet.

Bond has represented the limb of the globe of Saturn as seen through the whole width of the dusky ring. In this he agrees with all previous observers. All the drawings of Saturn represent the limb of this planet as plainly and equally visible throughout the dusky ring, becoming invisible only where it enters under the internal margin of the ring *E*. In Bond's memoir, it is positively stated that Mr. Tuttle saw the limb of the planet through the whole width of the dusky ring. If these observations are correct, — as without doubt they are, — the solid particles, vapors or gases, composing this ring, must have undergone some changes of position since Bond's time; as by using the same instrument, and even one of almost double the aperture, I have not been able to confirm these observations.

During the last four years, I have never been able to see the limb of the planet Saturn under the dusky ring, beyond the middle of its width. As it enters under it at *m* and *p*, it remains quite distinct for a short distance: but, as it advances farther in, it diminishes gradually; and it entirely vanishes at about the middle, at *u* and *v*; as if the matter composing the dusky ring was more dense or thicker towards its outer border. This observation has been so carefully made, and so many times repeated, the phenomenon has been so distinctly seen, that there is not the least doubt in my mind as to its reality. Therefore it seems pretty certain that changes have lately taken place in the distribution of the matter composing the dusky ring.

As already shown, the substance composing the dusky ring does not seem to be uniformly distributed; but seems moreover to be agglomerated here and there into denser masses, which I have often recognized upon that part of the dusky ring crossing the planet between *u* and *v*. These supposed agglomerations appeared as dark masses, intercepting the light of the planet. This phenomenon could not be attributed to dark markings on the planet, seen through the dusky ring; since there are no markings so dark and so small on Saturn. Neither could they be produced by the dark bands sometimes surrounding the globe of Saturn, as some traces would have been detected on the edge of the dusky ring, since these bands are usually wider than the transparent part of the dusky ring.

Of the planet itself I have little to say. It has certainly a mottled or cloudy appearance, like Jupiter. The clouds of Saturn are more finely divided, like certain forms of the cirri clouds of our own atmosphere. The cloudy appearance of Saturn, of course, is not so easily seen as that of Jupiter. It always requires a good steady night to see it.

I have never seen the planet striped with a large number of parallel bands, such as some observers have described. Three or four form the extreme limit. Nor have I seen the bands so conspicuously marked, so regular, so distinct in outline, and so dark; the equatorial band being always by far the most conspicuous, while the others were barely perceptible. The equatorial belt has always appeared to me to be slightly tinged with a delicate carmine red, very much like the equatorial belt of Jupiter; only the pink color of the former is much fainter. In no instance could I compare the color of this band to "brick red," as it is commonly described.

Like the equatorial belt of Jupiter, that of Saturn is variable in width, and changes its form as well as its position. It is usually composed of two grayish irregular bands, forming its limits north and south, between which are seen flocculent pinkish cloud-forms.

The general color of the planet differs from that of the rings, in being of a slight warm brown in which there is a yellowish tinge. The contrast of color with the rings is better seen by the use of very high powers.

To conclude: my observations show, —

I. That the inner margin of the ring *B*, limiting the outer border of the principal division, has shown on the ansæ some singular dark angular forms; which may be attributed to an irregular and jagged conformation of the inner border of the ring *B*, either permanent or temporary.

II. That the surface of the rings *A*, *B* and *C*, has shown a mottled or cloudy appearance on the ansæ during the last four years.

III. That the thickness of the system of rings is increasing from the inner margin of the dusky ring to the outer border of the ring *C*, as proved by the form of the shadow of the planet thrown upon the rings.

IV. That the cloud-forms seen near the outer border of the ring *C* attain different heights, and change their relative position, either by the rotation of the rings upon an axis, or by some local cause; as indicated by the rapid changes in the indentation of the shadow of the planet.

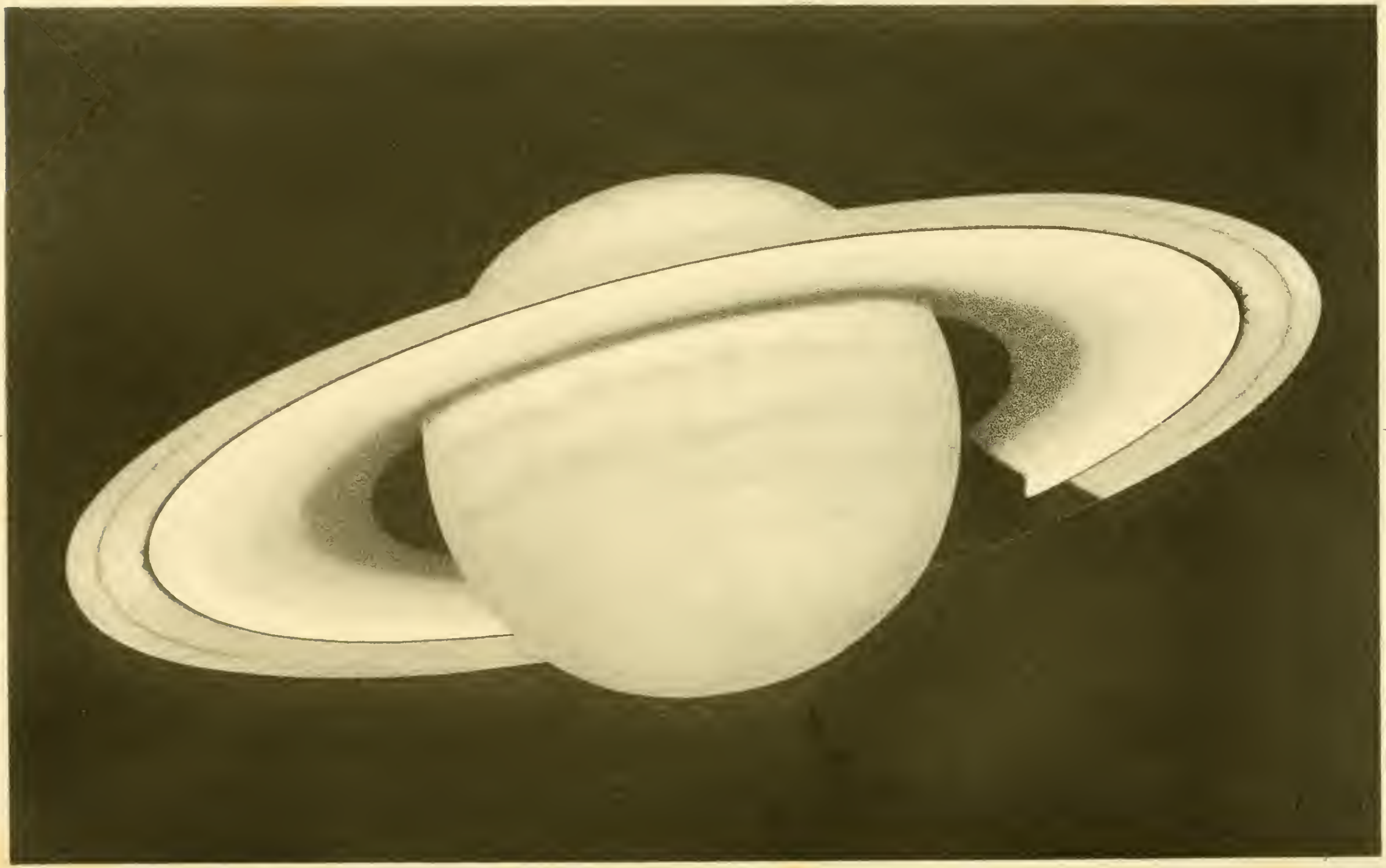
V. That the inner portion of the dusky ring disappears in the light of the planet at that part which is projected upon its disk.

VI. That the planet is less luminous near its limb than in the more central parts, the light diminishing gradually in approaching the border.

VII. That the dusky ring is not transparent throughout, contrary to all the observations made hitherto; and that it grows more dense as it recedes from the planet; so that, at about the middle of its width, the limb of the planet ceases entirely to be seen through it.

VIII. And, finally, that the matter composing the dusky ring is agglomerated here and there into small masses, which almost totally prevent the light of the planet from reaching the eye of the observer.

CAMBRIDGE, Dec. 1, 1875.



SATURN

X.

THE COMPANIONS OF PROCYON.

[*Communicated by Rear-Admiral C. H. Davis, Superintendent of the Naval Observatory, Washington.*]

Read, Feb. 9, 1876.

The discovery in 1862, by Mr. Alvan G. Clark, of a companion of Sirius very near the place indicated by the theory proposed by Bessel to account for the variable proper motion of this star, naturally led astronomers to an examination of Procyon, a star which also has a variable proper motion. On March 19, 1873, a companion of Procyon was discovered by Mr. Otto Struve, Director of the Pulkowa Observatory, near the place indicated by the theory of Professor Auwers.

As soon as the 26-inch refractor of the Naval Observatory was ready for use, Professors Newcomb and Holden began an examination of Procyon, which has been continued, on convenient occasions, to the present time.

Struve's companion has not been seen by either of these astronomers; nor, indeed, by any one who has examined the star through our instrument. Another companion, however, was soon suspected; and the existence of this and other companions has now been so well established that an account of the examination of this star will be interesting.

EXAMINATION OF PROCYON FOR THE DETECTION OF STRUVE'S COMPANION.

(*Extracts from Observing Books.*)

(1) 1873. Nov. 29. *Procyon* carefully examined, and all small stars within 2′ mapped down. Struve's companion not seen. Seeing very good, except *possibly* a slight haze. Observer: Newcomb.

(2) 1873. Dec. 30. Examined *Procyon*. Struve's companion not seen. Newcomb.

(3) 1874. Jan. 2. *Procyon's* distant companion measured. Struve's companion not seen. Newcomb.

(4) 1874. Jan. 8. 13 h. 30 m. *Procyon:* examined carefully for about 20 minutes, — distant companion plain. Seeing good, and rays round star quiet: no small companion. HOLDEN.

(5) 1874. Jan. 14. 10 h. Very good seeing at times: . . . no near companion to *Procyon.* HOLDEN.

(6) „ Jan. 25. Seeing very excellent: . . . no near companion to *Procyon.* HOLDEN.

(7) „ Feb. 5. *Procyon.* Good seeing. STRUVE's companion not seen. NEWCOMB and HOLDEN.

Suspected a companion *following* more distant than companion to Sirius. Position angle 76° or 77°, by rough sketch. (See observations of Nov. 12, 25, and 26.) HOLDEN.

(8) „ Feb. 14. *Procyon:* poor image. HOLDEN.

(9) „ Feb. 21. 6 h. 15 m. to 7 h. *Procyon:* distant companion plain. *Procyon* unsteady, and poor seeing: no suspicion of near companion. HOLDEN.

(10) „ Mar. 11. *Procyon:* no near companion. HOLDEN.

(11) „ Mar. 20. 7 h. 30 m. *Procyon:* image good. Struve's companion not seen. G. W. HOUGH, NEWCOMB, and HOLDEN.

(12) „ Mar. 21. 7 h. 30 m. *Procyon:* no near companion. HOLDEN.

(13) „ May 18. About 8 h. *Procyon:* no near companion. C. H. F. PETERS.

(14) „ May 26. *Procyon:* aperture reduced to 15 inches. Image poor: no near companion. NEWCOMB.

(15) „ Oct. 15. 17 h. *Sirius:* companion better seen with aperture reduced to 22 inches. — *Procyon:* aperture 22 inches. Struve's companion not found. Definition fine.

17 h. 44 m. Distant companion can still be bisected with ease in the increasing daylight.

17 h. 47 m. Bisection difficult, but companion plainly seen away from wire.

17 h. 51 m. Companion cannot be certainly seen at all. I am surprised at its sudden disappearance in the daylight. NEWCOMB.

[The sun was about 6° below the horizon at 17 h. 50 m.]

(16) „ Nov. 7. Cambridgeport, Massachusetts. Using the McCormick telescope; aperture, 26¼ inches. Seeing *very* good. *Procyon:* no trace of STRUVE's companion. ALVAN CLARK, G. CLARK, and A. G. CLARK.

(17) „ Nov. 12. *Procyon:* seeing about the same as at Cambridgeport [Nov. 7]. No sign of STRUVE's companion. Observation doubtful of a small companion 10″ off, marked in drawing position angle = 68° from sketch. ALVAN G. CLARK, with 26-inch refractor at Washington.

(18) „ Nov. 25. 14 h. 30 m. to 15 h. 10 m. *Procyon:* seeing not *very* good. STRUVE's companion not seen. Small companion suspected. [p = 47° from sketch.]

15 h. 20 m. Reduced aperture to 22 inches; no better seeing. HOLDEN.

(19) 1874. Nov. 26. 15 h. *Procyon:* full aperture. I see distinctly the same companion that I saw last night. Position about 90° more than old companion. [p = 42° from this estimate.] Seeing *perfect.* Planetary disc to *Procyon.* 15 h. 30 m. to 45 m.: reduced aperture to 22 inches. Sudden scud of cloud and haze: saw the small companion but once. HOLDEN.

Besides the above recorded observations, the companion has been looked for and not found on various occasions at the Naval Observatory by Professors Hall, Eastman, and Peters; and by Professor Peters at the Melbourne Observatory with the four-foot reflector under very good conditions.

On Jan. 12, 1876, Procyon was examined under exceptionally fine circumstances by Professor J. C. Watson and Professor Holden. No trace of Struve's companion was seen; but both observers independently discovered others of which they at once, and without consultation, made sketches which agreed in showing certainly *three* small companions quite within 10″ of distance, and between 0° and 90° of position angle; and one was *suspected* by Professor Holden somewhere between the old companion and *Procyon.* Designating these in the order of position angle by 1, 2, 3, and 4, the sketches agreed in making 2 the brightest of the three, and also the most distant, while 1 and 3 were nearly of equal brightness and of equal distance (less than the distance of 2). The following is a transcript from the Observing Book: —

(20) *Procyon* and neighboring stars: coincidence of wires 64 r. 14 approximately. Telescope west of pier; eye-piece, 400 A.

Reading for Position.	Reading for Distance.	
231.6	63.488	
p = 10° s = 6″	63.592	
		J. C. WATSON.
200	63.31	
208	63.40	
p = 34° s = 7″.9		E. S. HOLDEN.
Telescope east of pier.	Eye-piece 400.	
209.6	65.12	
p = 32° s = 9″.7		J. C. WATSON.
208	65.02 eye-piece 400.	
p = 34° s = 8.8		E. S. HOLDEN.

No signs of Σ's companion: image fine. At about 11 h. Procyon examined by Professor J. C. Watson, and Holden. Where ALVAN G. CLARK found a companion (see Observing Book, Nov. 12, 1874), which was verified by Holden (1874, Nov. 25 and Nov. 26), Professors Watson and Holden found three. One of these is somewhat brighter than the other two (see sketches I. and II.), and this was first seen by Professor WATSON (i. e., on Jan. 12), while HOLDEN saw the *preceding* one; and, finally, all three were well seen, and the first seen was measured in both positions of the instrument east and west of the pier, by both observers. The seeing was extremely fine, and these images were well and steadily seen for about two hours (till 13 h.). In the sketches, *a* is the old companion, p = 312° [s = 42″].

SUMMARY.

Telescope W.	p = 10°	s = 6.″	: J. C. W.
	p = 38	s = 7. 9	: E. S. H.
	p = 34	. . .	: J. C. W.
Telescope E.	p = 32°	s = 9.″7	: J. C. W.
	p = 34	s = 8. 8	: E. S. H.

Holden *suspects* a 4th companion somewhere about p = 320° — 330°. It should be noted further that 400 and 400 A are different eye-pieces, and that these satellites were seen in all parts of the field of view, and in all positions of the eye-piece.

(21) New companions to Procyon: 1876, Jan. 20. The seeing is not good.

Reading for position angle:

214°	HOLDEN	p = 28°
224	PETERS	p = 18
212	WATSON	p = 30

189°	PETERS	p = 53°
188	WATSON	p = 54

242°	PETERS	p = 0°

Saw the brightest of the three companions without difficulty and quite steadily, and caught occasional glimpses of one of the others. D. P. TODD.

Neither Peters, Watson, nor Holden see O.Σ's companion.

(22) Companions of Procyon: 1876, Jan. 21. 10 h. 11 m. Examined Procyon with power 400. Images generally blurred and flaring. Irregular whiffs of wind. During occasional moments caught quite distant glimpses of one or two companions about p 45° greater than old companion, but too unsteady to measure. [p = 357°] NEWCOMB.

About 11 P.M. saw, by glimpses only, two of the close companions of Procyon; viz., that nearest in angle of position to the old companion and the middle one. Procyon too much blurred to attempt any measurements. C. H. F. PETERS.

At 11 h. cannot be certain of seeing any thing in the place of the new companions, although there is at times something which looks like a companion. Images not good. HALL.

1876, Jan. 25. 10 h. 2 m. Procyon examined with powers 400 A, 400, 600 A, and single lens 500. I cannot see the new companions or Struve's. Distant companion seen steadily with all powers, but best with 400 A and 500. HALL.

(23) Procyon, 1876, Jan. 25. 10 h. 30 m. The new companion, i.e., the brightest of the three, suspected strongly, and a reading for position taken. Image of Procyon very poor. p = 37.° 0. HOLDEN.

RECAPITULATION.

It seems to be established by the preceding observations that there is no companion to be seen in the position indicated by STRUVE. Collecting all estimates and measures of other suspected companions in a table, and adding a supposed identification of them with one of the *four* satellites suspected by Watson and Holden on January 12, we have the following: —

Date of the Observation.			Position of the Companion.	Distance of the Companion.	Supposed identification.	Observer.
1874.	Feb.	5	76°::	s > 10″	?	HOLDEN.
„	Nov.	12	68	10 est	?	A. G. CLARK.
„	„	25	47	about 10	3	HOLDEN.
„	„	26	42	„ 10	3	HOLDEN.
1876.	Jan.	12	10	6	1	J. C. WATSON.
„	„	„	38	7.9	2	HOLDEN.
„	„	„	34		2	J. C. WATSON.
„	„	„	32	9.7	2	J. C. WATSON.
„	„	„	34	8.8	2	HOLDEN.
„	„	„	320°–330° ?	about 10	4	HOLDEN.
„	„	20	28°	„ 10	2	HOLDEN.
„	„	„	18	„ 10	1 ?	PETERS.
„	„	„	30	„ 10	2	WATSON.
„	„	„	53	„ 10	3	PETERS.
„	„	„	54	„ 10	3	WATSON.
„	„	„	0	„ 10	1	PETERS.
„	„	21	357 (est)	„ 10	1	NEWCOMB.
„	„	25	37	„ 10	2	HOLDEN.

The three companions about which no doubt is entertained are, —

1. p = about 10° s = 6″
2. p = 36° s = 8″8
3. p = about 50° s < 10″

It is quite possible that there may be one or two more. It is easy to understand why these have not been seen before, as the early examinations were principally for the purpose of detecting the existence of STRUVE's companion, and as the very finest atmospheric conditions are required for their certain detection. It is believed, however, that even in ordinarily good seeing *two* can be seen.

XI.

NOTES ON MAGNETIC DISTRIBUTION.

By Henry A. Rowland.

Presented, June 9, 1875.

In two papers which have recently appeared on this subject, by Mr. Sears (Amer. Jour. of Science, July, 1874), and Mr. Jacques (Pres. Amer. Acad. of Sciences, 1875, n. 445), a method is used for determining magnetic distribution, founded on induced currents, in which results contrary to those published by M. Jamin have been found. It does not seem to have been noticed that the method then used does not give what we ordinarily mean by magnetic distribution. In mathematical language, they have measured the surface integral of magnetic induction *across the section* of the bar instead of *along a given length of its surface.** M. Jamin's method gives a result depending on the so-called surface density of the magnetism, which is nearly proportional to the surface integral of the magnetic induction along a given length of the bar. Hence the discrepancy between the different results.

Had the experiments of Mr. Sears and Mr. Jacques been made by sliding the helix inch by inch along the bars, their results would have confirmed those of M. Jamin. Four or five years ago, I made a large number of experiments in this way, which I am now rewriting for publication, and where the whole matter will be made clear. At present, I will give the following method of converting one into the other.

Let Q be the surface integral of magnetic induction across the section of the rod, and let Qe be that along one inch of the rod: then $Qe \propto \frac{dQ}{dx}$ x being the distance along the road. Hence, M. Jamin's results depend on the rate of variation of the magnetization of the rod, while those of Mr. Sears and Mr. Jacques depend on the magnetization.

In conclusion, let me heartily agree with Mr. Jacques's remarks about M. Jamin's conclusions from his experiments. Such experi-

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* Meavill's Electricity and Magnetism. Art. 402.

ments as these give no data whatever for a physical theory of magnetism, and can all be deduced from the ordinary mathematical theory, which is independent of physical hypothesis, combined with what is known with regard to the magnetizing function of iron. This will be shown in the paper I am rewriting.

It seems to me that M. Jamin's method is very defective; and I know of no method of experimenting, which is theoretically without objection except that of induced currents, and this I have used in all my experiments on magnetic distribution for the last four or five years, and have developed into a system capable of giving results in absolute measure. Mr. Jacques is to be congratulated on pointing out these errors in M. Jamin's conclusions.

Troy, June 7, 1875.

XII.

ON THE METHOD OF LEAST SQUARES.

By Truman Henry Safford.

Presented, Oct. 12, 1875.

The method of least squares with the theory of errors of observation upon which it depends forms the foundation of modern practical astronomy, and is largely used in subjects akin to astronomy, as geodesy and physics: the object of the present note is to assist in their practical application, both in planning and reducing series of observations.

Legendre first seems to have published the method of least squares, mainly as a convenient and pretty method of computation. Gauss soon after showed that it was the same in principle as the ordinary method of taking the arithmetical means, in the simpler cases to which that is applicable; and that either method presupposes a distribution of the errors of observation, such that the probability of larger errors is less than that of smaller; and proportional to the function

$$e^{-h^2\Delta^2}$$

where Δ is an error of observation, and h a factor which reduces all systems of such errors to be comparable with each other.

Of course the probability of an error of observation exactly equal to a given amount, no hair more nor less, is infinitesimal; and the definite integral

$$\frac{h}{\sqrt{\pi}}\int_{\Delta_1}^{\Delta_2} e^{-h^2\Delta^2} d\Delta$$

denotes the probability that there will be errors between the limits Δ_1 and Δ_2; while the total probability of all the errors of observation denoted by unity will be equal to

$$\frac{h}{\sqrt{\pi}}\int_{-\infty}^{+\infty} e^{-h^2\Delta^2} d\Delta.$$

Shortly after this investigation of Gauss, Bessel examined long series of observations, to see whether the law of distribution of errors thus indicated was a true one: he found that it was approximately so. His tables and some results are in the Fundamenta Astronomiæ: from these it appears that the definite integral above mentioned does represent the actual distribution of errors with striking exactness; but that there is generally a surplus of perhaps 1 to 3 per cent of the larger errors.

I may here mention that the least favorable series quoted by Bessel — Bradley's declinations — are now in process of re-reduction by Prof. Auwers, of Berlin, and that his results in part are in my hands for another purpose. The larger discrepancies which Bessel's own reduction left in them will probably be found to disappear in the newer calculations, and seem to arise from variations in the zero point of the quadrant.

A few years after Bessel's results were published, Gauss wrote his Theoria Combinationis Observationum. In this he takes the ground, from the beginning, that

$$e^{-h^2 \Delta^2}$$

does represent the probability of error, and mentions casually that it is only an approximation.

About 1838, Bessel published his last paper upon this subject. It seems to be little known in this country, but is extremely important.

He shows that the law of error will be that mentioned with greater approximation, the nearer the following conditions are complied with.

First, that the sources of error are very numerous.

Second, that they give rise to errors of equal average magnitude.

He then points out that the first condition always holds good, by an enumeration of the known sources of error; and that in good observations the second condition has always a tendency to maintain itself, because if any one source of error is sensibly more influential than the rest, it will be detected and put away, or at least its effect diminished by a proper arrangement of the work.

The main object of this paper is to give the rules for good observing derived from this theory: I have tested them in two long series of observations, one made at Cambridge from 1862 to 1866, the other at Chicago from 1868 to 1871. The first series is of right-ascensions of the principal stars, about 500 in number, each observed at least eight times, and many from thirty to forty times. The second series is a portion of the great zone observations now going on under the charge of the Astronomische Gesellschaft of Leipzig. The rules for this series were formulated by Argelander.

The sources of error (not mistakes) in astronomical observations are partly psychological (deficiency of attention), partly psycho-physical (dulness of the senses, time expended in communications through the nerves), partly instrumental, or depending on temperature, partly optical, depending on the condition of the atmosphere. The first rule then is that the observer must keep himself in uniform condition, and therefore be temperate and regular in his life. He must keep his senses constantly under control. He must have good instruments, well and firmly mounted: all the parts of the instruments must be solid. The different instruments must correspond with each other in their degree of perfection, and must always be in good repair. Observations must not be made when the air is uncommonly disturbed, or when the observer cannot keep himself warm enough to be comfortable, — of course when it is practicable to make the observations at all under better circumstances.

The single observations should be uniform; *i. e.*, on nearly the same number of wires, with nearly the same number of settings and microscope readings.

Too great fatigue should be avoided by timely pauses, so that, for instance, the first observations of a night may not be very good, and the last very bad.

Long series of observations have been greatly damaged by the following causes, among others: —

Large errors of division, much exceeding the errors of setting upon a star.

The wearing at the centre of a quadrant; and a gradual flexure of the whole instrument.

Placing a transit instrument in a high tower, which expanded and contracted by the sun's heat. Too great trust in the fixity of an instrument. Closely counterpoising a meridian circle, so that, when observing zones in a hurry, the axis was lifted out of its bearings.

Weakness of the telescope tube, and an attempt to improve it by levers of flexure.

The wearing of the pivots of a transit instrument. Employing a person to note time for the observer proper.

Negligence in determining the zero-points ; too great trust in the Nautical Almanac in comparison with immediate observation.

The employment of two observers of very unequal skill upon the same work. The employment of a careless or ignorant person to direct good observers.

In all these cases, some one cause of larger error than is unavoidable is brought into the work, and manifests itself by larger discrepancies than the theory of probabilities indicates. In some old series, several such causes are visible: the effect of these is to produce much larger errors. Now-a-days an observer may be called upon to use an old and poor instrument upon distant service, and runs the risk of unusual discrepancies thereby.

So far with regard to the errors of *single* observations : I come now to the smaller errors of series of observations.

If a star's place is determined by *four* observations of equal value, it will be affected with but one-fourth the sum of all the individual errors ; and its probable error, the so-called internal probable error, will be but one-half that of each observation. But there will be new errors introduced, tending to slightly increase this. The skill of the astronomer is shown in making these as small as possible: first, by giving all the parts of his instrument as many reversals as he can, without affecting the stability, reversing his axis end for end, interchanging objective and ocular ; or else by making his observations more strictly differential. The former is best, when fewer objects are to be observed ; the latter, where the mass of work done is more important than its strict independence.

Now I wish to notice that the errors of uniform star places will be more exactly distributed according to the law of probabilities than those of the single observations from which they are formed. For, in the first case, the sources of error are more numerous, and more exactly uniform in their action ; while the resulting errors are more infinitesimal ; provided, that is, due care is taken with the elimination of constant error.

On the other hand, if one star be observed twice, and its neighbor, of just the same importance, twenty times, it will be difficult to bring the probable errors of the results under any general rule.

The *average* rule in first-class observatories is about this: —

Stars observed *en masse*, or by zones, should be twice observed, three times if the two observations disagree much.

Stars observed for ordinary catalogues of objects, interesting as bright or having proper motions, should be *four* times observed, twice in each of two opposite positions of the instrument. Stars requiring special accuracy, not of the very first order, should be observed eight or ten times. For fundamental determinations, it is not so much the number of single observations that is important, as the number of separate determinations (in different years) of eight or ten observations apiece; and also the number of variations in the position of the instrument and its parts.

For some months I have been bringing together all available material for a catalogue of latitude stars for the United States Engineers. Talcott's method puts a heavy strain on the catalogue, as it is very simple, and easily made accurate with a good instrument, but employs quite small and ill-known stars, for want of well-proportioned pairs enough at any given time and place.

Hence the British Association Catalogue, which contains stars enough, was found almost from the day of its publication to be far from precise. It could hardly be used with a two-inch zenith telescope in indifferent condition, on the boundary between this country and Mexico.

In supplying star-places for this purpose from time to time, the gradual increase of material has been greatly encouraging. But, on the other hand, there is a troublesome want of uniformity in modern star-catalogues. To say nothing of unreduced observations, it often happens that there is much carelessness in settling the zero-points of the instrument, and the clock- and other corrections; so that the errors in these are often larger than those of observations. Moreover, the star-places used as fundamental are often less accurate than those obtained by their help; and the various flexures and errors of division, and the variations in clock-rate, are neglected or ill-determined.

As a result, it becomes very difficult to assign the proper weights to the separate determinations, and to settle upon those which are to be excluded. The simplest rule would be to exclude certain doubtful catalogues altogether; but unfortunately they are sometimes indispensable, where the star is wanted, and no other authority of the same epoch is at hand.

Great assistance has been obtained by noting all the doubtful cases, and requesting their re-observation at the United States Naval Observatory, or re-observing them myself, when other duties would permit; but this is a matter which requires time. I might here mention that the future progress of sidereal astronomy proper will be greatly furthered by continually watching stars of doubtful proper motion until their motions are decided; and that the next few years will very greatly increase the necessity of so doing.

It is, therefore, very necessary that the system of co-operation among the astronomers of different countries, which has lately begun, should extend much wider than it has, or at least that every observer should strive to regulate his work by the uniform principles which guide the best ones, and also to do that which is most necessary for the general good. Fortunately, the making good observations, and reducing them well, requires chiefly industry, system, and order, and is not very dependent upon the capacity to appreciate the highest flights of mathematical genius.

The one thing needful for good observations is, in a word, discipline.

In computing probable errors, I generally use the *sums* of the discrepancies, not the sums of their squares. The formula is, —

$$\varepsilon = 0.845 \frac{\Sigma e}{\sqrt{m(m-n)}}$$

where Σe denotes the sum of the errors, ε the probable error of a single one, m their number, n the number of unknown quantities.

The little table annexed contains

$$M = \frac{\sqrt{m\,(m-n)}}{0.845}$$

so that

$$\varepsilon = \frac{\Sigma e}{M}$$

with the arguments m and n. I have extended it only so far as I habitually use it; beyond these limits, it is better to calculate by logarithms.

In the calculations above-mentioned, I have used two little devices for shortening the solution by least squares, which are best illustrated by the same example.

The star Piazzi xv. 176, has the following determinations of its declination, reduced to the movable planes of 1875, by Bessel's precession and proper systematic corrections : —

Authority.	Declination.	Ep.	Wt.
Piazzi & Lalande .	14°10′51″1	1798	$1\frac{1}{2}$
Taylor	47. 7	1835	1
Armagh	46. 9	1842	1
Quetelet	44. 2	1865	$\frac{3}{4}$

The equations to be solved by least squares will be : —

$$x - 0.77\,y = 9''.1 \quad \text{Wt} = 1\tfrac{1}{2}$$
$$x - 0.40\,y = 5.7 \quad 1$$
$$x - 0.33\,y = 4.9 \quad 1$$
$$x - 0.10\,y = 2.2 \quad \tfrac{3}{4}$$

Taking the mean by weights, we have $x - 0.461\ y = 6''.09$, which is the final determination of $x - 0.461\,y$.

Hence,

$$0.309\,y = -3''.01$$
$$0.061\,y = -0.39$$
$$0.131\,y = -1.19$$
$$0.361\,y = -3.89$$

with the same weights as before. Solving these equations by least squares (a very easy process), that is, multiplying each by its coefficient of y and its weight, we get —

$$0.142\,y = -1''.39$$
$$0.004\,y = -0.02$$
$$0.017\,y = -0.16$$
$$0.097\,y = -1.05$$

Adding $\quad 0.260\,y = -2.62$

$$y = -10''.08 \quad \text{hence } x = 6''.09 + 0.461 \times -10.08 = 1''.44$$

since the declination for 1875 was $14°10'42'' + x$, and the proper motions in one hundred years y; I took for y in round numbers — 10″ and brought up the declinations with its help as follows : —

		Wt.
Pi. & Lal. .	14°10′43″4	1½
T.	43.7	1
Arm. . . .	43.6	1
Q.	43.2	¾
	Means 43.48 Adopted 43.5	} strictly 43″44, see above.

The other process combines Taylor and Armagh into one place ; thus, —

	Authority.	Epoch.	Declination.	Wt.
(1)	Pi. & Lal.	1798	14°10′51″1	1½
(2)	T. & Arm.	1838.5	47.3	2
(3)	Q.	1865	44.2	¾

A theorem of Jacobi's tells us to multiply the result of any combination of the two unknown quantities by the square of its determinant, and add all together, and divide by the sum of the squares of the multipliers ; thus, —

Combination.	P. M. Result for one.	Square of Det. × product of wts.		
(1) (3)	—0″103	$67^2 \times 1\frac{1}{2} \times \frac{3}{4}$	=5051	520.3
(1) (2)	—0.094	$40.5^2 \times 1\frac{1}{2} \times 2$	=4920	462.5
(2) (3)	—0.117	$26.5^2 \times 2 \times \frac{3}{4}$	=1053	123 2
			11024	1106.0

final mean — 0″.1003.

Using — 0″.10 as before, and bringing up we get

Pi. & Lal. . . .	43″4
T. & Arm. . . .	43.65
Q.	43.2
	14°10′43.48 as before.

Table of $M = \frac{\sqrt{m\,(m-n)}}{0.8454}$

	$n=1$	$n=2$
$m=3$	2.90	2.05
4	4.10	3.35
5	5.29	4.58
6	6.48	5.79
7	7.67	7.00
8	8.85	8.19
9	10.04	9.39
10	11.22	10.58
11	12.41	11.77
12	13.59	12.96
13	14.77	14.14
14	15.96	15 33
15	17.14	16.52
16	18.33	17.70
17	19.51	18.89
18	20.69	20.07
19	21.87	21.26
20	23.05	22.44

XIII.

BRIEF CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

BY JOHN TROWBRIDGE.

No. IV. — ON THE EFFECT OF THIN PLATES OF IRON USED AS ARMATURES TO ELECTRO-MAGNETS.

Presented, Feb. 9, 1876.

In a paper presented to the Academy, April 13, 1875, I showed that the application of armatures to two strait electro-magnets, which formed the primary circuit of a Ruhmkorf coil, more than doubled the strength of the induction current produced by breaking the primary circuit. When, however, the circuit of the secondary coil was not closed, and a spark was allowed to jump across the interval between its poles, the striking distance of the spark, and its power to charge a condenser, did not seem to be notably increased by the applications of armatures to the electro-magnets of the primary circuit. My experiments, at that time, were made with solid iron cores; and I now resume these experiments with bundles of fine iron wires in place of the solid iron cores. The mechanical difficulty of making the ends of the bundles of fine wires constituting the cores plane surfaces was overcome by dipping them in melted solder, and then filing the surfaces. In this way, I had no difficulty in applying the armatures so that they should lie upon a plane surface.

The resistance of each of the two induction coils covering the two strait electro-magnets was 6000 ohms, and that of each of the strait electro-magnets .34 of an ohm. The diameter of the bundles of fine iron wires constituting the cores was 5 c.m., and the length of the electro-magnets was 28 c.m. Condensers of various sizes were placed in the primary circuit: the results given in this paper were obtained by the use of a condenser of about one Farad. The method of experimenting was to charge a condenser of $\frac{1}{3}$ of a Farad by means of a spark one millimetre in length, and then to discharge this condenser through a galvanometer. If we express the quantity of electricity received by the condenser by Q, the electro-motive force and the capacity of the condenser by E and C, we have $Q = EC$. We also have $Q = \frac{2nt}{\pi} \sin \frac{1}{2} \varphi$, where n is the reduction factor of the galvanometer, t the time of vibration of the magnet, and φ the arc through which it swings under the effect of the charge. Knowing the reduction factor of my galvanometer, I had thus the means of reducing my results to absolute measure. But I speedily found that the relative results obtained by the proportions

$$Q : Q' = \sin \tfrac{1}{2} \varphi : \sin \tfrac{1}{2} \varphi' = E : E'$$

would present the points of this investigation in a manner as valuable as if the results had been reduced to absolute magnetic measure.

My first experiments were made with solid armatures.

TABLE I.

	Without armatures.	With armatures.
	80	90
	70	80
	90	100
	60	70
	70	85
	80	90
	—	—
Mean	75	86

In this table, the numbers are the deflections of the reflecting galvanometer expressed in millimetres. In this case, the gain by the use of the armatures was trifling, being only about 14 per cent. These results were obtained by charging the condenser of $\frac{1}{3}$ of a Farad, by sparks one millimetre in length.

On a closed secondary circuit, however, a gain of one hundred per cent was clearly shown in the strength of the induced current produced by breaking the primary circuit. The question of how to make this great increase in the strength of the induced current by the employment of armatures manifest in the spark became an interesting one. It seemed at first as if the application of armatures, by maintaining the temporary magnetization of the iron cores, would be detrimental rather than otherwise.

I next tried the effect of bundles of thin iron plates, which were placed as armatures upon both poles of the electro-magnets, thus making a magnet of a horse-shoe form. On charging the condenser, I found a very great increase in quantity, which was manifested by the swing of the galvanometer needle, the indications being entirely off the scale. Table II. shows the results obtained by the use of iron plates $\frac{1}{24}$ of an inch in thickness, twenty in number, constituting each armature.

TABLE II.

Without plates.	With plates.
80	400
70	380
90	370
60	400
70	370
80	400
Mean 75	Mean 386.6

Here a gain of four hundred per cent was manifested by the use of the thin plates.

The next step was to ascertain how many plates were necessary to obtain the maximum effect. The difficulty of obtaining plates of the same homogeneity made it impossible to obtain smooth curves. To this difficulty was added that of breaking the primary circuit in a regular manner.

If the results of Table III. are plotted, it will be seen that the increase within small limits is very nearly proportional to the number of thin plates, which were $\frac{1}{24}$ of an inch in thickness.

TABLE III.

No. of plates.	Deflections of galv.	No. of plates.	Deflections of galv.
1	11	6	15
2	12	7	15.5
3	13	8	16
4	13	9	18
5	14	10	18.5

On increasing the number of plates, a point was reached where there was no additional effect. The best result was obtained where the mass of the armatures was approximately equal to that of the cores of the electro-magnets. Plates of $\frac{1}{32}$ of an inch in thickness were also used; but no advantage resulted in their employment, over those of $\frac{1}{28}$ of an inch. It would seem that the thin plates followed the same law as that of the bundle of fine iron wires which constitute the cores of induction coils of the present day, and that only a moderate degree of discontinuity in the mass of iron submitted to magnetic influence is necessary to prevent the formation of currents of induction which prolong the magnetism of the cores, and prevent the quick demagnetization necessary to produce intense currents of induction. The effect of insulating the thin plates with thin dielectrics, like paper, was also tried with no gain in effect. There appeared to be a slight gain by placing the plates edgewise on the poles of the electro-magnets, instead of allowing them to repose on their flat sides. This was doubtless due to better contact of the metallic surfaces.

Since the above results proved conclusively a very great gain in quantity and electro-motive force by the application of thin plates as armatures, I next measured the striking distance of the spark. Table IV. gives the results which are the mean of many trials.

TABLE IV.

Without armatures.	With armatures.
15 *c.m.*	32 *c.m.*
14 „	30 „
15 „	32 „
Mean 14.6	31.3

A curious fact came up in this connection. The lengthening of the spark was not shown when the spark leaped directly between the poles of the induction coil. The increase in quantity and electro-motive force was only made manifest to the eye by the employment of condensers in the secondary circuit. The results in Table IV. were obtained by the employment of a Leyden jar of large capacity. The increase in the quantity and electro-motive force was not only shown by the increased length of the spark, but also by its increase in volume and its loud snap. The spark consisted of a thick central bolt, surrounded by curious thin detached sparks. An attempt was made to measure the increase of light in Geissler tubes by Vierodt's photometric apparatus, but it was found too inexact for this purpose, if, indeed, there was any increase of light, which certainly remains to be proved. I know of no results which bear upon the relation of the increase of light to the increase of electro-motive force of the induction spark.

Without condensers in the secondary circuit, however, the increased electro-motive force of the spark was shown by its greater constancy in leaping over a given resistance of air.

The results of this investigation can be thus summed up: —

1. The application of thin plates of iron as armatures to two strait electro-magnets increases between four and five times the strength of the spark produced by the surrounding secondary coils.
2. The length of the spark is doubled, which is only shown by the use of a condenser in the secondary circuit.
3. The results show that it would be more economical to construct induction coils consisting of two strait electro-magnets constituting the primary circuit, and two fine coils constituting the secondary circuit, with the use of thin plates of iron as armatures to the electro-magnets, than to distribute the same amount of wire on one strait electro-magnet, as in the common form of Ruhmkorf coil.

NO. V. — ON THE SO-CALLED ETHERIC FORCE.

Articles have appeared in various newspapers during the past few weeks, calling the attention of the public to the evidences of a new force discovered by Mr. Edison, of Newark, N.J., which he has termed the Etheric Force. The New York "Tribune" of December 9th contains a letter from Dr. G. M. Beard, which details some experiments which he has tried; and in the same letter Dr. Beard invites the attention of scientific men to the alleged new phenomena.

Evidence of the force is obtained in the following manner: A bar of cadmium or other metal — cadmium having the preference — is placed upon the poles of a strong horse-shoe electro-magnet, in the same manner that a soft iron armature is usually placed; an insulated wire is connected with the bar of cadmium; and when the circuit in which the electro-magnet is placed is rapidly interrupted, either by a key or a vibrating armature, sparks appear at the end of the wire connected with the bar of cadmium. It is claimed that the kind of electricity thus evolved does not answer to the usual tests of static electricity; that there is no evidence of any polarity; that the force passes through ordinary insulators better than electricity of high tension; that no physiological effects are manifested when the discharge is received by the human body, and that it is impossible to charge a Leyden jar or to affect a sensitive electrometer or mirror galvanometer by this force. The spark, it is claimed, differs from that of ordinary electricity of high tension, in that it requires contact of the end of the wire conducting it with a metal or carbon point presented to it. The best sparks were obtained by rubbing a fine iron wire against a rusty file or stove-pipe. Dr. Beard found that a galvanoscopic frog gave no evidence of the existence of the force, although a spark was received after the passage of the force through the frog. Mr. Edison passed the force through iodized paper for three hours, and no effect was produced. He also took the wire connected with the apparatus out of doors, ran it along the ground and in a ditch on a rainy night, and brought it upstairs several rods from the battery, and the spark was seen by himself and Dr. Beard, at the terminal of the carbon point connected with the wire.

The apparatus which I used to produce the phenomenon was a strong electro-magnet, the limbs of which were six inches long, and were covered with large bobbins of coarse wire, having a resistance each of .70 of an ohm. Bars of iron, steel, and brass, were used as armatures to evolve the force; a copper wire was connected with the bar of metal at various places, sometimes at the end and sometimes in the middle; and the end of this wire was tested by one of Sir William Thomson's quadrant electrometers, by his most delicate mirror galvanometer, and by the carbon points advised by Dr. Beard in his letter which we have referred to at the opening of this article.

The electrometer immediately showed a slight tension on the surface of the bar of metal, which constituted the armature of the electro-magnet. By the method of multiplication, the swing of the needle was increased, so as to give unmistakable indications of polarity; the directions of the indication being in opposite directions at making and breaking the circuit of the electro-magnet.

It was evident that the want of polarity noticed by Mr. Edison was due to the rapid alternating nature of the induction currents produced in the bar of cadmium. That this so-called etheric force was nothing but a phenomenon of induction seemed evident at first sight; but one would hardly have predicted that currents of sufficient intensity could have been created in this way to produce a spark. The phenomenon possesses, however, considerable interest, which seems to have been overlooked by those who have given explanations of the phenomenon based upon the ordinary laws of induction. Faraday early showed that, if a copper disc be rotated between the poles of a strong electro-magnet, currents of considerable strength could be drawn from it by connecting one end of a wire with the axis of the disc, and the other with its periphery. It has never been shown, to the writer's knowledge, that by suddenly making and breaking the circuit of the electro-magnet a degree of static induction could be produced in a copper disc sufficient to produce a spark. It will be readily seen that making and breaking the circuit of the electro-magnet is equivalent to cutting the lines of force of the magnetic field by quick rotation; and therefore the phenomenon possesses an interest, because it supplies a break in the literature of the subject.

NO. VI. — ON A NEW FORM OF MIRROR GALVANOMETER.

The want of graduated circles for galvanometers is often seriously felt in Physical Laboratories. The method of reading the deflections of the needle by the reflection of a spot of light from a minute concave mirror over a scale, or by the reflection of a scale in a plane mirror attached to the swinging magnet, are methods of great delicacy.

In certain cases, it is difficult to obtain suitable mirrors. I present the following method of reading the deflections of a galvanometer needle, without the aid of minute mirrors either plane or concave, which are usually attached to the magnet. In this method, the mirror is stationary, while the magnet moves. I have applied the method to Helmholtz's modification of Gangain's galvanometer. In the line passing through the pivot or line of suspension of the needle, not necessarily above the centre of the needle, but somewhere in a line passing through its centre, and perpendicular to its length, an ordinary plane mirror is placed. A piece of looking-glass will answer. The silvering of the upper half of the strip of looking-glass is removed, and a fine scale is etched upon it; or for rough purposes a paper millimetre scale is pasted upon the unsilvered portion.

It will be readily seen that for small deflections with a magnet provided with the ordinary long aluminum pointers, tipped at the ends with a small vertical point, if the eye be placed so that the vertical point and its image in the mirror are in the same line that the projection of the arc of the circle of which the needle with its pointers constitutes the diameter, can be read along the scale placed upon the mirror.

For small angles, this projection is very nearly equal to the arc itself, for it is the sine of it; and if R is half the length of the needle with its pointer, and M the projection on the mirror, then the angle $\propto = \sin^{-1} \frac{m}{R}$ or $\sin \propto = \frac{m}{R}$.

This method obviates the difficulty of placing a plane mirror upon a magnet, so that it shall be perpendicular to it, and also in a vertical position in order that the image of a scale reflected from it can be seen in a telescope, which is often a troublesome adjustment. It is true that long pointers are needed, in order to magnify the indications of the needle; but a telescope pointed with a micrometer can be used, which, after focusing on the vertical point at the end of the aluminum pointer, one can focus on the deflection, and then read the fractions of a division with extreme accuracy. In this case, very long pointers are not necessary. The placing of the mirror perpendicular to the magnet is an adjustment very easily made, for the pointer should coincide with its image at the centre of suspension. A table of natural tangents is therefore not necessary with this form of galvanometer.

XIV.

ON THE SOLAR MOTION AND THE STELLAR DISTANCES.

By Truman Henry Safford.

(*Third Paper.*)

Presented, Oct. 12, 1875.

In previous papers, I have given investigations of this subject, based upon proper motions determined by others. In the present, I give the formulæ and tables necessary for the farther prosecution of the subject, in a form slightly different from the ordinary one. In view of previous investigations by Mädler and Kovalski, it will be necessary to inquire very minutely into the proper motions whose annual amount is about 0.″1. The more swiftly moving stars (as we see them) have been investigated by Argelander and other astronomers, and will be carefully tested: some of them, it is possible, will show a motion not directly proportional to the time, not only because the great circle in which the star appears to move does not meet the successive meridians at angles varying in the manner in which this hypothesis would require, but also because we are nearing or receding from them, relatively considered. Thus the terms depending on squares and products of proper motion, which Mr. G. W. Hill has, I believe, first introduced, which are the result of the varied relation between the star's apparent motion and any set of *fixed* planes, will not perhaps be the only terms of this kind; so that in such investigations I prefer to omit them and determine by observation the total amount of these terms, following in this matter the example set by Bessel.

But the proper motions between 0″.1 and 0″.2 are susceptible in many cases (not yet studied) of accurate determination from observations now extant; and in many other cases a few additional observations will be sufficient, so that the work immediately needed is to select from the whole mass such stars of this class as are adapted to either method of treatment.

The same is true in a greater or less degree of the stars whose annual proper motions are less than 0″.1. If these are Bradley's stars, the new reduction by Professor Auwers, and redeterminations at Pulcova and Greenwich, will be sufficient for the present; but, if not, so wide a field for minute criticism is thus opened, that I suspect the only cases at present worth testing will be those in which special accuracy is to be expected; as in the vicinity of the north pole, where the early observations of W. Struve afford the best possible means of comparison, in addition to the standard places of Groombridge.

In what follows, I give first the precession-constants and formulæ; and next an auxiliary table for the computation of the relations between the star's proper motion and the solar motion supposed directed to the point whose AR. is 259°50′.8 and Decl. + 32°29′.1.

The computation of the most probable proper motion involves: first, the reduction of all observations with proper systematic corrections to a fixed epoch by precession, next the assignment of weights and establishment of conditional equations, and lastly their solution; but when the proper motion is large, or the star near the pole, either the geometrical formulæ must be used, or a preliminary proper motion employed to compute the terms of secular variation depending on it. In volume IV. Part I. of the Annals of Harvard College Observatory (also included in Volume VIII. of the Memoirs of this Academy, New Series), I have given some examples of a still more rigid treatment of such cases.

PRECESSION-CONSTANTS AND FORMULÆ.

Fundamenta Astronomiæ, p. 297 (Bessel, I.).

For $1750 + t$

$$m = 45''.99592 + t\ 0''.0003086450$$
$$n = 20\ .05039 - t\ 0\ .0000970204$$

Annales de l'Observatoire Impériale (Mémoires, II. 209).

For $1850 + t_0$

$$m\ (\mu) = 46''.05912 + 0''.00028372\ t_0$$
$$n\ (\nu) = 20\ .05197 - 0\ .00008663\ t_0$$

Tabulæ Regiomontanæ (Bessel II.).

For $1750 + t$

$$m = 46''.02824 + t\ 0''.0003086450$$
$$n = 20\ .06442 - t\ 0\ .0000970204$$

Peters, Numerus constans Nutationis, p. (195).

For $1800 + t$

$$m = 46.''0623 + 0''.0002849\, t$$
$$n = 20\ .0607 - 0\ .0000863\, t$$

	Bessel II.				Struve.— Peters.		
	m	$\frac{m}{15}$	n	Log. n	m	n	Log. n
1750	46''.0282	3.06855 (s)	20''.0644	1.302427	46''.0481	20''.0650	1.302439
60	.0313	.06876	.0634	406	.0509	.0642	421
70	.0344	.06896	.0625	385	.0538	.0633	402
80	.0375	.06917	.0615	364	.0566	.0624	383
90	.0406	.06937	.0605	343	.0595	.0616	365
1800	.0437	.06958	.0596	322	.0623	.0607	346
10	.0468	.06978	.0586	301	.0651	.0598	327
20	.0498	.06999	.0576	280	.0680	.0590	309
30	.0529	.07020	.0567	259	.0708	.0581	290
40	.0560	.07040	.0557	238	.0737	.0572	271
50	.0591	.07061	.0547	217	.0765	.0564	253
60	.0622	.07081	.0537	196	.0794	.0555	234
70	.0653	.07102	.0528	175	.0822	.0547	215
80	.0684	.07122	.0518	154	.0851	.0538	197
90	.0715	.07143	.0508	133	.0879	.0529	178
1900	46.0745	3.07164	20.0499	1.302112	46 .0908	20 .0521	1.302159

The formulæ for secular variation are, as given by Menten, —

$$100\, \frac{d^2 a}{dt^2} = A + B \tan \delta + C \tan \delta^2$$

$$100\, \frac{d^2 \delta}{dt^2} = A' + B' \tan \delta$$

in which, employing Bessel's constants for 1860, —

$$A = 0\overset{s}{.}00206 + 0\overset{s}{.}00650 \sin 2\, \alpha = 0\overset{s}{.}00206 + \tfrac{1}{2}\, C$$

$$B = [8.4750] \cos \alpha + [6.811\, n] \sin \alpha$$

$$C = [8.1139] \sin 2\, \alpha$$

$$A' = -\ 0.''0097 \cos \alpha - 0.''4479 \sin \alpha$$

$$B' = [9.2900\, n] \sin \alpha^2.$$

Menten has tabulated the values of A and A', and the logarithms of the other quantities for every minute of right ascension. These expressions do not include the effect either of precession in changing the apparent amount of proper motion, or of proper motion in changing the precession; in other words, they are geometrical secular variations only. The secular variation of the whole motion, omitting terms of the order of the squares and products of the proper motions, is obtained by adding to Menten's formula the terms, —

$$0.01944 \left[\mu \tan \delta \cos \alpha + \frac{\mu'}{15} \sec \delta^2 \sin \alpha\right]$$

$$- 0.01944.\ 15\ \mu \sin \alpha$$

in right ascension and declination respectively; where μ and μ' are the annual proper motions, μ expressed in time, μ' in arc of a great circle.

Argelander in his Åbo catalogue gives secular variations of precession only, and includes one half of these terms. Thus for σ Draconis, the geometrical secular variations for 1830, computed by Menten's formulæ (without allowing for the trifling secular change in the table), are, —

$$- 0\overset{s}{.}03622 \text{ and } - 0''.0299.$$

The proper-motion terms in the secular variation of the whole motion, according to the previous formulæ, are, —

$$+ 0\overset{s}{.}01921 + 0''.0254.$$

Hence the secular variation of the total motion is, for 1830, —

$$- 0\overset{s}{.}01701 \text{ and } - 0''.0045,$$

not including squares and products of proper motion.

The Åbo Catalogue has, —

$$- 0\overset{s}{.}0265 \text{ and } - 0''.017;$$

that is, one half the proper-motion terms in the secular variation of the whole motion, or, in other words, the whole effect of proper motion in changing the precession, is included.

Sometimes it is necessary to employ the geometrical formulæ: they are these, according to Carrington, using Bessel's constants, for the reduction from $1750 + t$ to $1750 + t'$.

$$z + \lambda = 23''.0144\ (t' - t\ ) - 0''.0115\ (t' + t) - 0''.000056\ t'^2 - 0''.000210\ t^2$$

$$z' - \lambda' = 23''.0144\ (t' - t) + 0''.0115\ (t' + t) + 0''.000210\ t'^2 + 0''.000056\ t^2$$

$$\theta = 20''.0652\ (t' - t) - 0''.000048\ t'^2 + 0''.000048\ t^2$$

$$a = \alpha + z + \lambda$$

$$\cos \delta' \sin a' = \cos \delta \sin a$$

$$\cos \delta' \cos a' = \cos \delta \cos a \cos \theta - \sin \delta \sin \theta$$

$$\sin \delta' = \cos \delta \cos a \sin \theta + \sin \delta \cos \theta$$

$$\alpha' = a' + z' - \lambda'$$

Using Struve's constants, the values become: —

$$z + \lambda = 23''.0311\ (t' - t) - 0''.0001922\ t^2 - 0''.0000497\ t'^2$$

$$z' - \lambda' = 23\ .0311\ (t' - t) + 0\ .0000497\ t^2 + 0\ .0001922\ t'^2$$

$$\theta = 20\ .0611\ (t' - t) + 0\ .0000432\ t^2 - 0\ .0000432\ t'^2$$

According to Bessel II., the formulæ for the computation of these quantities are, —

$$\lambda = 0''.17926\ t - 0''.0002660394\ t^2$$

$$\omega = 23°28'18''.0 + 0''.00000984233\ t^2$$

$$\psi = 50''.37572\ t - 0\ .0001217945\ t^2;$$

λ', ω', and ψ', are the same functions of t'.

$$\tfrac{1}{2}\ (z' - z) = 0''.1011804\ (t' + t) + 0''.0000002446\ (t' + t)^2$$

$$\tan \tfrac{1}{2}\ (z' + z) = \frac{\cos \frac{1}{2}\ (\omega' + \omega)}{\cos \frac{1}{2}\ (\omega' - \omega)} \tan \tfrac{1}{2}\ (\psi' - \psi)$$

$$\tan \tfrac{1}{2}\ \theta = \frac{\sin \frac{1}{2}\ (z' + z)}{\cos \frac{1}{2}\ (z' - z)} \tan \tfrac{1}{2}\ (\omega' + \omega)$$

The time is counted from 1750.

According to Struve and Peters, the time is counted from 1800,

$$\text{and } \lambda = 0''.15119\ t - 0''.00024186\ t^2$$

$$\omega = 23°27'54''.45 + 0\ .00000735\ t^2$$

$$\psi = 50\ .3798\ t - 0\ .0001084\ t^2$$

$$\tfrac{1}{2}\ (z' - z) = 0''.075573\ (t' + t) + 0\ .0000001626\ (t' + t)^2$$

The last formula is quoted from Carrington.

LeVerrier counts his time from 1850, and finds (I employ here Bessel's notation), —

$$\tfrac{1}{2}(\omega' + \omega) = 23^\circ 27' 32''0 + 0''.00000360\,(t^2 + t'^2)$$
$$\tfrac{1}{2}(\psi' - \psi) = 25''.18516\,(t' - t) - 0''.00005440\,(t'^2 - t^2)$$
$$\tfrac{1}{2}(z' - z) = 0\,.07396\,(t' + t) + 0\,.00000016\,(t' + t)^2$$
$$\lambda = 0\,.14790\,t - 0\,.00024167\,t^2$$

TABLE FOR *M* AND *m*.

[*See page* 53 *of this Volume.*]

a	*M*	log. sin *m*	log. cos *m*
0°	105°.45	9.7460	9.9193
2	108.27	9.7525	9.9163
4	110.99	9.7598	9.9127
6	113.58	9.7679	9.9086
8	116.05	9.7766	9.9040
10	118.40	9.7857	9.8987
12	120.62	9.7952	9.8928
14	122.71	9.8050	9.8864
16	124.68	9.8150	9.8793
18	126.53	9.8250	9.8715
20	128.26	9.8350	9.8630
22	129.88	9.8450	9.8539
24	131.39	9.8549	9.8440
26	132.80	9.8645	9.8333
28	134.12	9.8740	9.8218
30	135.35	9.8832	9.8095
32	136.50	9.8922	9.7962
34	137.56	9.9009	9.7820
36	138.55	9.9092	9.7668
38	139.47	9.9172	9.7505
40	140.32	9.9249	9.7329
42	141.11	9.9322	9.7141
44	141.84	9.9392	9.6939
46	142.52	9.9458	9.6721
48	143.14	9.9520	9.6486
50	143.71	9.9579	9.6232
52	144.24	9.9633	9.5958
54	144.72	9.9684	9.5658
56	145.15	9.9731	9.5331
58	145.55	9.9774	9.4971

TABLE FOR *M* AND *m* (*continued*).

a	*M*	log. sin *m*	log. cos *m*	*m*
60	145°.90	9.9814	9.4573	73°.34
62	146.22	9.9850	9.4129	75.00
64	146.50	9.9881	9.3628	76.67
66	146.74	9.9909	9.3056	78.34
68	146.95	9.9934	9.2391	80.01
70	147.14	9.9954	9.1598	81.69
72	147.27	9.9971	9.0622	83.37
74	147.38	9.9984	8.9354	85.06
76	147.46	9.9993	8.7546	86.74
78	147.50	9.9998	8.4382	88.43
80	147.51	0.0000	7.3036 n	90.12
82	147.50	9.9998	8.4976 n	91.80
84	147.45	9.9992	8.7842 n	93.49
86	147.37	9.9982	8.9551 n	95.17
88	147.25	9.9969	9.0770 n	96.86
90	147.10	9.9952	9.1716 n	98.54
92	146.92	9.9931	9.2488 n	100.21
94	146.71	9.9906	9.3139 n	101.89
96	146.46	9.9877	9.3700 n	103.56
98	146.18	9.9845	9.4193 n	105.22
100	145.86	9.9809	9.4630 n	
102	145.50	9.9769	9.5022 n	
104	145.10	9.9725	9.5377 n	
106	144.66	9.9677	9.5701 n	
108	144.17	9.9626	9.5996 n	
110	143.64	9.9571	9.0269 n	
112	143.06	9.9512	9.6520 n	
114	142.43	9.9449	9.6752 n	
116	141.75	9.9383	9.6967 n	
118	141.01	9.9313	9.7168 n	
120	140.21	9.9239	9.7354 n	
122	139.35	9.9162	9.7528 n	
124	138.42	9.9081	9.7690 n	
126	137.42	9.8997	9.7840 n	
128	136.35	9.8910	9.7981 n	
130	135.19	9.8820	9.8112 n	
132	133.95	9.8727	9.8234 n	
134	132.62	9.8632	9.8348 n	
136	131.19	9.8535	9.8454 n	
138	129.66	9.8436	9.8552 n	
140	128.03	9.8337	9.8642 n	
142	126.28	9.8236	9.8726 n	
144	124.42	9.8136	9.8802 n	
146	122.43	9.8037	9.8873 n	
148	120.32	9.7939	9.8937 n	

TABLE FOR M AND m (*continued*).

α	M	log. sin m	log. cos m
150	118.09°	9.7844	9.8995 n
152	115.72	9.7754	9.9046 n
154	113.23	9.7668	9.9092 n
156	110.62	9.7588	9.9133 n
158	107.89	9.7516	9.9167 n
160	105.06	9.7452	9.9196 n
162	102.13	9.7398	9.9220 n
164	99.12	9.7356	9.9238 n
166	96.03	9.7324	9.9251 n
168	92.92	9.7306	9.9259 n
170	89.79	9.7300	9.9261 n
172	86.65	9.7308	9.9258 n
174	83.53	9.7328	9.9250 n
176	80.47	9.7361	9.9236 n
178	77.47	9.7405	9.9217 n
180	74.55	9.7460	9.9193 n

$$\cos \chi = \sin m \cos (\delta - M)$$
$$\sin \chi \cos \psi' = \sin m \sin (\delta - M)$$
$$\sin \chi \sin \psi' = \cos m.$$

If α exceeds 180°, cos m changes sign, and the supplements of m and M are given in the table with argument α — 180°.

XV.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

No. VIII. — ON THE INDUCTION SPARK PRODUCED IN BREAKING A GALVANIC CIRCUIT BETWEEN THE POLES OF A MAGNET.

By B. O. Peirce, Jr.

Presented, Feb. 9, 1875.

Becquerel, in the "Journal de Physique," IV. 206, states that the spark obtained by breaking the current, which circulates through an electro-magnet between its poles, is entirely a mechanical effect.

To test the accuracy of M. Becquerel's result, I placed in the same circuit four Grove cells, an electro-magnet of the form used in experiments upon Diamagnetism, and a coil of coarse wire wound around a bundle of iron wires on a core. Over this coil was slipped an induction coil of 6000 ohms resistance.

I first experimented upon the spark given by the induction coil when the primary circuit was broken between the poles of the electro-magnet, and then outside of them.

The number of cells in the circuit was varied, and its resistance was several times changed, in order to vary the circumstances as much as possible; and, at each change, a series of observations were taken to see whether the spark from the induction coil had any greater power of overcoming resistance when the primary circuit was broken between the poles of the magnet.

A long series of observations on sparks, which were of all lengths from $2\frac{1}{2}$ to 15 mms., justifies the statement that the distance over which the spark of the induction coil would regularly leap was more than *doubled* when the circuit was broken between the poles. The absolute length of spark obtained depended, of course, on the electromotive force in the primary circuit being apparently within certain limits directly proportional to it. In almost all cases, the length of spark was increased three or four times; but in no one set of observations was the spark less than doubled in length. These experiments were repeated several times on different days.

I found great difficulty in breaking the primary circuit uniformly, and it was only after a long time that my results became regular.

I tried breaking from the surface of mercury; but, although the same relative effects were attained, the actual effect was far inferior to that obtained when two bright copper wires were separated in the air.

Rowland has shown that a very powerful electro-magnet is not needed, in order to obtain good results in studying Diamagnetism. In order to see whether a small magnet would not do to increase the length of the spark, a small electro-magnet, capable of supporting perhaps two kilogrammes, was set up, and a series of observations taken when the circuit was broken between its poles. In this case, the length of the spark was just doubled. Might not a rather small horseshoe electro-magnet be advantageously placed upon the Ruhmkorff coil, so that the primary circuit should be interrupted between its poles?

I next put the electro-magnet in one circuit, and broke another circuit containing the primary of the induction coil between the poles of the magnet. With this arrangement, two sets of observations were taken under slightly different circumstances. The results are given below in the actual space over which it was found that the sparks would just pass. The words "outside" and "inside" denote that the primary circuit was broken outside of the poles and between them respectively.

Outside.	Inside.
2½ mm.	12½ mm.
3 "	20 "

Of course the relative increase in the length of the sparks depended upon the relative strengths of the two currents. When the electro-magnet is very weak, and the outside current very strong, subsequent experiments showed that there was little, if any, increase in the length of the spark.

As a direct means of showing that the extra effect obtained by breaking between the poles is not mechanical, the following method was employed. The electro-magnet was placed in a circuit with two Grove cells. To the end of one of the large wires used for breaking the circuit a very fine wire was fastened, leading to one pole of a Thomson's Quadrant Electrometer, whose other pole was put to earth. Whenever the two large wires were separated, there was of course a deflection of the electrometer mirror corresponding to the difference of potential of the poles of the battery; but, beside this, there was an increased effect when the circuit was broken between the poles, that seems to be unaccountable, if we assume the effect to be mechanical.

When a condenser of about 1 Farad capacity was put into the circuit, the following deflections were obtained: —

Primary broken outside.	Primary broken inside.
21	27
20.5	28
22	28
20	27
Mean 20.9	27.5

When no condenser was used, the deflections were as follows: —

Primary broken outside.	Primary broken inside.
20	22.5
19	23.5
20	23.5
20	24.
19.75	23.4

The electro-motive force in the circuit was very small, hardly enough to render the poles strongly magnetic. With a proper electro-motive force, we might expect the effects to be more striking.

In order to measure the increase of quantity obtained by breaking the primary circuit between the poles of the magnet, the electro-magnet and the primary of an induction coil were placed in the same circuit as at first. The poles of the induction coil were connected, the one directly, the other by means of the spark leaping between two points with a condenser of $\frac{1}{3}$ Farad capacity. The poles of the condenser were connected with a Thomson's galvanometer of 5880 ohms resistance. Each of the following results is the mean of two observations. The length of spark was the same in both cases.

	Primary broken outside.	Primary broken inside.
6 cells.	17.5	21.05
4 „	12.	17.

The resistance of the six cells (Bunsen) was greater than the resistance of the primary circuit.

On another day, the same arrangement gave the following result, where each is a mean of two observations: —

Length of spark.	Primary broken outside.	Primary broken inside.
1 mm.	22	30
3 „	12	23

In a great many cases, where the magnet was quite powerful, it was not easy to get comparable results. When the primary circuit was broken between the poles, the spot of light was driven off the scale; but, when the primary was broken outside, there was frequently very little deflection.

At another time, a Thomson's mirror galvanometer of 6 ohms resistance gave, with an arrangement otherwise the same as above, the following deflections as a mean of twelve observations: —

Outside 12.9 Inside 15.37.

When the electro-magnet was in a separate circuit from the primary of the induction coil, the following observations were obtained with the Thomson's galvanometer. Each result is the mean of about twenty observations.

Length of spark.	Primary broken outside.	Primary broken inside.
1 mm.	21	35.8
2 ,,	20	23
3 ,,	16.5	19.9
4 ,,	15.2	17

All these results were taken, interrupting the primary circuit by separating two copper wires held one in either hand. Practice made the results then obtained quite accurate. I at first tried breaking from the surface of mercury; but, beside the irregularity in the amount of the deflection, there was a most unaccountable change of polarity every few moments. I distrusted the evidence of my own senses so much in this case that I asked several other people to observe for me, without previously telling them any thing of this change of polarity. In each case, the observer noticed the reversal for himself. The deflection was almost always in one direction when the circuit was broken between the poles, and in the other direction when the circuits were broken outside of the poles. This rule is not, however, absolute. This reversal of polarity only occurred when *copper* was used to break from the surface of the mercury. The separation of iron from iron, or copper from copper, or iron from mercury, never gave any reversal. This reversal was best seen with the electrometer.

At several different times, I took a series of observations upon the deflection, by breaking inside the poles and outside of them when the distance over which the spark had to leap was varied. The curves obtained by laying down these deflections were not, as one might suppose, hyperbolas, but were apparently exponential curves, having the axis of x as an asymptote, but not the axis of y. A series of very careful observations was taken by observing the deflections when the distances over which the spark passed were small. The curves obtained by breaking the primary between the poles were similar to those obtained when the primary was broken outside. The observations were taken by breaking the primary with the interrupter of one of Ritchie's induction coils. The sparks passed between two circular discs of copper 10 cm. in diameter. In the centre of one of the discs was an almost imperceptible protuberance, in order to insure the sparks always passing in the same place. One plate was fixed in a horizontal position; the other was suspended, by a thin ivory handle perpendicular to its plane, to a glass rod placed in the telescope socket of a cathetometer. In this way, it was found possible to get the plates sensibly parallel. The poles of the induction coil were connected with a condenser; one directly, and the other by means of the spark passing between the two discs. The condenser was then discharged through a galvanometer. The micrometer screw of the cathetometer reads easily to the $\frac{1}{1000}$ of a millimetre, and observations were taken with its aid at intervals of .050 mm. The plates were considered to be in contact, whenever *making* the primary circuit gave any deflection in the galvanometer. The zero thus obtained was quite constant, whereas it was almost impossible to tell by the eye just at what point the spark ceased to pass when the circuit was broken. The poles of the battery were kept apart when not actually in use, and it was supposed that the electro-motive force remained constant during the time of observation.

In laying out a curve, it must be remembered that there was a resistance of 6000 ohms already in the circuit. Each of the following results is the mean of a series of closely agreeing observations: —

Separation of plates in mms.	Deflections.
.050	183
.100	176
.150	164
.200	145
.250	130
.300	136
.350	123
.400	127
.450	120
.500	106
.550	102
.600	97
.650	92
.700	88
.750	90
.800	91
.850	95
.900	96
.950	88
1.	93
1.050	79
1.100	85
1.150	84
1.200	70
1.250	75
1.500	63
1.750	51
2.000	50
2.250	45
2.500	42

When the sparks passed between the ends of two copper wires, $\frac{3}{8}$ mm. in diameter, carefully filed so as to be parallel, the curves obtained were very regular, but of the same general shape. As an example, I give the following: —

Dist. over which the spark leaped in mms.	Deflections.
1	90
2	70
3	55
4	44
5	35.6
6	27
7	20
8	13
9	7
10	2.5
11	1.4
12	.8

Sir William Thomson has shown, in his paper on the "Electro-motive Force necessary to produce a Spark," that a greater force per unit of length is needed for short distances than for long distances. He does not state in his paper whether he experimented upon the Ruhmkorff coil or the Holtz Machine. In using the Quadrant Electrometer in measuring the electro-motive force of the sparks from an induction coil, it is, of course, necessary to use a small leaping distance from the sparks to avoid the return current. At times, I have found that a greater actual deflection was obtained when the leaping distance was as great as $\frac{1}{2}$ mm. than when it was much smaller. May not Sir William Thomson's results be partly accounted for by induction in the same manner?

Another method of experimenting upon the extra spark obtained by breaking the circuit between the poles of an electro-magnet gave excellent results. One of the poles of the induction coil was connected with the outer coating of a very small Leyden jar; while the other pole connected with the inside coating through a small interval of air, to avoid the return current. The inside coating of the jar was connected by a very fine wire to a thin copper disc, 261 mms. in diameter. Opposed to the copper disc, at a perpendicular distance of 160 mms., was the end of a short rod, 1 mm. in diameter. Attached to the other end of the rod was a very fine wire connecting with one pole of the

Quadrant Electrometer. The other pole of the electrometer was connected with the ground. The very fine wire leading from the opposing section of the rod was so arranged that experiment showed no inductive effect from the disc upon it. When the primary circuit was broken, a spark passed charging the Leyden jar, and consequently the circular plate. The insulated plate was consequently charged to some constant potential V_0.

According to Maxwell's Electricity, Vol. I. § 177, and Thomson's "Papers," 233, the surface density at any point on a thin circular insulated plate is —

$$\sigma = \frac{V_0}{2\pi^2\sqrt{a^2 - m^2}}$$

where a^2 is the radius of the plate, and m the distance of the point from the centre.

If the plate is in the co-ordinate plane $x\,y$, we have, —

$$\sigma = \frac{V_0}{2\pi^2\sqrt{a^2 - x^2 - y^2}}$$

The potential at any point (x, y, z) in space due to this distribution is $\int\int \frac{dy\,dy\,\sigma}{r}$, since the plate is thin. The limits must be so chosen as to comprehend the whole surface of the disc, and to avoid errors the point (x, y, z) must be opposed to the disc.

$$r^2 = (x - x_1)^2 + (y - y_1)^2 + z^2$$

$$V_{x,y,z} = \int\int \frac{V_0}{2\pi^2} \cdot \frac{1}{r} \frac{dx\,dy}{\sqrt{a^2 - x_1^2 - y_1^2}}$$

At any fixed point (x_1, y_1, z_1), therefore, the potential is proportional to V_0. It was supposed necessary that the potential of the quadrants attached to the short rod, which was at a great distance from the electrometer, would be proportional to V_0. The opposite quadrants were at potential zero, being connected with the earth; and since, when the deflections are small they are proportional to the difference of potential of the two poles of the instrument, it was supposed that the deflection of the electrometer needle would be a relative measure of the potential of the plate.

A great many observations were taken with this apparatus, and the results agreëd with the former ones, not only qualitatively, but very nearly quantitatively. I select the following series of observations to show this. The difference is in this case not so widely apparent, owing to the extreme weakness of the current used; it being at this time, in order to get small deflections, the weakest used in the whole of my work.

Primary broken outside.	Primary broken inside.
7.5	9.5
10.	9.
7.3	9.4
7.	9.5
8.2	8.5
8.2	9.2
10.6	9.5
9.5	8.6
5.2	8.4
10.	9.7
8.8	8.5
8.	9.4
6.5	10.5
9.4	10.9
7.	8.1
9.2	10.
5.3	8.7
10.5	12.
8.3	7.8
8.5	8.4
9.8	10.6
9.9	8.6
Mean 8.4	Mean 9.3

These were taken in sets of ten, with wonderfully close means, notwithstanding the apparently great probable error.

Another series, with a stronger current, gave as the ratio of the results 1.364.

The results of the investigation are as follows: —

1. By breaking the primary circuit of an induction coil in a magnetic field, the length of spark produced by the secondary coil is more than doubled in length. An application of this fact to the induction coil is suggested.

2. The results by the different methods used all show an increase of electro-motive force when the circuit is broken in a magnetic field; and that the effect cannot be purely a mechanical phenomenon, as M. Becquerel affirms.

3. By breaking the circuit between mercury and copper in the magnetic field, a remarkable change of polarity was observed with the electrometer.

4. An explanation is offered of the fact noticed by Sir William Thomson, that a greater electro-motive force per unit of length is needed to produce a spark at a short distance than at a long one.

The subject of this paper was suggested to me by Professor Trowbridge, and throughout all my work he has kindly given me his advice and help.

XVI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

No. IX. — CONDENSERS AND GEISSLER'S TUBES.

By William P. Wilson.

In the secondary circuit of a Ruhmkorff's coil of 6000 ohms resistance was joined a galvanometer, and successively Geissler's tubes containing *CO*, *H*, and *O*. The galvanometer was constructed from a Ruhmkorff's coil equal in resistance to the one used in the secondary circuit. Upon sending a spark through a Geissler's tube of *CO*, a deflection of 8 centimetres was given by the galvanometer.

The light was strongest in the centre of the tube; near the positive and negative poles of the platinum electrodes it was very feeble.

The color in the middle of the tube shaded into red; at the extremities it was a pale bluish-white. The light in the enlarged part of the tube, approaching the positive pole, was beautifully stratified with alternate light and dark bands. A condenser, consisting of a Leyden jar of 66.5 sq. cm. surface, was connected with the opposite poles of the coil, and a spark again passed through the Geissler's tube. The galvanometer gave the same deflection of 8 cm. as before, but the difference in light was very marked. This increase in light did not show itself in the centre of the tube, but towards the extremities; both poles, and especially the positive, becoming much more brilliant. The dark and light bands seen near the positive pole, before the introduction of the condenser, now entirely disappeared. The Geissler's tube was removed, and an equal air resistance substituted. This was done by placing near together, and in line, the broken ends of the wire. By a micrometer adjustment, these wire points could be made to recede from or approach each other, until the galvanometer gave a deflection of 8 cm. with the condenser in the circuit. Upon sending a spark through this air resistance, having previously disconnected the condenser, the deflection of the galvanometer was at once increased from 8 to 26 cm. The light did not vary as much as in the Geissler's tube, but could easily be seen to be brighter when the condenser was in the circuit. The following is the record of observations upon three gases, and the equal air resistance, with and without a condenser: —

1. Current passing through Geissler's tube of *CO*.

With condenser, deflection = 8 cm.
Without ,, ,, = 8 cm.
With ,, light increased.
Without ,, ,, decreased.

2. Current passing through Geissler's tube of *H*.

With condenser, deflection = 8 cm.
Without ,, ,, = 8 cm.
With ,, light increased.
Without ,, ,, decreased.

3. Current passing through Geissler's tube of *O*.

With condenser, deflection = 8 cm.
Without ,, ,, = 8 cm.
With ,, light increased.
Without ,, ,, decreased.

4. Current passing through air resistance equal to the resistance of Geissler's tube.

With condenser, deflection = 8 cm.
Without ,, ,, = 26 cm.
With ,, light increased.
Without ,, ,, decreased.

Let *C*, be the condenser; *S*, the entire energy of current which would produce magnetic effect; *L*, that part of the energy expended in light; and *m*, the deflection of the galvanometer. We shall then have *in air:* —

Without $C, S - L = \phi\ (m)$
With $C, S - L_1 = \phi\ (m_1)$
$m = 3.25$ times m_1
$L < L_1$

in gas: —

Without $C, S - L_2 = \phi\ (m_2)$
With $C, S - L_3 = \phi\ (m_3)$
$m_2 = m_3$
$L_2 < L_3$.

In other terms, having an air resistance equal to that of the Geissler's tube, the introduction of a condenser *increased* the *light*, and *decreased* the *deflection* of the galvanometer. Or replacing the air resistance with the Geissler's tube, the introduction of a condenser gave a marked *increase* in the *light*, much more so than in air, but no *decrease* in the *deflection* of the galvanometer.

An attempt was made by Vierodt's method to measure the increase and decrease of light consequent upon the introduction and withdrawal of the condenser; but it was found that the intensity was not sufficient to obtain any accurate results.

It will thus be seen that the effect on the galvanometer was the same when any one of the gases was used; and also that, when the Geissler's tubes were in the circuit, the condenser might be introduced or withdrawn with no visible result in the deflection of the galvanometer.

With an air resistance the spark was a small one with two bright points and a dark centre. This spark gave a larger deflection of the galvanometer, but very little light. When the condenser was introduced into the circuit, the character of the spark was changed at once to a larger one of even intensity. The light was greatly increased, and the deflection of the galvanometer correspondingly decreased. But with the Geissler's tubes in the circuit, the only difference which could be observed between the sparks when the condenser was introduced or withdrawn was in light. The galvanometer continued to give the same deflection in both cases.

A Geissler tube, therefore, affords a test for the presence and action of a condenser in the secondary circuit of an induction coil when a galvanometer fails to do so.

XVII.

ON VIVIPAROUS ECHINI FROM THE KERGUELEN ISLANDS.

By Alexander Agassiz.

Presented, March 8, 1876.

The function of the deeply sunken petaloid ambulacra of several genera of Spatangoids, such as Moira, Schizaster, Hemiaster, and the like, has thus far remained unknown. Philippi, in 1845, while describing some South American Spatangoids, found in the deeply sunken posterior ambulacra of Hemiaster cavernosus minute Echini, which he regarded as the young of the species, though they differed widely from the adults, and seemed, from their shape and the nature of their spines, to approach nearer the regular Echini than the Spatangoids. The Echini of this genus being but rarely found in collections, no opportunity occurred of verifying the observations of Philippi. A somewhat analogous observation was made by Grube, who described more in detail the young of Anochanus (Echinobrissus), which he found living under very similar circumstances, in a cavity opening in the abactinal pole of the specimens. No details of the nature of this cavity having been as yet published, it is not possible to compare these two modes of carrying the young in these two genera more closely.

In Spatangoids, with deeply sunken ambulacra, we find, nearly in all cases, that from the sharp edge of the ambulacral groove long spines extend, so as nearly to close the opening of the cavity, entirely bridging it over, and completely concealing from view the ambulacral pores. This arrangement has usually been considered in Spatangoids as a sort of filter to keep foreign particles from affecting the delicate water tubes, which in the Spatangoids perform more or less the function of gills. This is undoubtedly the case in several genera; but in the case of Hemiaster, and perhaps in other allied genera, the sunken ambulacral area is used for an entirely different purpose, as was correctly observed by Philippi, that of sheltering the young.

That the many specimens (eight) found in the two posterior sunken ambulacral areas are really the young of Hemiaster, is of course only probable, from the fact that the genital openings, which are unusually large, open directly into the upper part of their sunken area ; so that the eggs (or more probably an imperfectly developed Pluteus, like that of Echinaster) on escaping from the genital openings would readily find their way into the artificial cavity formed by the spines which conceal the presence of the sunken areas.

Unlike many Echini, the ovaries of this genus are small, consisting of compact grape-like clusters of eggs, in very different stages of development, a few of the eggs only attaining a considerable size (nearly 1 mm.) and apparently ready to escape into the sunken area, as soon as the place should be left unoccupied by the preceding brood. No two of the small Echini were in the same stage of development: they varied in size from 2 mm. to 3 mm., the smaller specimens having a somewhat pentagonal outline, with rounded angles ; the larger ones were more nearly elliptical and cylindrical in shape. In the smaller

Fig. 1.

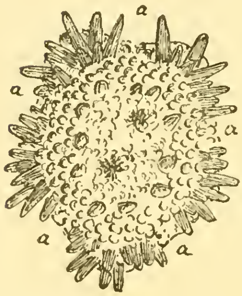
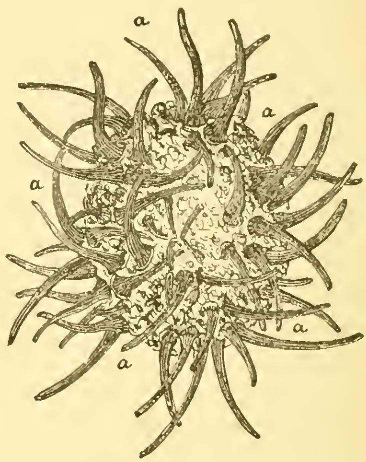


Fig. 2.



specimens (Fig. 1), the spines were short, straight; the longest, and only a few in each interambulacral area, about one-fifth the length of the axis, while the greater number were mere tubercles, scarcely rising above the level of the test. In the largest specimens (Fig. 2),

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FIG. 1. Young Hemiaster, measuring 2 mm., seen from the abactinal pole. *a,a*, ambulacral spaces. The peripetalous fasciole is already developed.

„ 2. Somewhat older Hemiaster, measuring 3 mm., seen from the actinal side. *a, a*, ambulacral areas.

many of the spines, nearly equalling the radius of the test, had become curved and assumed the characteristic appearance of Spatangoid spines. Seen from below (Fig. 3), the large angular mouth, covered by a thick membrane, was nearly central, somewhat anterior, the edge of the mouth on the level of the test, and a few small indistinct pores (Fig. 4)

Fig. 3.

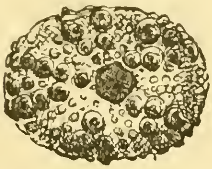


Fig. 4.

arranged in parallel lines, showing the position of the future actinal petal; the ambulacral areas were occupied by coarse granulation, while the tubercles of the interambulacral spaces were large with well-developed crenulation, and already perforated. The interambulacral areas were already broad, leaving but narrow ambulacral spaces, in which the short, club-shaped ambulacral tubes could with difficulty be traced; they were largest near the apex, and near the actinostome (Figs. 4, 5). Seen from above (Fig. 5), the most marked feature of all these young Echini was the broad fasciole, occupying so large a part of the abactinal surface, the position of the interambulacral area being clearly marked by the two large tubercles at the extremity of these areas on the abactinal edge of the fasciole. The whole fasciole was covered by a coarse granulation.

Fig. 5.

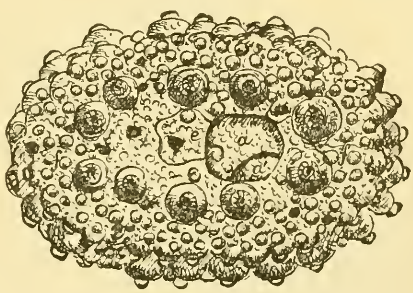


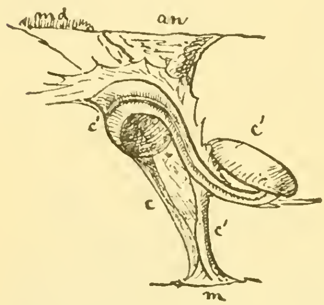
Fig. 3. Young Hemiaster denuded of spines, seen from the actinal side.

„ 4. Portion of actinal surface of Fig. 3, adjoining actinostome to show structure of tubercles. *a*, ambulacral area with pores; *ia*, *ia*, adjoining interambulacral spaces.

„ 5. Fig. 3, seen from the abactinal side, somewhat more enlarged to show the position of anal system (*a*), entirely enclosed by the peripetalous fasciole (*f*), the few ambulacral pores of the lateral ambulacra, and the more numerous pores of the odd ambulacrum.

The most striking feature in the structure of these small Echini is the position of the anal opening (Fig. 5, *a*). This is nearly in the central part of the abactinal surface towards the posterior edge, and entirely surrounded by the fasciole. This fasciole, from its position, must undoubtedly be the peripetalous fasciole, as it agrees in position with the same fasciole in Brissopsis, though in the latter genus it does not enclose the anal opening. In the adult Hemiaster the anal opening is not thus surrounded, an additional example of the little value we can place upon the position of the anal opening as a systematic character. The transfer of the anal opening to the exterior of the fasciole I was not able to trace, all the specimens being too young to show when it took place. There is no trace in these young stages of any genital openings, or of genital plates; the ocular plates are somewhat more prominent than the other ambulacral plates, one specially, that of the odd ambulacrum (see Fig. 5). On opening one of these young Echini (Fig. 6), we find that, notwithstanding the position of the anal opening, the intestine already makes a half circuit round the edge of the test, and is attached to the sides by the usual mesenteries, the actinal extremity of the alimentary canal towards the anterior end being free; the stone canal also leads nearly vertically from the anal opening to a terminal interambulacral plate situated to the right of the odd ambulacrum. The anal opening is large, pentagonal, separating completely the trivium from the bivium, and is covered by a large plate having a small opening opposite the left posterior ambulacrum.

Fig. 6.



The only other young Spatangoid known, resembling so closely a regular Echinus, is a young Spatangoid figured by Müller, while still in the Pluteus stage, with straight spines similar to these figured here in the youngest specimen. This was the first indication we had of the great similarity of the spines of the young stages in the regular and irregular Echini. The presence of an anal opening in the young

FIG. 6. Section of Hemiaster, showing the course of the alimentary canal *c'*, from the mouth *m*, to the anal system *an*; *c*, the stone canal, extending from the circular ring to madreporic body *md*.

Hemiaster connected, so to speak, with the abactinal system is a most interesting feature, as well as the complete separation of the bivium and trivium, the origin of which among Echini had not been understood. The whole family of Collyritidæ, in which this is the normal state, appear in geological times as an abnormal group, disconnected entirely, and isolated from all the other Spatangoids, which it precedes in time, and seeming thus far to have no connection with the Spatangoids of later geological periods. Their connection as an embryonic stage is now clearly shown by the young of Hemiaster here figured, as well as the close relationship existing between the regular Echini and such Spatangoids as Collyrites, appearing as the earliest geological representatives of the Spatangoids. The Collyritidæ are, therefore, not structurally so far removed as has been generally supposed from the regular Echini.

The earlier development, that preceding the stage when the embryo escapes in to the ambulacral area, could of course not be traced satisfactorily. But enough could be seen of the shape of the embryo mass to render it highly probable that the development was very similar to that of other viviparous Echinoderms (Star-fish and Ophiurans), in which the young are carried about by the parents till they are well advanced star-fishes (Sars, Müller, Agassiz), or hatched from the main cavity as well-developed Ophiuridæ (Quatrefages, Schultze, Lyman, Agassiz), and where the plutean development is passed through in a very imperfect manner, owing to the rudimentary development of the arms, which take such an extreme degree of growth in the pelasgic Pluteus of Echini and Ophiurans, traces only of these arms being found in the younger stages of growth of these viviparous Echinoderms.

The specimens I have had the opportunity of examining were collected at the Kerguelen Islands by Dr. J. H. Kidder, the Naturalist attached to the Transit of Venus Expedition, and were sent to me for examination by Professor Verrill. He has described the species as new, under the name of H. cordatus; but I cannot distinguish it from Hemiaster cavernosus and H. Australis, which I was led to consider (from analogy with H. Philippii) to be identical species. It is remarkable that, in the young stages of both these species, all the ambulacra are but little sunken, and it is only when they have attained a considerable size that the posterior ones begin to deepen. Philippi considered this might be a sexual feature. We have not sufficient data to decide the question, but can only say that up to a certain size, at any rate, there is no difference in the depth of the ambulacra of males and females. See Pl. IV., Figs. 4–8, Echini of Hassler Expedition. Ill. Cat. Mus. Comp. Zoöl. No. VIII. I have examined a large number of a common Spatangoid from our southern coasts (Moira atropos), with ambulacra still more deeply sunken than in Hemiaster, in hopes of finding the young, but thus far without success; from the eggs of Schizaster canaliferus from the Mediterranean, in which some of the ambulacra are also deeply sunken, a pelasgic Pluteus is known to be developed; so that in many of the genera with sunken ambulacral petals the sunken area does not shelter the young in their earliest stages of development.

XVIII.

ON A POSSIBLE EXPLANATION OF THE METHOD EMPLOYED BY NOBERT IN RULING HIS TEST PLATES.

By William A. Rogers.

Presented, June 9, 1875.

I recognize the fact that no explanation of a purely mechanical process can be regarded as either satisfactory or final, which does not answer the crucial test of reproduction. I offer to the Academy what I believe may prove to be an explanation of the process followed by Nobert in ruling his test plates; the highest band which has been resolved under the microscope, reaching 112,600 lines to the inch. You properly ask me if I can reproduce these rulings. I frankly answer that I cannot. Indeed, I can hardly hope ever to succeed in producing lines which combine the wonderful delicacy, uniformity, and distinctness found in nearly all of Nobert's plates. But I have reached what I hope may prove to be a useful approximation to Nobert's results. Beginning with 2000 lines to the inch in 1871, I have now little difficulty in reaching 60,000, the width of each line being a little less than one half of the intervening space. Several of my plates have been correctly counted as far as 80,000 to the inch; the observer having no knowledge of the actual number ruled. Two plates in the possession of Frederick Habirshaw, Esq., of New York, contain bands proceeding by 10,000 as far as 120,000 to the inch. The bands of both these plates were correctly counted by Samuel Wells, Esq., of Boston, as far as 80,000, but beyond that point the number counted was less than the number ruled. While the lines of the higher bands seem to be nearly as distinct as Nobert's, they are by no means as smooth and uniform throughout their whole length.

The theory which I offer to the Academy is wholly the outgrowth of my own experience. In the various experiments which I have made, I have noted the constant recurrence of certain results under certain conditions, and these results form the basis of my conclusions. Whether they form a true explanation of Nobert's process is, of course, entirely a matter of conjecture. I am well aware of the risk incurred in offering a theory which can at once be refuted by a single stroke of the pen. Nobert has well kept the secret of his process. If I have failed to detect it, it is easy for him to say, "You are wholly mistaken." Even if this proves to be the case, the facts developed in the course of my experiments may possess sufficient interest to warrant their publication.

The problem is naturally divided into two parts: —

(*a*). The mechanical operation of moving the plate to be ruled over given and equal spaces.

(*b*). The operation of producing on glass, lines of varying degrees of fineness.

If a screw is employed to give the required motion, it would seem at first sight very easy to reach any desired limit of accuracy. In my own machine, the head of the screw, which is 11 inches in diameter, is divided into 100 equal parts. For subdivisions, a microscope is employed, having an eye-piece micrometer, 100 divisions of which exactly cover one division of the screw-head. It is therefore easy to read directly to $\frac{1}{10000}$, and by estimation to $\frac{1}{40000}$ of a revolution. Since the pitch of the screw is $\frac{1}{24}$ of an inch, these numbers correspond to a motion of $\frac{1}{240000}$ and $\frac{1}{960000}$ of an inch. By a device which I shall presently describe, the subdivisions can be carried to $\frac{1}{1000000}$ of a revolution.

But nothing can be farther from the truth than to suppose that, because this high limit of theoretical accuracy can be reached, therefore the lines ruled are separated by spaces accurate within the same limits. It is difficult to name the lowest limit of deviation from the truth which it is possible to reach; but I have long since despaired of being able to rule, e.g. 100 lines, covering successive revolutions of the screw which shall contain no errors of any kind, whether individual or accumulated, greater than $\frac{1}{30000}$ inch. I have availed myself of every opportunity to measure the ordinary stage micrometers furnished by dealers in microscopes, and I find the usual range of error to be between $\frac{1}{2000}$ and $\frac{1}{10000}$ of an inch.

Of course the average error may fall far within these limits; and, especially when the lines are closely ruled, the individual errors may seem by comparison insignificant; but I have been unable to find *any* rulings which invariably surpass the limit which I have named. As an illustration of the limit of accuracy attainable, I give in Tables I., II., and III., measurements of an excellent Nobert diffraction plate, a

Rutherford diffraction plate, and a plate ruled by myself for the purpose of investigating the errors of my screw. The measures were all made with a $\frac{1}{15}$ objective. and an eye-piece micrometer, 200 to the inch, the lines of which were about $\frac{1}{18000}$ of an inch in breadth. Using a B. ocular, the value of one division was found to be $\frac{1}{15200}$ of an inch. With this arrangement, it was found easy to measure any given space to $\frac{1}{500000}$ of an inch with considerable certainty. To eliminate errors in the micrometer, the same divisions were used in all comparisons. In the Nobert plate, the width of the lines is about $\frac{1}{18000}$ of an inch; in the Rutherford plate, $\frac{1}{35000}$ of an inch; and in my own, $\frac{1}{28000}$ of an inch. The space measured was $\frac{1}{240}$ of an inch.

Table I. contains the residuals obtained by subtracting the measure of each space from the mean of all the spaces.

Table II. contains the residuals obtained by subtracting the error of each space from the error of the next consecutive space.

Table III. contains the periodic errors deduced from Table I.

TABLE I.

RESIDUALS FROM THE MEAN.

Spaces.	I. Nobert.	II. Rutherford.	III. Rogers.
	Fraction of inch.	Fraction of inch	Fraction of inch.
1	$+\frac{1}{21700}$	$-\frac{1}{33800}$	$-\frac{1}{44700}$
2	$-\frac{1}{76000}$	$+\frac{1}{27600}$	$-\frac{1}{44700}$
3	$+\frac{1}{38000}$	$-\frac{1}{30700}$	$-\frac{1}{23800}$
4	$-\frac{1}{76000}$	$-\frac{1}{101000}$	$-\frac{1}{34500}$
5	0	$-\frac{1}{27600}$	$-\frac{1}{34500}$
6	$+\frac{1}{38000}$	$-\frac{1}{43400}$	$-\frac{1}{44700}$
7	$+\frac{1}{16900}$	$-\frac{1}{33800}$	$-\frac{1}{108600}$
8	$-\frac{1}{21700}$	$-\frac{1}{101000}$	$-\frac{1}{380000}$
9	$-\frac{1}{152000}$	$+\frac{1}{307000}$	$+\frac{1}{253000}$
10	$-\frac{1}{38000}$	$+\frac{1}{101000}$	$+\frac{1}{27200}$
11	$-\frac{1}{50700}$	$+\frac{1}{33800}$	$+\frac{1}{27200}$
12	$+\frac{1}{76000}$	$-\frac{1}{33800}$	$+\frac{1}{20000}$
13	$+\frac{1}{152000}$	$+\frac{1}{307000}$	$+\frac{1}{33100}$
14	$-\frac{1}{76000}$	$-\frac{1}{101000}$	$+\frac{1}{42200}$
15	$+\frac{1}{19000}$	$+\frac{1}{43400}$	$+\frac{1}{57500}$
16	$+\frac{1}{50700}$	$-\frac{1}{60800}$	$+\frac{1}{23100}$
17	$-\frac{1}{19000}$	$-\frac{1}{307000}$	$-\frac{1}{108600}$
18	$-\frac{1}{30400}$	$-\frac{1}{307000}$	$-\frac{1}{380000}$
19	$-\frac{1}{50700}$	$+\frac{1}{43400}$	$-\frac{1}{34500}$
20	$+\frac{1}{152000}$	$+\frac{1}{43400}$	$-\frac{1}{44700}$

TABLE II.

CONTIGUOUS ERRORS.

Spaces.	I. Nobert.	II. Rutherford.	III. Rogers.
	Fraction of inch.	Fraction of inch.	Fraction of inch.
1	$\frac{1}{16900}$	$\frac{1}{15200}$	$\frac{1}{50700}$
2	$\frac{1}{25300}$	$\frac{1}{25300}$	$\frac{1}{76000}$
3	$\frac{1}{25300}$	$\frac{1}{152000}$	0
4	$\frac{1}{76000}$	$\frac{1}{21700}$	$\frac{1}{152000}$
5	$\frac{1}{38000}$	$\frac{1}{16900}$	$\frac{1}{76000}$
6	0	$\frac{1}{152000}$	$\frac{1}{152000}$
7	$\frac{1}{30400}$	$\frac{1}{50700}$	$\frac{1}{152000}$
8	$\frac{1}{9500}$	$\frac{1}{76000}$	$\frac{1}{30400}$
9	$\frac{1}{25300}$	$\frac{1}{152000}$	0
10	$\frac{1}{50700}$	$\frac{1}{50700}$	$\frac{1}{76000}$
11	$\frac{1}{152000}$	$\frac{1}{16900}$	$\frac{1}{50700}$
12	$\frac{1}{30400}$	$\frac{1}{30400}$	$\frac{1}{152000}$
13	$\frac{1}{15200}$	$\frac{1}{76000}$	$\frac{1}{152000}$
14	$\frac{1}{50700}$	$\frac{1}{30400}$	$\frac{1}{38000}$
15	$\frac{1}{15200}$	$\frac{1}{25300}$	$\frac{1}{19000}$
16	$\frac{1}{30400}$	$\frac{1}{50700}$	$\frac{1}{152000}$
17	$\frac{1}{13800}$	0	$\frac{1}{38000}$
18	$\frac{1}{50700}$	$\frac{1}{76000}$	$\frac{1}{152000}$
19	$\frac{1}{76000}$	0	0

TABLE III.

PERIODIC ERRORS.

Spaces.	I. Nobert.	II. Rutherford.	III. Rogers.
	Fraction of inch.	Fraction of inch.	Fraction of inch.
1	$+\frac{1}{21700}$	$-\frac{1}{33800}$	$-\frac{1}{44700}$
2	$+\frac{1}{30400}$	$+\frac{1}{152000}$	$-\frac{1}{22400}$
3	$+\frac{1}{16900}$	$+\frac{1}{30400}$	$-\frac{1}{11500}$
4	$+\frac{1}{21700}$	$-\frac{1}{152000}$	$-\frac{1}{8700}$
5	$+\frac{1}{21700}$	$+\frac{1}{33800}$	$-\frac{1}{6900}$
6	$+\frac{1}{13800}$	$+\frac{1}{152000}$	$-\frac{1}{6000}$
7	$+\frac{1}{7600}$	$-\frac{1}{43400}$	$-\frac{1}{5700}$
8	$+\frac{1}{11500}$	$-\frac{1}{30400}$	$-\frac{1}{5600}$
9	$+\frac{1}{12700}$	$-\frac{1}{33800}$	$-\frac{1}{5700}$
10	$+\frac{1}{19000}$	$-\frac{1}{50700}$	$-\frac{1}{7200}$
11	$+\frac{1}{30400}$	$+\frac{1}{100300}$	$-\frac{1}{9900}$
12	$+\frac{1}{21700}$	$-\frac{1}{50700}$	$-\frac{1}{19500}$
13	$+\frac{1}{19000}$	$-\frac{1}{60800}$	$-\frac{1}{47000}$
14	$+\frac{1}{25300}$	$-\frac{1}{38000}$	$+\frac{1}{380000}$
15	$+\frac{1}{10900}$	$-\frac{1}{30400}$	$+\frac{1}{50700}$
16	$+\frac{1}{8900}$	$-\frac{1}{76000}$	$+\frac{1}{15800}$
17	$+\frac{1}{16900}$	$-\frac{1}{60800}$	$+\frac{1}{18500}$
18	$+\frac{1}{38000}$	$-\frac{1}{50700}$	$+\frac{1}{19500}$
19	$-\frac{1}{152000}$	$-\frac{1}{100300}$	$+\frac{1}{44700}$
20	0	0	0

It is quite evident that in the three cases under consideration, there are numerous accidental errors amounting to $\frac{1}{30000}$ of an inch and more, while in the last case the evidence of periodicity is very decided; its value at the maximum point being $\frac{1}{5000}$ of an inch. An examination of the values in Tables I. and II., column III., will show how easy it is to be misled by a seeming accuracy when only consecutive spaces are measured. It is only when the errors become magnified by successive increments that they attract attention.

The following will be found a very convenient and accurate method for measuring directly the magnitude of the periodic errors.

First, a series of equidistant lines is ruled on thick glass, care being taken to use glass having a plane surface. It is better also to have the spaces correspond to equal parts of a revolution of the screw. On one side a heavy finding line is ruled. This band is then reproduced on microscopic cover glass, having a thickness of about $\frac{1}{100}$ of an inch. Of course care is taken to use the same part of the screw, and the same divisions of a revolution as before. By cementing the glasses together with balsam, face to face, but with the finding lines coincident and on opposite sides, the periodic errors, if they exist, will appear under the microscope with twice their real magnitude.

In this way it is easy to measure not only the maximum value, but the values corresponding to every division of the screw-head. If an objective of high power is employed, care is necessary to have the surfaces of both pieces of glass as nearly plane as possible. Much better results are obtained by using a piece of cover-glass not larger than $\frac{1}{16}$ of a square inch.

Mr. John M. Blake, of New Haven, did me the kindness to photograph on cover-glass, the plate whose measures are given in column III. By reversing the plates, in the way indicated above, he found almost precisely the same value for the maximum periodic error deduced above; viz., $\frac{1}{5000}$ of an inch.

In passing, it may be interesting to note that though the lines of the Rutherford plate are more distinct than those of the Nobert plate, and though the errors of spacing are considerably less, yet the former was rejected from the start as an imperfect one, while the latter gives excellent results, yet both plates will show with about equal distinctness four lines between the components of the magnesium line *b*. This is hardly in accordance with the theory that the optical test of parallelism of lines, and of equality of spacing, is far more perfect than the test of actual measurement. It is evident that the theoretical limit of accuracy required, in order to produce the solar lines in the greatest perfection, has rarely if ever been reached in actual practice. All the evidence seems to point to the conclusion that the brilliancy of the spectrum depends as much on the character of the lines, and especially on the character of the edges, as on the equality of the spacing.

It is obvious, then, that the errors which are to be the most feared, both on account of their magnitude and the likelihood of their escaping detection, are those which are periodic in their character. To the investigation of the sources of these errors, in my own machine, several months of careful study have been given. Without entering into a detailed account of fruitless experiments, I will give only the conclusion at which I have arrived; viz., *that the periodicity resides, not in the screw itself, but in the mounting of the screw.* The evidence on this point seems to be conclusive. In a large number of separate measurements extending over several weeks, substantially the same system of values as those given in column III. were found. These values were also constant for different parts of the screw. Conjecturing that the trouble might arise from unequal friction between the screw and the nut at different parts of the revolution, owing to the want of parallelism, between the screw and the fixed way on the bed of the machine, a slight movement was given to the adjusting screws, which clamped the split nut. At once the system of corrections was wholly changed, not only in value but in sign, and the values now found, remained constant under every variety of tests applied. After a few weeks, a slight movement was given to the screws holding the plate against which the precision screw works as a shoulder. The sign of the errors was again changed, but their magnitude was very much reduced, amounting at the maximum to about $\frac{1}{250000}$ of an inch. This system of errors also remained, as long as no further changes were made.

Having definitely found by these and several other similar experiments that the periodicity was not due to the precision screw itself, but to the constrained motion caused by unequal friction between the nut, the screw, and the ways on which the gravity slide, which carries the plate to be ruled, is moved, I addressed myself to the task of removing as far as possible this source of error. While I have not succeeded with entire satisfaction, the errors of a periodic character have been so much reduced that those which still remain give no serious trouble. By a device to be presently described, these residuals are overcome by an automatic movement connected with the screw itself. Omitting an account of many fruitless trials, I describe the following permanent changes which were finally made.

(*a*) The ways over which the gravity slide moves, one of which was at first ∧ shaped, and the other plane, and both of which were permanently fixed, were both made ∧ shaped and both movable. The ends nearest the point where the bearing of the shaft of the screw works against its shoulder, were pivoted. The other ends were made adjustable with set screws. The precision screw being set in its normal position, and attached to the slide by its nut, the ways are set parallel with the screw by the motion of the slide upon them.

(*b*) The nut, which at first was only about one inch long, was made four inches in length, being one half the length of the screw. About equally good results were obtained with a lead and a brass nut. The lead nut is much the more difficult to make, as a tap cannot be used. Even when it was cut with a chaser on the lathe, it was found impossible to get a smooth thread until the very simple remedy of keeping the interior wet with a strong soap lye was tried.

The nut having been fitted to the screw, the threads were reduced to a homogeneous system, and at the same time polished, by grinding with the finest emery. It should be remarked that the screw was originally finished in this way, using coarser emery at first. The rule adopted was to grind the screw till all tremor perceptible to the touch in the passage of the nut over the entire length of the screw disappeared.

(*c*) In order to set the screw parallel to the ways in a vertical direction, a hollow cylinder was firmly attached to the under side of the gravity slide. The screw, with the nut upon it, and passing through this cylinder was first set in position. The gravity slide having been firmly clamped down upon the ways, the open space surrounding the nut was then filled with plaster of Paris.

In this way the screw is set in perfect adjustment for one position of the gravity slide. Practically, it is found to be in good adjustment for every position upon the ways. But any slight deviation from adjustment in a horizontal direction is corrected by means of the adjustable ways, while that in the vertical direction is for the most part overcome by leaving one end of the precision screw free.

Good results have also been obtained by using a "free nut." In this case nice adjustments are unnecessary, as the nut moves freely upon the screw, pushing the gravity slide before it. If this arrangement is adopted, care should be taken that the nut, if not symmetrical with respect to the screw, should fall freely in the direction of gravity, and bear at every point throughout its whole length against whatever holds it in position while the screw is in action. The most serious objection to this arrangement is a certain amount of lost motion, which seems inevitable.

It is not to be inferred that all periodic errors have been overcome by the arrangement described above; but experience has shown that they have been very much diminished. In fact, I have never succeeded in ruling but two precisely similar plates, in which there was an exact coincidence of every line from beginning to end, when examined under the microscope. In one plate of 100 lines, ruled with great care, each interval being $\frac{1}{2400}$ of an inch, there are, according to three independent measures made by different persons, 84 cases in which the errors are less than $\frac{1}{100000}$ of an inch, and the greatest individual error is $\frac{1}{47500}$ of an inch; but the maximum periodic error varies with the different observers between $\frac{1}{200000}$ and $\frac{1}{500000}$ of an inch.

Nobert's bands proceed by increments of 5630 lines to the English inch. The following table gives the number of lines to the inch in each band.

Band.	Lines in an inch.	Band.	Lines in an inch.
1	11259	11	67556
2	16889	12	73186
3	22519	13	78816
4	28148	14	84445
5	33778	15	90075
6	39408	16	95705
7	45037	17	101334
8	50667	18	106964
9	56297	19	112594
10	61926		

How are these Lines accurately spaced?

The ordinary way is to give to the head of the screw, which carries the plate to be ruled, the desired movement over equal intervals by means of a ratchet and pall: but this method is open to the two objections, that one is limited to the number of teeth cut on the disc, or to an even combination of them; and, also, that all errors of the gear-cutter with which the ratchet was originally cut are transferred directly to the rulings, with the addition of other errors arising from want of centring, &c.

I have employed for this purpose the following device, which, as far as I am aware, is new in its application: A rigid arm two feet in length vibrates upon a shaft set exactly in a line with the precision screw. At one end a magnet, fitted to the curvature of the head of the screw, is attached by eight pivots in such a way as to give parallel motion with respect to the arm. The outer portion of the head of the screw consists of a rim of soft iron, which operates as an armature to draw the magnet to it when the circuit is completed. The other end of the arm works between two stops, one of which is adjustable. The action, then, is this: the circuit being completed, the magnet becomes firmly attached to the head of the screw, and by the movement of the arm from one stop to the other, it is carried over a given space. The circuit being broken, the arm during the reverse movement carries the magnet with it without disturbing the precision screw. In order to guard against every possibility of disturbance, a second magnet holds the head of the screw in place while the first one is moving back to prepare for the next increment of motion. By varying the distance between the stops, any desired motion whatever, within certain limits, can be given to the screw. From repeated experiments, it is found that about twenty movements of the arm for $\frac{1}{10000}$ of a revolution of the screw-head can be made without varying more than one from this number.

If now the lower stop is replaced by a wheel made to revolve simultaneously with the head of the screw, and if to the periphery of this wheel a curvature is given corresponding to the known errors of the screw, it is obvious that the screw can be made to correct its own errors. Thus, if at any point in its revolution the screw gives too small intervals, the periphery of the wheel must be filed away enough to increase the space ruled by the amount of the error. I am indebted to Professor Joseph Winlock, the late Director of Harvard College Observatory, for the suggestion of this elegant method of overcoming the residual errors of the screw.

How are Nobert's Lines of Varying Degrees of Fineness ruled on Glass?

First of all, the evidence seems quite clear that they are ruled with a diamond having a knife-edge. In all of the cases which I have examined the lines start in with a curvature, which is maintained throughout the whole extent of the band. I have been able to produce this result only by setting the cutting edge of the diamond slightly inclined to the direction of the line ruled, and this inclination seems to give a decided improvement to the character of the lines.

I assume that Nobert uses a prepared diamond, instead of a natural crystal. It is everywhere assumed by writers on the subject, that only the natural crystal possesses perfect cutting qualities. While this is probably true where a deep cut is wanted for the purpose of fracture, it does not seem to be true where distinct, smooth, and uniform lines are desired. I believe this is also the experience of Mr. Rutherford, who long ago abandoned the natural crystal, either unbroken, or broken into chance fragments. A circular point is objectionable for several reasons, mainly on account of its lack of durability.

Starting with the theory that Nobert's lines are ruled with a highly polished knife-edge diamond, I had constructed from my own designs an apparatus for preparing diamonds in this way.

The machine does not differ from the ordinary tool of the lapidary, except in two particulars; but these are vital to success. It is well known that diamonds can be ground and perfectly polished only in the direction of the cleavage planes, of which there are twenty-four in every perfect stone. A skilful diamond-worker will locate the position of these planes by simple inspection. I found myself obliged to employ the more tedious, but not less sure, method of finding them by a tentative process. The machine was therefore so constructed that the direction of the cleavage planes could be detected after a few trials.

Again, it is customary either to press the lap, on which the diamond dust is placed, up against the diamond, which is set in a rigid holder, or else to connect the holder to a rigid shaft by means of an intervening flat spring. In either case, the diamond is liable to crumble when it is reduced to a sharp edge. In the arrangement adopted, the holder containing the diamond is *free in the direction of gravity only.* This action is secured by two shafts set at right angles, and connected with the required supports by three universal joints. By weighting the horizontal arm or by lifting it with a spiral spring, the pressure can be regulated with great nicety. The lap has a circular movement, while the frame in which it rests has two motions in a horizontal plane, at right angles to each other. In order to give a motion in revolution to the holder, for the purpose of grinding circular points, a Hook joint is used to connect it with a driving pulley.

It may be proper at this point to offer a few observations, derived from experience, on the kind and quality of glass best suited to receive delicate lines. I have previously made some remarks before the Academy on what, for the want of a better term, was described as the *grain* of polished crown-glass. Subsequent observations have not entirely confirmed the views expressed at that time. Still, there does not seem to be much doubt but that certain kinds of glass are capable of receiving perfect lines only in one direction. When the lines are ruled at an angle with the general direction of the grain, the edges at once become serrated if they are very fine; whereas, if they are coarse, they either become enlarged throughout their whole length, the edges remaining smooth, or else they wholly break up, presenting a very ragged appearance. If the lines are as fine as 25,000 or 30,000 to the inch, this delicately serrated appearance can be detected at once; whereas, if the lines are coarse, several days may elapse before the tension by which the particles seems to be held together, is broken.

Two instances occurring in my own experience may serve to illustrate this action. In one, while I was examining a set of lines some days after they were ruled, I was fortunate in seeing two or three lines enlarge throughout their whole length. From being fine lines, they became, almost in an instant, very heavy lines, smooth, black, and of excellent quality every way. The action of breaking up was just slow enough to enable me to follow it. In the other, the lines had been ruled about two weeks; and for protection they were covered with microscopic glass, closely cemented to the surface. During my examination, the whole surface became completely broken up. Such was the force of the explosion that particles of glass $\frac{1}{1000}$ of an inch in length were driven a distance of $\frac{1}{100}$ of an inch. In fact, the debris covered the whole surface of the glass under examination. All the particles presented a curved appearance; and, with hardly an exception, the curvature was always in the same direction, On both of these plates lines were afterwards ruled in an opposite direction, but without noticeable results.

It may be said that this phenomenon was due to the peculiar action of the cutting crystal with respect to the surface of the glass; but in all subsequent experiments, in which similar but less striking results were noticed, lines were ruled in both directions at the same time, and under the same conditions. In the case of a particular importation of polished crown-glass from Chance & Sons, the evidence of grain is so marked and of such constant recurrence that all the large plates have been cut into slides 3 × 1 inches, in the direction indicated by the observations. In general, the direction of the grain can be detected at once by the appearance of lines as fine as 30,000 to the inch, while coarse lines may retain their initial character for several days.

The present indications are that the grain is only surface deep, and that it is the result of polishing in one direction. Common window glass seems to be wholly free from it. Nobert's lines are ruled on microscopic cover-glass about $\frac{1}{200}$ of an inch in thickness. The evidence of grain in this kind of glass is strong; but it is hardly decisive. In some specimens it is very marked, while in others it seems to be entirely wanting. Indeed, any conclusions on this subject must be regarded as only provisional, owing to the extreme difficulty of separating the action of the cutting crystal upon the glass from the effect due to the character of the glass itself. It is, however, safe to say that in certain kinds of glass the best results can only be obtained by ruling in a given direction.

In order to rule bands with lines separated by intervals, *e.g.* of $\frac{1}{60000}$ an inch, it is of course necessary to rule single lines whose width is less than this. Great precaution is requisite here, in order to avoid optical delusion. Every microscopist is familiar with the phenomenon of false lines. To avoid errors from this source, a few single lines are ruled between two heavy finding lines. They are then filled with graphite. This precaution is necessary in order to give both visibility and distinctness to the edges. If the lines are not filled, they may appear much finer than they really are; that is, the objective being in focus for the bottom of the furrow may fail to reveal abrasions of the surface on either side. The graphite of the New York Graphite Company will easily fill the finest line that can be ruled with a diamond.

In order to measure the width of the lines, the following plan is adopted as presenting some advantages over the usual method of estimating it by comparison with the known value of a given division in the eye-piece micrometer.

First, a single line is ruled, which in the eye-piece apparently exactly covers the line to be measured under the objective. A few trials will suffice for this purpose. Having found what weight must be applied to the diamond to produce such a line, the next step is to ascertain how many lines, exactly like this one, can be ruled within the space of $\frac{1}{200}$ of an inch with a minimum space between each line. This will also require a few trials. For example, if with a $\frac{1}{15}$ objective and a B ocular, the space $\frac{1}{1200}$ of an inch in the eye-piece corresponds to $\frac{1}{15200}$ of an inch under the objective, and if it is found that fifteen lines can be ruled within this space, then the width of the line under examination is $\frac{1}{15200} \times \frac{1}{15} = \frac{1}{228000}$ of an inch; a result which is obviously *within* the truth, especially if the line in the eye-piece is made a shade larger than the line under the objective. Tested in this way, the lines of Nobert's 19th band are about $\frac{1}{180000}$ of an inch in width. The photographs made by Dr. Woodward seem to give a little greater value. The finest lines I have succeeded in ruling are about $\frac{1}{160000}$ of an inch in width. These values are substantially the same as those given by Dr. Royston Pigott, as representing the ultimate limit of visibility under the microscope. The smallest angle at which an object can be distinctly seen is stated by him to be 6″, while other writers place it as high as 60″, or even 120″. Even the smallest value named is much too large. I will at any time undertake to rule a single line, $\frac{1}{30000}$ of an inch in breadth, which can be seen at the distance of seven inches from the eye. This corresponds to an angle of about 1″. In this case the line is filled with plumbago, but, if it is reflected from a silvered surface, it can be easily seen at the distance of eleven inches from the eye. Comparing minute particles of matter which can be *seen* under a Tolles $\frac{1}{10}$ objective with those which can be *measured*, in the way indicated above, there is every reason to suppose that the limit of visibility falls beyond $\frac{1}{400000}$ of an inch. It is quite possible that the conclusion reached by Sorby, that the microscope has already reached the limit of its power in *separating* lines whose distance apart is equal to one half of a wave length, may be found to be justified by future observations. It is certain that no lines *beyond* Nobert's 19th band have ever been resolved. The great difficulty in distinguishing true from spurious lines has caused more than one skilful microscopist to doubt whether the resolution has been *certainly* carried a far as that point. But that light is "of too coarse a nature" to enable us to see particles of matter as small as $\frac{1}{200000}$ of an inch, is a conclusion which can be refuted without the slightest difficulty.

How are Nobert's Finest Lines produced?

In trying to answer this question, I shall give the results of four distinct lines of investigation. Neither of these furnish conclusive evidence, but they are all suggestive of possibilities.

I. I have already stated that there is strong evidence that they are ruled with a diamond having a knife-edge. To this is added a fact derived from my own experience, and confirmed by a trial of several months; viz., *that when a diamond, having a polished knife-edge, is set slightly inclined to the direction of the lines ruled, its ruling qualities improve with use.* The diamond with which bands of 50,000 lines to the inch were first successfully ruled would at first barely rule 10,000. It was only after a service of several weeks, its position in the holder meanwhile remaining unchanged, that the highest limit named was reached. Four new diamonds have since been mounted with precisely the same result. It is not to be understood that this remark holds entirely true for heavy lines, such as are requisite for good diffraction plates. It is the experience of Rutherford and others, that one of the chief difficulties in producing such plates is the inability to find a diamond which will do its work equally well throughout the entire process of ruling. But when only very fine lines are desired, the longer the diamond is used, the greater the pressure which can be applied without increasing the size of the line. In this way the lines can be made much more uniform throughout their entire length, than when the diamond barely touches the surface. One can hardly say that the diamond sharpens itself by use, but there is some evidence that the wear is greater on the two faces than on the knife-edge.

When the diamond does its work perfectly, the cut, even of the finest line, produces a sharp singing sound. My ear has become so accustomed to this peculiar tone, that I can judge of the quality of the lines ruled almost as well by sound as by sight. In ruling the highest bands, this sound can be heard throughout the entire length of every line. It does not always have exactly the same character, however, being sometimes much sharper in tone than others.

II. From Mr. Herman, a successful diamond worker of New York, I learned a fact which was thought to be of sufficient importance to justify a somewhat difficult experiment. He stated to me that his experience had shown him that the only really hard points of a diamond are those where the line formed by the intersection of two faces terminate. His directions, therefore, were to grind the faces to a knife-edge, exercising great care to leave the natural line of intersection untouched as far as possible, and then to grind and polish a face nearly at right angles to this line, stopping just at its extremity. He assured me that the success of the experiment would depend entirely upon neither falling short or going beyond this point. Only one diamond has been successfully prepared in this way, and even in this case it is not quite certain that this requirement has been met. Its performance is sufficiently good to warrant further experiments.

III. I am indebted to Mr. D. C. Chapman, of New York, for a third method of preparing a ruling diamond. It is allowed by all familiar with the subject, that the natural face of a crystal is harder than any surface formed by breaking the stone into chance fragments. By splitting a stone in the direction of a cleavage-plane, forming an angle of about 40° with this natural face, an exceedingly sharp knife-edge may be formed, possessing excellent ruling qualities. Moreover, in ruling heavy lines for diffraction plates, the cutting-edge retains its form for a long time. In setting the diamond for ruling, the natural face should be slightly inclined to the surface to be ruled. The Brazilian "bort" seems to give the best and most durable cutting-edge. With a diamond prepared in this way, the line formed by the intersecting faces being about $\frac{1}{16}$ of an inch in length, I find little trouble in ruling from 60,000 to 80,000 lines to the inch.

IV. A few months since Mr. R. C. Greenleaf, of Boston, placed in my hands a Nobert plate which had been entirely spoiled by the introduction of some kind of fluid between the ruled glass and the slide on which it was mounted. Mr. Greenleaf requested me to undertake the restoration of this plate, kindly offering to assume all the risk of failure. The cover, which had been imperfectly cemented to the slide with something like opal cement, resisted every attempt at loosening. As a last resort, two pieces, about $\frac{1}{10}$ of an inch square, were cut with a diamond from the centre of the cover glass. After several trials, one of these pieces was cleaned and remounted without material injury to any of the bands. The 19th is quite as easily resolved as in other Nobert plates.

The other piece, being less perfect, was made the subject of a somewhat careful study. Among other experiments, an attempt was made to fill the lines with graphite; but it was found impossible to do so. Even the coarsest lines would not receive and hold it. As I had never before found any difficulty in filling lines either coarse or fine, this result, so entirely unexpected, was noted down as one of which no explanation could be given at that time.

A few weeks afterwards, I succeeded in reducing a black carbon to a knife-edge. Upon an examination of the first lines ruled with it, two facts at once engaged my attention. First, the lines were finer and smoother than any I had ever before ruled. They possessed that quality of glossy blackness which characterizes nearly all of Nobert's lines. Moreover, they seemed to stand out more boldly in perspective than lines ruled with the ordinary diamond. Every one who has made a study of Nobert's diffraction lines will at once recognize this boldness of perspective as a characteristic feature. Secondly, I was equally surprised to find that the lines *would not receive and hold graphite.*

As these results were confirmed by further observations, it did not seem too much to say that possibly the secret of Nobert's success might consist in his use of a prepared carbon. The natural stone is entirely unfit for ruling purposes.

But it appeared subsequently that this conclusion was quite too hastily formed, as far as the capability of receiving graphite is concerned. During all these observations, the position of the diamond in its holder remained unchanged; but it was afterwards found that, by giving it a certain inclination with respect to the surface of the ruled plate, it was possible to rule lines, both coarse and fine, which would receive the graphite in the most perfect manner. In general, however, lines ruled with a carbon will take the plumbago perfectly but once. If they are filled and the surface of the glass is afterwards cleaned by rubbing, it is not possible to fill them equally well again. As the filling is not disturbed by mounting in balsam, the better way is to clean the glass thoroughly before ruling, and then mount permanently after the first filling.

Though the carbon is reduced so perfectly to a true knife-edge that the intersection of the two faces appear as a line when examined with an eye-piece of high magnifying power, it is apparent, nevertheless, that the cutting-edge is composed of distinct and separate crystals; for in many cases two lines have been ruled at the same time. Generally one is much coarser than the other. Indeed, by regulating the pressure, companion lines can be ruled so fine that it is impossible to see them until they are filled. The setting of the diamond to rule lines of a given kind and quality is simply a question of time and patience. In one hundred trials, perhaps two or three may give lines which will receive plumbago, four or five may give double lines, and one or two may give lines of great delicacy. Great care is necessary in the preservation of the minute cutting crystal when once found. Notwithstanding the most careful manipulation, it often gives way without visible cause. In several instances, I have been able to locate the exact point where it was destroyed.

In general, the best results have been obtained with the prepared carbon. It is, however, somewhat capricious in its action. The labor of preparation is also much greater than with the African or the Brazilian diamond. The process of grinding occupies from five to ten days. That it is much harder than any other kind of diamond is conclusively shown by the fact that one specimen in my possession has been used in shaping a jewel weighing 180 carats, with only a trifling abrasion of its surface.

In conclusion I ought to say, in explanation of the somewhat incomplete and fragmentary character of this investigation, that it has been the gradual outgrowth of experiments undertaken for a different purpose. Indeed, whatever has been accomplished thus far may be said to be the result of an unsuccessful search after a spider that would spin a web suitable for the meridian circle of Harvard College Observatory. Failing to find suitable "spider lines," an effort was made to produce on glass, lines of the desired quality and size. This was finally accomplished by etching with hydrofluoric fumes; the lines having been first ruled in a coating formed by dissolving white wax in gasolene, and uniting the solution by emulsion with liquid gelatine. The coating thus formed will receive lines as fine as 10,000 to the inch, while its protecting qualities are sufficient to withstand very strong fumes. The subsequent experiments detailed in this paper have occupied my attention from time to time during the past three years, when not engaged in my regular duties as Assistant in the Observatory.

XIX.

MOUNTAIN SURVEYING.

By Professor E. C. Pickering.

Read, Jan. 11, 1876.

The difficulties and expense of a topographical survey are always very great; and this is particularly the case in a mountainous country, owing to the short horizontal interval between the contours, their irregularity, and the labor involved in reaching the more elevated portions. The objections to the usual trigonometrical methods are, that the theodolite, or transit, needed to measure the angles, is heavy, liable to injury when carried over a rough country, and the time required to measure each angle is considerable. The labor and cost of measuring a base-line are also very great. Moreover, the accuracy attained is much greater than is ordinarily needed; since, as the land is commonly of little value, there is no need of determining positions with more accuracy than they can be shown on a map. If the tract of country is large, a scale greater than $\frac{1}{100000}$, or $\frac{1}{50000}$, is rarely used; and, owing to the unequal expansion and contraction of the paper, long distances could not be measured with accuracy on such a map much nearer than within fifty to one hundred metres. Another objection to the trigonometrical method is, that the work must be carried on continuously from one base to the other; and no positions can be determined except by connection with a base through a series of triangles. If, however, the latitudes and longitudes of several points are ascertained, each of them may be used as a centre from which the form of the surrounding country may be determined; and an error in one will in no way affect the position of the others. The problem proposed, therefore, was to devise some instrument which should give approximately the distance and elevation of a mountain summit or other object, and which at the same time should be light and not easily injured. With such an instrument, an exploring party, whenever they camped at a point commanding an extensive view, could, during the night, determine their latitude and longitude, and, during the day, locate all prominent visible objects.

To measure small distances, the method of the stadia and telemeter gives excellent results, but is open to the objection that an assistant is needed, who must carry a graduated pole to each point whose distance is to be determined. This method also is only applicable to short distances; as beyond five hundred, or at most a thousand metres, the pole appears so small, that its apparent length cannot be determined with accuracy.

These difficulties are, in a great measure, avoided in the following instrument. A good traveller's telescope, or spy-glass, is mounted firmly on a tripod, and a spider-line micrometer or scale of equal parts is inserted in its eye-piece. In front of the object-glass is fastened a piece of plane-glass, which may be set at any desired angle, and clamped firmly. The angle may be roughly measured by a small circle divided into degrees. The whole is free to turn around the axis of the telescope. To measure the distance of any object, *D*, Fig. 1, the angular magnitude of the divisions of the scale in the eye-piece, is first determined by the usual methods. The telescope is then mounted at *A*, and directed towards *D*, taking care to select for it some sharply defined object, as a rocky crag, the trunk of a tree, or the edge of a snow-bank. Select a second object, *C*, nearly at right angles to *D*, and turn the glass in front of the telescope until the reflection of *C* in its front surface shall be in the field at the same time as the image of *D* transmitted through the glass. Measure accurately the interval between the two images with the micrometer. Next measure off a distance *AB* from *A* towards *C* of one or two hundred metres, and place the telescope at *B*. Again measuring the interval between the two images, taking care not to disturb the mirror, a result will be obtained which will differ from the previous measurement by the angle *ADB*. From this triangle we deduce $DB = AB \frac{\sin A}{\sin D} = AB \sin A \frac{206265}{ds}$, in which d is the difference in the scale-readings, and s the magnitude of each division in seconds. A should be taken nearly 90°; in which case $\sin A$ will very nearly equal unity. Its value may be found with sufficient precision with the divided circle attached to the mirror, or by a plane-table. The greatest accuracy will be attained when *AB* has

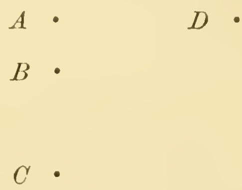


Fig. 1.

such a value as to make the angle at D nearly twice the diameter of the field. To determine the degree of accuracy attainable with such an instrument, suppose the diameter of the field of view 1°, and that an error of .1′ or 6″ is committed in the measurement, — a large error, considering how accurately seconds are determined with the spider-line micrometer in astronomical work. Suppose, again, that the object D is ten thousand metres distant, or 6.21 miles, and that AB is taken equal to two hundred metres: the error in question would then equal only fourteen metres, or forty-six feet, — a quantity quite insensible on the scale proposed above. Again: if the object is fifty or a hundred kilometres distant, it is only necessary to increase AB in the same proportion, and we shall still be able to measure the distance of D with the same proportionate accuracy, without yet using a base of inconvenient length. In this way, if the country is dangerous, the observer may measure the distance of all visible objects without going far from camp. Comparing this instrument with the stadia, we see that it has the advantage that it is not necessary to send a man to the point to be measured, and that the accuracy is the same as if he could carry a pole one or two hundred metres in length.

Three methods have been employed for the determination of heights. First, by the barometer. But this involves a visit to every point to be measured, and, at the best, is very inaccurate. Observations in Switzerland and California have shown, that with the best barometers, after applying all the known corrections, and even if each observation is the mean of thirty, taken once a day for a month at the same hour, at both the upper and lower stations, there still remains an uncertain error, amounting sometimes to two per cent of the whole height. How much greater, then, must be the error of a single reading, often made without simultaneous observations below, and with the defects of an aneroid added to the other errors! The most accurate method of determining a height is by levelling; but the labor and expense of this are too great to allow its frequent use in mountainous countries. The third method is that of zenith distances, which is largely used in the Coast Survey for determining heights. The altitude is here observed by a large vertical circle, which must be read with the utmost precision, since the angle, if the object is distant, rarely exceeds two or three degrees. It is claimed that at least an equal degree of accuracy may be attained by the instrument described below, while the expense of a graduated circle and delicate mounting is wholly avoided. The principle employed is that of the zenith telescope, so largely employed in determining the latitude. It consists simply of the telescope, described above, turned around its axis 90°, and a delicate level screwed firmly to its tube. To make sure that the telescope is turned by precisely the right amount, it is well to have a second level at right angles to this to render the threads of the micrometer exactly horizontal. The size of the divisions of the level and of the micrometer must be previously determined; their relative value being most easily found by directing the telescope towards any distant object, and slightly inclining it, so that the bubble shall occupy various positions in the tube. The corresponding positions of the object are read by the micrometer, and a curve constructed with ordinates equal to these readings, and abscissas to the position of the middle of the bubble of the level. The reading of the micrometer corresponding to a perfectly level line must next be determined. This may be found by setting the telescope up at two not very distant points, and reading the height of each from the other. The mean will give the direction of a horizontal line; since the elevation in one case equals the depression in the other. The direction is, however, best found by observing the height of some known objects; since this eliminates various errors, as will be described below. The height of any object is more readily determined by directing the telescope towards it, and bringing the bubble nearly to the centre of the tube. Then read the position of the object by the micrometer; and, finally, read the exact position of the two ends of the bubble, taking care not to touch the telescope. These readings may then be reduced to seconds of altitude, as follows: Call A the required altitude in seconds, m the reading of the micrometer, m^1 its reading when the telescope is directed towards an object at the same height as its own, and b the mean of the two ends of the bubble of the level. Again, let s equal the magnitude of each division of the level in seconds, and l the corresponding magnitude of the level divisions. Then $A = (m - m^1)\ s + bl$. The elevation in metres or feet is then found by multiplying the tangent of this angle by the horizontal distance of the object, and correcting for the curvature of the earth and for refraction. The first of these corrections may be made with great precision by the formulas or table given in the Coast-Survey Report for 1871, pp. 160 and 169. The second correction is, however, very irregular, and may, therefore, generally be regarded as nearly proportional to the square of the distance. Since the correction for curvature is also nearly proportional to the square of the distance, we may write the elevation $E = D \text{ tang } A + m D^2$, in which D is the horizontal distance, and m a quantity dependent on the condition of the air. If, therefore, the height of any distant object visible is known, it is better to deduce *m* from its observed altitude, and from this compute the other elevations. Were it not for the uncertain error of refraction, this instrument would give results of extreme precision. Thus an error of 6″ in the altitude of a mountain one hundred kilometres distant would only correspond to a difference in height of about three metres. The uncertainty of refraction is much greater than this, and far exceeds the instrumental errors, except in a small telescope. Since, however, this cause of error is present when the theodolite is used, we see that altitudes can be obtained by this instrument with all the precision of the best theodolite; in fact, with all the accuracy of which the method is capable. Apart from its lightness and cheapness, it has this great advantage over a theodolite, — that, since the level is firmly attached to the telescope, there is little liability to error; while, as the theodolite measures the angle between the telescope and the horizontal limb of the instrument, any injury is liable to throw it out of adjustment. With the instrument as described above, no angles could be measured greater than the diameter of the field of view. This difficulty may be remedied by attaching another level, slightly inclined to the first, so that the two fields of view corresponding to a horizontal position of the two levels shall be nearly tangent to each other. A third level serves still further to extend the range of the instrument. Thus, if the field of view is about 2°, angles between 1° and — 1° may be measured by the first level, between 1° and 3° with the second, and between — 1° and — 3° with the third. The instrument, in this form, may be called a micrometer-level. One of its greatest advantages is the rapidity with which elevations may be measured. There is no difficulty in measuring thirty or forty mountains in this way per hour, without the labor of ascending them; while by the barometer it rarely happens that more than one can be measured in a day, and with the ordinary level the altitude of a high mountain would be the labor of days or weeks. The rapidity is also much greater than that of a theodolite; since no accurate mounting is needed, and a micrometer-scale can be read at least as quickly as the telescope can be set, so that the entire time of reading the circle by the vernier is saved.

One of the principal advantages of both the instruments here proposed is, that either may be made out of a telescope such as any explorer would be likely to carry. By simply adding a mirror in front, a photographed scale, and three levels, distances and elevations may be measured with all the accuracy ordinarily required. This method may be applied with especial advantage on a mountain-top;

since the elevations of all other mountains in sight, except those in the immediate vicinity, may be determined.

The fact is worth noting, that, even if the error from refraction could be eliminated, the method of zenith-distances would not equal in accuracy that of ordinary levelling. For suppose that the sights are taken at distances d, and that the probable error of each is e. If n sights are taken, or the distance travelled is nd, the probable error will be only $e\sqrt{n}$, since the positive and negative errors will probably in part neutralize. The error in the method of zenith-distances will, however, be proportional to the distance, or will be ne. Thus, if sights are taken every hundred metres with a probable error of 1 mm., the probable error of the level in ten kilometres will be 10 mms., since $n = 100$; while with zenith-distances the error would be 100 mms. Evidently, therefore, within reasonable limits, to attain the greatest accuracy with the level, the sights should be as short as possible, — a fact in accordance with general experience.

Evidently the telescope of a theodolite may be converted into a micrometer level by inserting in its eye-piece a scale, and attaching three levels. Small vertical angles, which are those most used in surveying, can then be measured more accurately than by a vertical circle. In the same way, a similar attachment may be made to the telescope of a plane-table; and the advantage is especially marked in this case, since an accurate mounting is not needed. A further application may then be made; namely, to determine the distance when the height is known. Suppose that a distant pond is observed from the top of a hill. The telescope is directed to various portions of its shore, and the apparent depression observed. Since every portion must be at an equal distance below the observer, it is easily shown that the distance is always inversely proportional to the depression. Accordingly, if the direction of each part of the shore is marked on the plane-table sheet by a line, and a distance is laid off on this inversely as the observed depression, a map of the pond is quickly made. This may be reduced to its true scale if we know the position of any one point, or the height of the observer above the water. If the shore is abrupt or wooded, only the farther edge of the shore can be thus surveyed, or rather the portion where the actual shore-line is visible. This method is in fact a form of stadia, in which the measuring-pole is replaced by the constant vertical distance between the eye and the plane of the water. The same method may be used for determining the form of an island, of a coast-line, or of a river winding through a nearly level meadow. The form of a pond or island may also be obtained in the same way from a drawing made by a camera obscura or camera lucida, or from a photograph; and has the advantage that it begins to be accurate for depressions greater than 2° or 3° just where they pass out of the range of the micrometer-level as described above.

Valuable observations on the changes in the dip and in the refraction might be made with a large telescope of this form. It is much to be desired that such observations might be conducted for a period of years from two such stations as Mount Washington and Portland. As the pressure, temperature, and moisture of these points is already determined by the Signal-Service Department, a small additional expense would furnish a valuable addition to our knowledge of the atmospheric refraction.

XX.

HEIGHT AND VELOCITY OF CLOUDS.

By Professor E. C. Pickering.

Presented, Jan. 11, 1876.

The velocity of the wind at different altitudes is an important element in Meteorology, and the ordinary methods of measuring it are far from satisfactory. By the following method, it is believed that the velocity of the wind at considerable heights may be measured with an accuracy at least equal, and probably greater, than that of similar measurements near the surface of the earth. The apparatus consists simply of two similar camera obscuras formed of tripods covered with black cloth, and with cosmorama lenses above, which form an image of objects near the zenith on a sheet of paper placed beneath. A day is selected when cumuli clouds are crossing the sky, and the two cameras are placed at any convenient interval, as a hundred metres, in a direction nearly perpendicular to the direction of the wind. An observer with a watch is stationed at each camera, and when a cloud enters the field a signal is given, and each draws a line tangent to the edge of the cloud and parallel to the direction of the wind every half minute. At the intermediate quarter minutes, other lines are drawn perpendicular to these, and also tangent to the cloud. The first series of lines will be nearly coincident, the second at intervals marking the cloud's motion. The zenith is now marked on each drawing by suspending a plumb-line from the centre of each lens, or in some other way, and a line drawn through it parallel to the direction of the cloud's motion. It will now be found that the distance of this line from those parallel to it and tangent to the cloud is different in the two sheets by an amount equal to the parallax of the cloud, or the angle between the two cameras as seen from the cloud. The height of the cloud may then be easily determined, if we know the focal distances of the lenses and the interval between the cameras, by the proportion: Difference of distances of the two lines : focal length of lenses = interval between the cameras : required height of cloud. To determine the accuracy of this method, suppose the interval between the cameras one hundred metres, the focal lengths one metre, and the height of the cloud one kilometre; then the difference between the distances of the two lines will be a decimetre. If this distance is measured with an error no greater than a millimetre, the height will be given within ten metres, or within one per cent. The velocity per minute is then readily deduced from the lines perpendicular to the direction of the wind, and the velocity of the latter may thus be determined within one or two per cent, a degree of accuracy at least equal to that of the best determinations of the velocity of the wind at the earth's surface and much greater than the degree of uniformity of any ordinary wind. Each cloud will furnish a measurement at a different height, and a comparison with observations at the surface of the earth will readily give the relative velocities at these various altitudes.

Various other applications of this principle will suggest themselves. For instance, if the paper is replaced by a sensitive photographic plate, and the cameras directed towards a distant thunder cloud at night, an image of each flash may be taken. A great many flashes may be recorded on each plate, and the corresponding images recognized by their forms. The distances and true dimensions may then be determined with considerable accuracy. If observations are made at the same time, of the interval between the flash and the thunder, the velocity of the sound may be measured, and it may be proved whether, as has been claimed, the velocity of such an intense sound is far greater than that of any ordinary noise.

XXI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

VIII. — AN EXPERIMENTAL PROOF OF THE LAW OF INVERSE SQUARES FOR SOUND.

By William W. Jacques.

Presented, May 10, 1876.

There is every dynamical reason for believing that the intensities of light, heat, and sound, diminish as the reciprocals of the squares of the distances from their origins.

That this is true of light and heat has been demonstrated experimentally. The case of sound, however, has only been put to the test in experiments so crude as not at all to warrant the assumption of the law on experimental grounds.

The following method (which was suggested by the reading of Professor Mayer's paper in the "American Journal" for January, 1873) ranks in its degree of accuracy with those which have been applied to the verification of this law in the cases of light and heat. It depends, primarily, on the principle, that, when a particle of air is solicited by two equal and opposite forces, it will remain at rest.

If two resonators, adjusted so as to resound with equal intensity, be placed equally distant from an organ-pipe, and connected by tubes with the two prongs of a fork-shaped tube in such a way that the sound-wave from one resonator shall arrive at the fork in opposite phase to that from the other, we shall have this condition; and, if the stem of the fork be placed in the ear, no sound will be heard. If, in place of one of these resonators, we put two, each of the same intensity as the first, both connected with the same prong of the fork, we may, by moving them farther from the source of sound than was the single resonator, at the same time altering the length of the tubing so that the wave from the single one shall arrive at the fork in opposite phase to that from the pair, produce the same effect of complete interference. If the law of inverse squares holds true, the distances of the single resonator from the source of sound should be to the corresponding distance of the pair as $1:\sqrt{2}$. If three resonators be opposed to one, the distances should be $1:\sqrt{3}$; if four resonators, $1:\sqrt{4}$ or $1:2$, &c.

It will be seen that the accuracy of the above method depends upon the following conditions: —

1st, That the resultant wave from the combination of two resonators has twice the intensity of that coming from one.

2d, That the decrease in intensity of a sound, in passing through a tube, is inconsiderable.

3d, That the intensity of resonance is proportional to the intensity of vibration at the mouth of the resonator.

Let us first see the arrangement of the apparatus used, and then determine how nearly these three conditions are satisfied.

As a source of sound, a C_3 closed organ-pipe was used, blown by a stream of air from a large gas-holder having an arrangement for keeping the pressure constant. The pipe was mounted on a small standard, raised some four feet above the floor, so that the sound-waves produced might have opportunity to diverge equally in all directions. At a measured distance from the embouchure of the pipe were placed two resonators, each cylindrical in shape, and capped with a hemisphere at one end, through which ran a tube $\frac{1}{4}$-in. in internal diameter, and at the other end with a flat plate, in which was a circular aperture of 1.5-inch diameter. The resonators were telescoped, so as to be readily adjusted for pitch and intensity. From the small tubes of the pair of resonators pieces of rubber tubing led to the two prongs of a forked brass tube, in which the waves from the two resonators came together, and augmented each other. From the stem of the fork another tube led to one arm of the trombone interference apparatus of Herschel. The third resonator was placed at an appropriate distance from the embouchure of the pipe, and so arranged that it could be moved to or from the pipe, and, at the same time, one arm of the interference apparatus could be moved to compensate for the change in phase due to such motion. From the small opening of this resonator a rubber tube extended to the other arm of the interference apparatus; and in this tube was inserted a brass fork precisely like that used for the pair of resonators, excepting that one of its arms was stopped, so that the conditions of reflection for this wave might be as similar as possible to those from the pair of resonators. If all these conditions of reflection be the same, it follows that two resonators give twice as great an intensity as one placed at the same distance from the source of sound.

The second condition, that the decrease in intensity in passing through a tube is inconsiderable, is abundantly proved by the experiments of Biot and Regnault in water-pipes. The third condition, that the intensity of resonance varies directly with the intensity of vibration of the air just outside of the resonator, seems not to be susceptible of experimental proof, excepting on the assumption of the law of inverse squares.

There seems, however, to be no cause for any considerable variation from this ratio: and if, upon trial, we find that the law does hold, it is reasonable for us to conclude that the variation of resonance is proportional to the intensity; for it is extremely improbable that there would be two errors which would exactly counterbalance each other.

The resonators having been adjusted so as to resound with equal intensity by comparing them two at a time on the interference apparatus, it was only necessary to connect three resonators as described above, so that the resultant wave should act on the air contained in the tube which enters the ear. Keeping now the pair of resonators in a constant position, and moving the single resonator and one arm of the interference apparatus until the resultant sound is at its minimum intensity, the relative distances should be $\sqrt{2}:1$.

Below are given several series of readings of the distance of the single resonator from the source of sound. The first three columns are the results of experiments made in front of the pipe, the pair of resonators being placed at a distance of 142 cms. from the embouchure. The resonators were lettered, for convenience, A, B, and C; and the three series of readings are the results of opposing successively A to B and C, B to A and C, and C to A and B. In the last three columns are given the results of similar measurements behind the pipe, the embouchure being still taken as the source of sound, and the pair of resonators being distant 177.5 cms.

At the bottom of the table the means are compared with the calculated positions of the single resonator.

The mean of the means of the first three columns is 100.3 cm; which differs from the theoretical by only 0.3 cm. The mean of the last three is 128.2, giving a difference from theory of 3.2 cm.

An inspection of the following table shows us, that, assuming the embouchure of the pipe as the source of sound, in front of the pipe the law of inverse squares holds almost exactly true: behind the pipe there is a slight difference. Theoretical considerations of the way in which the sound-waves are given off from a closed pipe would lead us to expect an error of this kind. The error due to the experiments being conducted in a hall was probably inconsiderable, as the hall was 92 feet long and 65 feet wide; and, moreover, the windows were partially open. It should be remarked, that bringing the resonators too near the pipe introduced an error of a nature and magnitude which indicated that for a sound of considerable intensity the resonance was not proportional to the intensity of sound at the mouth of the resonator; but this exception only serves to prove the rule for the case of moderate intensity.

A opp. to B & C.	B opp. to A & C.	C opp. to A & B.	A opp. to B & C.	B opp. to A & C.	C opp. to A & B.
cm.	cm.	cm.	cm.	cm.	cm.
99	102	100	128	128	128
100	100	99	129	127	131
100	100	103	129	128	133
101	100	99	129	128	131
99	102	101	125	127	132
99	99	99	127	129	127
100	100	104	125	129	128
101	103	100	127	129	129
100	104	100	126	129	126
98	103	100	129	128	126
101	100	101	128	129	127
99	100	100	128	127	127
99	101	100	128	129	128
100	101	99	128	128	129
98	100	101	128	126	124
100	102	100	132	124	129
Mean = 99.6	Mean = 101.0	Mean = 100.4	Mean = 128.4	Mean = 128.5	Mean = 127.8
Theor. = 100.0	Theor. = 100.0	Theor. = 100.0	Theor. = 125.0	Theor. = 125.0	Theor. = 125.0

It is true that these experiments do not furnish an *exact* proof of the law of inverse squares for sound; but we have not an *exact* proof of the same law in the cases of light and heat. All that we can say of any of them, on experimental grounds, is, that they are *very* approximately true.

The above experiments show that we may make this assertion for sound on as valid experimental grounds as for light or heat.

IX. — DIFFRACTION OF SOUND.

By William W. Jacques.

Presented, May 10, 1876.

The following experiments were made in order to test the possibility of applying to our atmosphere the principles of Fresnel and Huyghens, which, in their application to the ether, have been attended with such fruitful results.

There seems to be no *a priori* reason why the particles of air, forming, as they do, a medium which, so far as the transmission of wave motion is concerned, is essentially similar to the ether, should not be so acted upon as to produce the interferences known in optical science as diffraction fringes. The following experiments bear upon this point.

The apparatus was so arranged, in the first course of experiments, as to give the best conditions for the study of external fringes, or those produced outside of the geometric shadow of a sharp edge, on which sound waves, diverging from a centre, were allowed to fall.

In the second course, similar waves were made to impinge upon an isolated narrow obstacle, and so to give rise to a system of interior fringes.

All other phenomena of diffraction may be classed as particular cases of one or the other of these two kinds.

First series. A board one hundred and fifty centimetres wide was placed at right angles to, and in contact with, the side of the hall. One hundred and fifty centimetres from the edge, in a line at right angles to the plane of the board, was placed a B_4 stopped lead organ pipe. On the other side of the board, a system of co-ordinates was established by means of light wooden rods, running parallel and perpendicular to the board; these rods being divided into centimetres, it became very easy to locate the points of interference by referring them to these co-ordinates, and so to trace out the bands of interference.

In order to distinguish these bands, I first tried applying my ear to different points along one of the rods; but they were not sufficiently well marked to make them apparent to the unaided ear. I then arranged a resonator, of proper size to resound to the pipe, to slide along the rod; connecting this, by a piece of firm rubber tubing, with the canal of my ear. The other ear I filled first with cotton, and then with putty; so that it was entirely deaf to all sounds. I was thus enabled to annul the effect of every sound but that which was re-enforced by the resonator. Moving now the resonator along the rod, I was able distinctly to mark points of maximum and of minimum intensity, which, in general, coincided with the positions which these bands should occupy as calculated by formulæ essentially similar to those applied in the diffraction of light.

In the first experiments, a number of quite serious difficulties were encountered. Perhaps the most important was that due to the fatigue of the sense of hearing, in consequence of which a maximum was estimated before it actually occurred. By alternately opening and closing the mouth of the resonator with the finger many times in quick succession, however, and by taking a reading by first moving the resonator in one direction, and another by moving it in the other, it became possible to set it with considerable accuracy, the differences being, generally, only a few centimetres. Another difficulty was met with in the shape of a distinct band of interference, seeming to have no connection whatever with the other bands, and following quite a different law. Upon tracing it out, however, it was found to be due to an interference of the direct wave with the wave reflected from the gas-holder used to blow the pipe. Upon covering the holder with a cloth, this was very much diminished: and, upon removing the holder, the interference band disappeared altogether. There seemed to be slight evidences of nodes and loops formed in the hall, as in an organ pipe; these, however, were very indistinct indeed, and were probably not a source of error. An attempt was made to use the manometric flame and revolving mirror to determine the points of most complete interference, but the difference in effect upon the flame was so slight as to render this method entirely impracticable.

In fact, the phenomena of diffraction can be studied only by the closest attention with the ear, and the ear is certainly far more delicate than any instrument of this kind that has ever been constructed. A very pure note, and one of constant intensity was necessary for the best results, and these were obtained by blowing the pipe with a stream of air from a gas-holder, having an arrangement for keeping the pressure constant.

Second series. The same board was set up near the middle of the hall. Two hundred centimetres from its middle point, on one side, was placed the pipe used in the preceding experiments. On the other side was arranged a system of co-ordinates within the sound shadow. The method of determining the points of interference was the same as in the first series; excepting that only the bands of minimum intensity were noted. The whole phenomenon was less distinctly marked than in the case of a single edge; and the bands of maximum intensity were not definitely recognizable. It was only with careful attention that even the bands of minimum intensity could be discovered.

Below are given tables showing the observed and theoretical co-ordinates of the points of interference noted. Table I. is the case of diffraction from a single edge, and Table II. from a narrow obstacle.

In Table I., the first column gives the distances from the edge of the board measured perpendicularly to its plane: the second and third columns give the observed and calculated abscissas corresponding to these ordinates, for the points of maximum intensity noted; and the fourth and fifth columns the corresponding values for the points of minimum intensity.

In Table II., the first column gives the distances from the middle of the board; the second and third, the observed and theoretical ordinates of the first curve of minimum intensity; and the fourth and fifth columns, the ordinates of the second curve, — all to the right of the middle line; the sixth, seventh, eighth, and ninth give corresponding values for the two curves to the left of the middle line.

TABLE I.

Distances.	Curve of Max. Intens.		Curve of Min. Intens.	
	Obs.	Theor.	Obs.	Theor.
cm.	cm.	cm.	cm.	cm.
100	94	88	129	148
150	120	115	196	200
200	142	144	235	250

TABLE II.

Distances.	Obs.	Theor.	Obs.	Theor.	Obs.	Theor.	Obs.	Theor.
cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
100	18	19	52	59	17	19	49	59
150	22	25	68	74	21	24	69	74
200	24	30	80	87	24	28	75	89

The theoretical values in the above tables were obtained by a graphical solution, as the formulæ, after undergoing the changes necessarily made, because of the sound waves being of considerable magnitude, became quite cumbersome, and extreme accuracy was not required. The value of λ was carefully determined and properly corrected for temperature.

It should be remarked that all of the above experiments were made in the large hall of the Institute, a room 92′ by 65′.

The phenomena of the diffraction of sound are not so distinctly marked as those of the diffraction of light. An examination of the tables, which are the results of a most careful series of observations, show that we are not warranted in accepting them as a basis for such excellent further work as has been done in the case of light. It is quite possible, of course, to calculate, from the positions of the fringes, the values of λ and therefore of V; to determine the temperature of the room in which the experiments are carried on; or, given these quantities, to deduce the values of physical quantities which are intimately connected with the propagation of sound, and to determine acoustic quantities analogous to those similarly deduced in physical optics: but the method is difficult, uncertain, requires the use of a large hall, physical annoyance to the observer, and, above all, is not susceptible of the desired degree of accuracy.

Their chief value seems to lie in their reactive effect on physical optics. In acoustics we are *sensibly* aware that we are dealing with waves propagated in an elastic medium. These waves may be felt and even seen.* Finding similar effects in optics to those here observed, we immediately refer these similar effects to similar causes, and so place our explanations of the diffraction of light and of the various cases of ethereal interference on a much firmer basis. The experiments show, too, that the principles of Fresnel and Huyghens, announced for the ether, are also applicable to our atmosphere.

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* Expts. of Topfer. Pogg. Ann. 1867.

X. — COMPARISON OF PRISMATIC AND DIFFRACTION SPECTRA.

By Professor E. C. Pickering.

Presented, June 9, 1875.

The object of the present communication is to afford a means of comparing the advantages of the two methods commonly employed for producing spectra, by diffraction gratings and by prisms. Two questions at once present themselves, the comparative length or dispersion, and the comparative brightness of the spectra. In adopting a standard of comparison, it is evidently necessary to select an absolute unit, which shall be wholly independent of the instrument employed, and defined entirely by the ordinary units of distance and direction. In comparing the two kinds of spectra, since an observing telescope and collimator are employed in both, it will be best first to compare the effect of the prisms and gratings alone, and then see how far both are affected by the telescopes. In the case of a diffraction grating, if i is the angle of incidence, r the angle of reflection, D the distance between the lines, λ the wave length, and n the order of the spectrum, these four quantities must be connected by the relation $n\lambda = D\,(\sin i + \sin r)$. The dispersion or angular deviation of two rays whose wave length differs by $d\lambda$ is found by differentiating r with regard to λ, recollecting that i being constant, its differential equals zero. We thus obtain $n d\lambda = D \cos r dr$, or $\frac{dr}{d\lambda} = \frac{n}{D \cos r}$. If now the grating is placed at right angles to the observing telescope, as in Meyerstein's spectrometer, the dispersion takes the very simple form $\frac{n}{D}$, or is independent of the angle of incidence and of the wave length, and hence is uniform throughout, and is simply proportional to the order of the spectrum, and inversely as the distance between the lines. This position has the further advantage that it gives a minimum of dispersion, and that consequently a slight error in setting is unimportant. If N is the number of lines per millimetre, or equals $\frac{1}{D}$, the dispersion assumes the still simpler form nN. This, then, forms the proper term of comparison for diffraction gratings, or the length of any minute portion of the spectrum will be proportional to its order, and to the number of lines per millimetre.

As an example, the grating that Angström employed in most of his measurements contained about 133 lines to the millimetre; and, as he commonly observed the fifth or sixth spectrum, his dispersion equalled 665 or 798. The admirable gratings of Mr. Rutherford contain 6480, 8640, 12,960, and 17,280 lines to an inch, or 255, 340, 510, and 680 lines to a millimetre. Accordingly the fifth spectrum of the 8640 grating would have a dispersion of 1700.

The case of refraction is a little more complex. As shown elsewhere (Proc. Am. Acad. vii. 478), when a beam of light, having an index of refraction n, passes through a prism having an angle a, we shall have the relation $\frac{dr_2}{dn} = \frac{\sin a}{\cos r_1 \cos r_2}$, in which r_1 and r_2 are the angles of refraction after passing the first and second surfaces. For the position of minimum of deviation, $r_1 = r_2 = \frac{1}{2} a$, and in this case $\frac{dr_2}{dn} = \frac{2 \sin \frac{1}{2} a}{\cos i} = \frac{2}{n} \text{tang } i$. If, as is commonly the case, $a = 60°$, $\frac{dr_2}{dn} = \sec i$. But this gives $\frac{dr}{dn}$, while we want $\frac{di}{d\lambda}$, which may be obtained by multiplying by $\frac{dn}{d\lambda}$. The latter may be deduced from Cauchy's formula, $n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}$. Differentiating this equation, $\frac{dn}{d\lambda} = -\frac{2B}{\lambda^3} - \frac{4C}{\lambda^5}$, and multiplying by $\frac{dr_2}{dn}$, gives $\frac{dn_2}{d\lambda} = \frac{-4}{n\lambda^3} \text{tang } i \left(B + \frac{2C}{\lambda^2}\right)$, or for a 60° prism $-\frac{2}{\lambda^3}\left(B + \frac{2C}{\lambda^2}\right) \sec i$.

The substances most commonly used for spectroscope prisms are flint glass and bisulphide of carbon. The indices of refraction of the first of these varies very greatly with the composition, and that of the second with the temperature. The lines B, E, and G are selected as showing the effects of the ends and central portion of the spectrum. The indices for flint glass are those given by Fraunhofer for the specimen No. 23, and equal 1.62775, 1.64202, and 1.66028. For the bisulphide of carbon the temperature of 11°5 C. is employed, and the indices 1.6207, 1.6465, and 1.6886. These values give for the flint glass, $B = .00789$ and $C = .000307$. The corresponding values for the bisulphide are, $B = .00614$ and $C = .001972$, the wave lengths being expressed in thousandths of a millimetre. From these we may compute the three values of $\frac{dn}{d\lambda}$ for flint glass to be .0568, .1381, and .2804; and for bisulphide of carbon, .0818, .2293, and .6073. And finally multiplying these values by 1000 to change the unit from thousandths of a millimetre to millimetres, and by $\frac{dr}{dn}$, gives the following values for the dispersion of a 60° flint glass prism. For *B*, 98; for *E*, 242; and for *G*, 503. The corresponding values for a 60° prism filled with bisulphide of carbon are: for *B*, 140; for *E*, 404; and for *G*, 1133. Comparing these numbers with those given above for diffraction gratings, we see the superiority of the latter as regards dispersion, especially at the red end of the spectrum.

These advantages are, however, in a measure counterbalanced by the greater loss of light. It is shown elsewhere (Am. Jour. Sci. xlv.) that in a spectroscope containing ten 60° prisms the loss of light by reflection would equal 50.9 per cent; so that the transmitted ray would have an intensity of 49.1, the incident ray being taken as 100. This would be further reduced by the loss from absorption, but the amount would vary with the material, the wave length, and the length of path, or size of prisms. Estimating this loss as one half, still leaves the intensity of the whole of the spectrum as 25 per cent of the original beam passing through the slit. In a diffraction spectrum the light is much less; allowing one half for the light lost in the central white image, evidently if we have five spectra on each side, the average amount of light in each cannot exceed five per cent. And even this must be diminished by the loss due to reflection and absorption in the case of glass gratings, and to imperfect reflection in the case of speculum metal or silvered glass.

The discussion of the effect of the collimator and observing telescope on the dispersion involves another consideration; namely, the size of the image of the slit. To render this clearer, suppose we are observing the sodium spectrum, when a small amount of the metal is present.* We shall then obtain two sharply defined images of the slit separated by an interval dependent on the dispersion. These images may overlap, and will vary in width as the slit is open or shut, but their distances apart will not alter. Call *w* the true width of the slit, *W* that of its image as seen through the telescope, and referred to the distance of distinct

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* If much sodium is present, the lines widen and become hazy, and with a large dispersion both appear again double, owing to the absorption of the outer layer of sodium vapor. This effect is readily obtained by putting a lump of borax in the flame, when at first it gives a bright blaze and shows the four lines; presently, however, the light becomes feeble, and the usual double line is alone seen. If now an image of the flame is projected on the slit, the spectrum of any part of it may be studied, and it will then be found that the central portion only gives the four lines, the edges giving the usual double line.

vision, 250 mms., or ten inches. Also call c the focal length of the collimator, o that of the observing telescope, and e that of a lens equivalent to the eye-piece. Then $W = \frac{250\,wo}{ec}$. Again, the dispersion or interval between the two images will equal that of the prism or grating, multiplied by the magnifying power of the observing telescope, or $\frac{o}{e}$, and will be quite independent of the collimator.

As in the microscope and telescope the highest powers are by no means those which give the best results, so in the spectroscope the best effects are not always obtained with the greatest dispersion. Increased angular dispersion is readily obtained by using a high power with the observing telescope, but the limit is soon reached, since the apparent width of the slit, and the various distortions, are increased in the same ratio. Moreover, with a very great dispersion the light is so far enfeebled that the spectrum becomes faint and the slit must be opened wider.

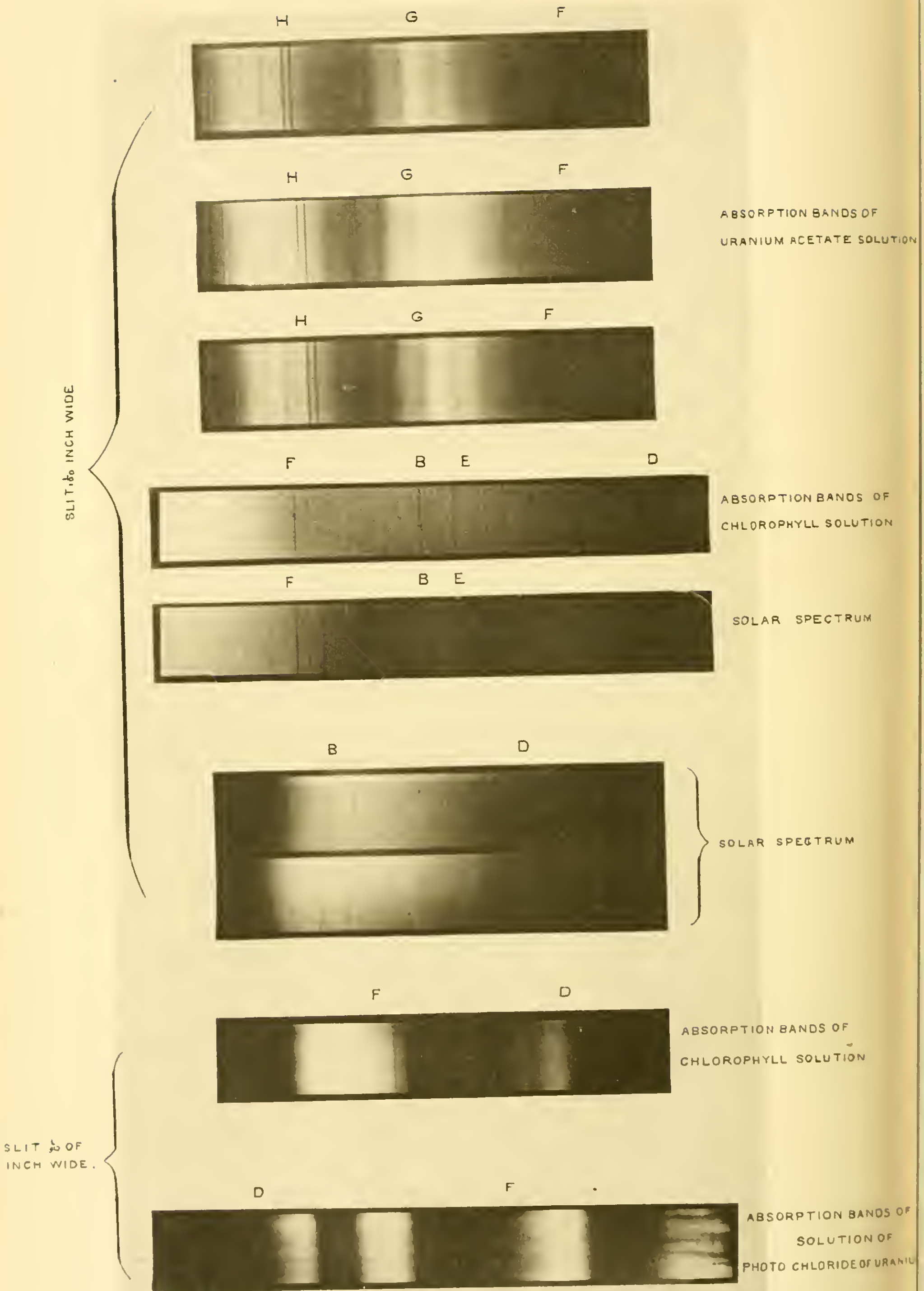
The most satisfactory test of the efficiency of a spectroscope, as of other optical instruments, is to examine some delicate object and compare the appearance with that obtained with other similar instruments. Formerly the D line was used for this purpose, which with any but the smallest instruments is seen to be double. In the solar spectrum it was soon found that there was a third line between these, and afterwards several other lines were noticed. The observations of Professor Cooke (Proc. Am. Acad. viii. 57), however, showed that most of these lines were due to the aqueous vapor in the earth's atmosphere, and that their visibility therefore depended very largely on the condition of the air. The E line is free from this objection; and, as it contains many more components, it furnishes a much more complete test. The following table gives the appearance of the E line as seen with various instruments. A dash denotes that the line opposite which it is drawn was visible. When a double line is seen as single, one of its components only is marked. The lines given in the map of Kirchhoff are shown in the column headed Kir. Those given by Angström are, in like manner, marked Ang. To obtain the lines seen with various instruments of the largest size, I asked several friends to draw all the lines they could see with their spectroscopes; and I take this occasion to express my thanks to them for the results. The column headed Sh. gives the results obtained by Mr. Sharples, with a large spectroscope belonging to Dr. Gibbs, having six 60° prisms, filled with chemically pure bisulphide of carbon.

The dispersion, therefore, as shown above, would be about 2400. Column Am. gives the lines seen by Dr. Amory, with a diffraction grating of Mr. Rutherford's, having 510 lines to a millimetre. As he employed the sixth spectrum, the dispersion was 3060. For the most recent and complete measurement I am indebted to Professor Young, who has measured the E line with a very perfect grating by Mr. Rutherford, having 340 lines to the millimetre ruled on silvered glass. As he used the eighth spectrum, the dispersion was 2720. These results have been taken as a basis, and the resultant wave lengths are given in the second column. My own observations are given in the column marked P., and were made in 1869 and 1870, with a spectroscope in which the light traversed each prism twice, giving a dispersion equivalent to 7, 9, or 11 flint glass prisms. This would correspond to dispersions of 1700, 2200, and 2640; but the best results were obtained with the two lower powers. All the observers used telescopes about a foot and a half in length.

We have thus four entirely independent maps, as neither observer had at the time a copy of the work of any of the others. The similarity of the results, with instruments differing so greatly in form and power, seems to show that we have nearly reached the limit beyond which an increase of dispersion is unadvisable; and as if with our largest instrument nearly all the lines really present in the spectrum were visible. It is much to be desired, however, that these lines may be compared with any other instruments of greater power, if such are ever constructed. It is only essential that the measurements should be made *before* comparison with the above results, since with the lines, as with faint stars, it is much easier to detect them when we know exactly where to look. Various tests may be selected from these lines for an instrument of any power. Thus to double the *E* lines, or to show 24 and 26 as two lines, is a good test for a one prism spectroscope of large size. The five pairs, (27, 28), (29, 30), (31, 32), (35, 36), and (37, 38), also form an excellent test for any but a very large instrument. The great number of double lines in this group, and more particularly in the *B* line, and in the electric spectrum of sodium, seems to prove most conclusively, as in the case of double stars, some real relation between the two components.

The last two columns give the relative intensity and width of the lines as estimated by Professor Young. Nos. 2, 16, and 27 are hazy, and No. 35 is a mere shade. The numbers under the observers' names give the approximate dispersion employed by each.

No.	Wave length.	Kir. 1400	Ang. 800	Sh. 2400	Am. 3060	P. 2000	Y. 2720	In-tensity.	Width.
1	5260.9	—	—	—	—	—	—	3	2
2	1.3	—		—	—	—	—	6	3
3	1.8			?	—	—	—	1	1
4	2 1						—	3	1.5
5	2.4	—	—	—	—	—	—	5	2.5
6	2.8			—	—	—	—	1	2.5
7	3.2						—	2.5	1.5
8	3.4	—	—	—	—	—	—	6	2
9	4.0			—	—		—	2	2
10	4 4			—	—	—	—	1.5	1
11	4.8			—		—	—	2	1.5
12	5.0	—	—	—	—	—	—	2	1.5
13	5.1			—		—	—	2	1.5
14	5.3			—	—	?			
15	5.6			—	—				
16	5.8	—	—	—	—	—	—	7	3 5
17	6.3						—	1	1
18	6.5			—	—	—	—	1	1
19	6.6						—	.5	1
20	7.0			—		—	—	1.5	1
21	7.5	—	—	—	—	—	—	2	1.5
22	7.7			—		—	—	1.5	1
23	8.3						—	.5	1
24	8.7	—	—	—	—	—	—	10	3.5
25	9.0			?		—	?	.5	2
26	9.5	—	—	—	—	—	—	8	2
27	69.9						?	.7	
28	70.3						—	.7	1
29	0.5			—	—	—	—	1.5	· 1
30	0.7			—		—	—	1	1
31	1 2			—	—	—	—	2	1.5
32	1.6			—		—	—	2	1.5
33	2.3			—		—	—	6	2
34	2.5	—	—	—	—	—	—	5	1.5
35	3.1						—	1	3
36	3.9			—	—	—	—	.7	1
37	4.2			—		—	—	1.5	1
38	4.4	—	—	—	—	—	—	2	1.5
39	5.0			—		—	—	2.5	1
40	5.3	—	—	—	—	—	—	4	2



H G F
H G F
ABSORPTION BANDS OF
URANIUM ACETATE SOLUTION
H G F
F B E D
ABSORPTION BANDS OF
CHLOROPHYLL SOLUTION
F B E
SOLAR SPECTRUM
B D
SOLAR SPECTRUM
F D
ABSORPTION BANDS OF
CHLOROPHYLL SOLUTION
D F
ABSORPTION BANDS OF
SOLUTION OF
PHOTO CHLORIDE OF URANIU

HELIOTYPE

XXII.

ON PHOTOGRAPHS OF THE SOLAR SPECTRUM.

By Robert Amory, M.D.

Read, May 10, 1876.

In continuation of the experiments first presented to the Academy a year ago concerning the photography of absorption bands from light transmitted through colored solutions, I take pleasure in announcing, that owing in great part to the assiduous application of my assistant, Mr. J. H. Hubbard, the lines between F and D of the solar spectrum have been distinctly impressed upon a sensitized collodion plate. The plate I now present to the Academy shows these lines unmistakably, the double line of D being perfectly visible. The image is impressed upon that kind of collodion which is coated upon what are known as the " Stuart-Wortley Plates."

I believe this is the first time that a sharp photographic image of the D line has ever been exhibited; though I am well aware that others have reported that they have been able to obtain photographic effects from the yellow and red rays of the spectrum.

You are probably aware that these are dried plates; and in addition to the advantage of using a dry plate, in which the decomposition may be supposed to continue more favorably than on a wet plate, which is constantly drying up when exposed, mention may be made of the probable ingredients used in the dry process. These consist of bromide of silver, salicine, and uranium, among others; and it was evident to us, from certain of our preliminary experiments, that the glucosides, added to collodion, increased the sensitiveness of the plates exposed to the green rays. Hence we were induced to use these in preference to the ordinary dry tannin plates. An exposure of thirty to forty-five minutes is required in order to obtain a distinct image of the solar lines in that portion of the spectrum which I have here presented.

You will observe that the image is brought to a principal focus in the vicinity of E and b lines; in fact, that eight of the group of E lines are quite easily made out, especially if viewed through a magnifying lens of low power. It may also be noticed that the two lines of D are quite sharp, and distinctly visible: possibly the positive impression taken from the same negative, which is here exhibited, may make these lines more visible in the dazzling gaslight of this room. I also present negatives and their positives of the absorption bands of a solution of uranium acetate, of uranium chloride, and also of a solution of chlorophyll, the latter of two kinds, one of which is obtained from grass, and the other from green tops of the asparagus-plant.

In conclusion, I will state that we have used the most simple apparatus that could be devised, so that we may only lose a small portion of light, and not complicate the results by too many reflections of the image submitted to the photographic action. This apparatus consists, 1st, of the heliostat; 2d, a mirror arranged in the central axis of the heliostat to intercept and reflect the beam into a dark room; 3d, a slit (width about one-hundredth of an inch) in the shutter of the dark room; 4th, a collimating lens at its exact focal distance from the slit; 5th, a dense glass prism arranged at the minimum angle of deviation for the especial line whose image we wish to photograph; 6th, a common spectacle lens of forty-two-inches focus; 7th, the sensitized plate. Between the prism and the sensitized plate, a square, dark box of large capacity excludes all other light than that we wish to use.

On the following page will be seen heliotype prints of these bands, though it should be borne in mind that it is almost impossible to obtain an exact reproduction of details in a positive on paper, unless the negative be retouched, which for obvious reasons cannot be allowed. Mr. E. Edwards very obligingly has devoted much pains to the reproduction of these prints by the heliotype process.

XXIII.

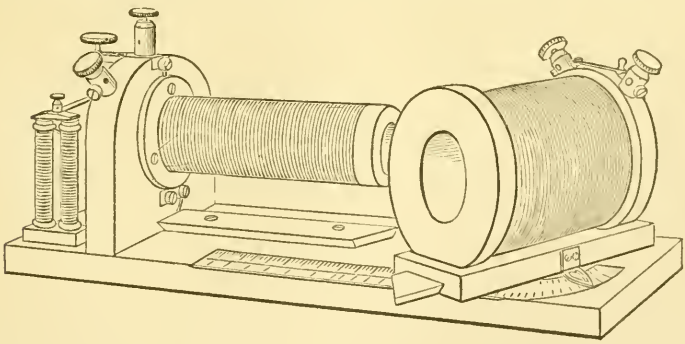
A NEW FORM OF INDUCTIVE APPARATUS.

By Henry P. Bowditch.

Presented, Oct. 12, 1875.

The inductive apparatus commonly used in physiological laboratories is the so-called "Sledge Apparatus" of Du-Bois Reymond. In this instrument, the intensity of the induced current is regulated by varying the distance between the two coils, their axes being always kept in the same straight line. By this method, very feeble currents can only be obtained by separating the coils to a considerable distance, and an instrument made to permit this separation has often an inconvenient length.

In the instrument here presented, and which is figured in the accompanying wood cut, this difficulty is obviated by allowing the secondary coil, as soon as it has been withdrawn enough to be fairly free of the primary coil, to rotate round a vertical axis. In this way,



the intensity of the induced current may be reduced to any desired degree, zero being obtained when the coils are at right angles to each other. The effect of simple rotation of the secondary coil, regarded by itself, would doubtless be to cause the intensity of the induced current from that coil to vary in the same proportion with the cosine of the angle of rotation. This effect is, however, complicated by the variation in the distance of the different parts of the two coils from each other which attends this rotation. It is accordingly found that the curve which represents the actual variations in intensity (obtained, according to Fisk's method, by measuring with the galvanometer the intensity of single induction shocks at every ten degrees of revolution of the secondary coil *) differs from the curve of cosines in being slightly convex towards the abscissa just before it reaches that line.

The scale with which the instrument is provided indicates the intensity of the induced current at different positions of the secondary coil, expressed in terms of an arbitrary unit employed in the graduation of a large "sledge apparatus," in use at the physiological laboratory, and similar to the unit adopted in German laboratories for the graduation of similar instruments.

* See Cyon's Methodik der physiologischen Experimente, p. 379.

XXIV.

HYDROGRAPHIC SKETCH OF LAKE TITICACA.

By Alexander Agassiz.

Presented, March 8, 1876.

From the position of Lake Titicaca, its exploration promised to give interesting results in Natural History, judging at least from the materials collected in lakes situated at great heights. It was therefore with considerable disappointment that my companion and myself after a protracted examination of this great sheet of water examined our plunder. We had come prepared with all the necessary apparatus for dredging, for taking observations of temperature and making soundings; and, with the facilities placed at my command by the Peruvian government, we hoped to gather a rich harvest. Mr. Garman spent nearly six weeks in skirting the shores of the lake, stopping at all convenient places for making collections of the Fauna of the lake and of its shores, and for exploring the ancient remains found on the islands in the lake and at several points in the vicinity of the shore line. While Mr. Garman was sailing on the lake in a small iron sloop, the only sailing vessel on the lake, if we except an old flat bottom ferry plying across the Straits of Tiquina, I made two expeditions in the steamers "Yavari" and "Yapura" placed at my disposal by the Peruvian government, landing at all the noted points where interesting Inca ruins existed: the islands in the lower lake, the islands of Coati and of Titicaca, Copacabana, and Tiaguanaco. During these two expeditions, I crossed the lake longitudinally twice, and ran several lines of soundings from shore to shore. The captains of the government steamers, Capt. F. Guerrero especially, taking the greatest interest in my proceedings and assisting me in all possible ways, sparing neither time nor pains to secure proper observations. The first mate of the "Yavari" was fortunately assisted by a number of English sailors, who were devoted in hauling the sounding lines at all times of the day and during all kinds of weather. The sketch map accompanying this notice is compiled from the map of Thompson and of Pentland, with such corrections of the shore line as we could make from personal examination. The latitude as given by Pentland, 16° S. for the northern extremity of the Island of Titicaca, is very nearly correct, Capt. Guerrero and myself having taken several sextant observations off the northwest point of the island, which agreed quite closely with Pentland's positions. The longitude of Puno, however, as given by Pentland, 70° W., is probably not quite correct, and too far to the eastward. The distance of Puno from the harbor of Mollendo being only seven minutes in time, as ascertained by telegraph between the two points, of course this is approximate; while taking the longitudes as given on the English admiralty map 73° 39′ for Mollendo, as given by Fitzroy, and 70° for Puno, by Pentland, the difference of longitude is somewhat greater, more than 3°.

Mr. Garman and myself took more than sixty-five soundings, from which a number were selected to represent the surface of the bottom. The whole bottom of the lake in its deepest parts, and frequently quite close to the shore, up to the point at which the myriophyllum and the totora grow so plentifully in certain localities, is covered by a thick bed of mud, the finest possible greenish black silt. This bed of mud must have been several feet in thickness, to judge from the ease with which the heavy sounding leads disappeared in it. It contained but few fragments of shells, being almost always made up of pure fine mud. It was only in a small number of localities near the shore, and away from the mouth of any rivers, that occasional patches of sand and of shelly or rocky bottom were found. In the lower lake, however, the bottom was generally sandy, the water having deposited the bulk of the matter held in suspense before reaching the Straits of Tiquina. At the time of our visit to the lake, although during the last part of the rainy season, when all the rivers pouring into the lake were very high and turbid with the mud and materials they brought down from the mountains, yet, a short distance from the shore, the surface water was remarkably pure and clear. According to an analysis made by Professor Raimondi of Lima, there is but a mere trace of saline substances, and not sufficiently large to affect the potability of the water. Having an outlet to Lake Aullagas through the Desaguadero, there is no chance for an accumulation of saline matter, while Lake Aullagas is already, as I am told, somewhat saline, and the sink into which that pours is quite saline. The unpleasant taste of the lake water near the shore is due to the immense amount of decayed vegetable matter abounding in the extensive fields of myriophyllum and of totora, which line the shores for miles, and which extend to a depth of from six to seven fathoms. The totora fields are most extensive in Puno

Bay and the southern shores of the lower lake. The myriophyllum grows very luxuriantly, and forms an important article of food for the cattle of the lake shore. It is not an uncommon sight to see the cows of Puno wading up to their middle in the water, and diving boldly in search of their food which they cannot find on the shore. This habit has as yet produced no apparent effect on these amphibious cows, although carried on for a good many generations. The fields of Totora are also the feeding places of the myriads of aquatic birds which abound along the lake shore, and which are the most characteristic feature of the Fauna of the lake. The fishes and reptiles are not numerous,* and our collections of the former showed a poverty in species which is most remarkable, and this is also accompanied by a comparative poverty in the number of specimens, except in certain localities. The scarcity of fishes can, however, be readily explained when we examine the physical condition of the water, which is certainly not well adapted to them. In the first place, the whole bottom of the lake, as I have mentioned before, is covered with silt, thus rendering unfit a large part of the area of the lake for the fishes and reptiles, leaving only the shallower bays, a more or less wide belt along the shore according to the nature of the adjoining country, and the lower lake, which appears to be the favorite fishing post of the Indians. This, however, may be due to the greater energy of the Bolivian Indians, who are a finer set of men, more willing to work, and in every way superior to the lazy natives found near Puno and the northern end of the lake. In the second place, the temperature of the water of the lake is so high that none of the fishes which abound in the lakes of our temperate zone are to be found. There are in all only six species of fishes, Cyprinoids and Siluroids, — a remarkably small number for a sheet of water as large as Lake Erie. They were all known before. In the way of reptiles, the most interesting species was a huge frog, which remained often for hours perfectly quiet on the bottom, suspended on fronds of myriophyllum, apparently too lazy to come up to the surface to breathe.

The effect of the vertical sun upon the temperature of the water is very marked, extending to its deepest point, and heating the whole body of water to such an extent that the greatest difference we observed was in one case, it is true, as high as 6½ degrees at a depth of 103 fathoms; but the usual difference between the surface and

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* See Bull M. C. L. Vol. III. No. 11.

the bottom, even at the greatest depth (154 fathoms), was not more than from 3 to 4 degrees. The lowest temperature of the bottom was only 51°, the general temperature varying from 54 to 55°; while the surface temperature ranged from 53 to 59°, the greater part of the time 56 to 57° Fahr.

We used the ordinary deep-sea thermometer of Miller Casella, kindly loaned to me by Captain Patterson of the United-States Coast Survey. As is well known, deep-sea observations show that the effect of the sun does not extend in the ocean much beyond 50 fathoms: but, in a closed basin like this, at so great an altitude, the effect of the direct rays of the sun passing through so little atmosphere is very great. It must be remembered, that, even in the winter months of that region (the dry season), the sun never goes farther north than 52°, and that only for a short time; and that, in the summer months (the rainy season), it is nearly vertical the greater part of the time. The water, of course, retains its heat readily, and, even in summer, is but little cooler than the surrounding air, which becomes very rapidly chilled by the least cloud interposing between it and the sun. It is a very common thing for the thermometer to rise or fall eight or nine degrees in as many minutes from the effect of the sudden appearance or disappearance of the sun. Ice is said to form only in small quantities along the shores or shallow places: this is easily imagined when we take into account the immense body of water which must be cooled, 120 miles long by 30 wide, and an average depth of about 100 fathoms; the surface of the lake, even in winter, receiving a large amount of heat by absorption, although the air itself is uncomfortably cold. We find here, as is the case in many other sheets of water comparatively isolated, but few species, and these peculiar to the lake. We find at this great elevation a condition of things reminding us of the marine life of arctic regions, — a great abundance of specimens, with a comparatively small number of species; the shoals of Orestias and Siluroids, which are seen in certain localities, agree with the accounts we have of the swarms of fishes and other animals haunting the arctic realms. Still there are peculiar physical conditions of the bottom of the lake, the immense deposits of mud formed by the settling of the silt brought down annually by the mountain-streams, the great elevation of the lake, the high temperature of the water; all of which causes should tend to specialize to a remarkable degree the genera found to thrive in such a condition of things. We find, however, no such specialization brought about among the fishes: on the contrary, their isolation, even while living under such peculiar physical conditions, appears to have deprived some of them, at any rate, of any capacity for development in the direction of their congeners. The genus Orestias is closely allied to Fundulus, one of the most widely distributed of fresh-water genera. The species of the genus Orestias resemble in a remarkable degree the young of some species of Fundulus, and might be considered, without exaggeration, its embryonic type, at a time when the young Fundulus is remarkable for its large head, prominent opercula, its large scales resembling plates along the anterior part of the back and sides. The other genera of fish found in the lakes are eminently fresh-water, having a great geographical distribution. The great number of water-birds recalls to us vividly also the more northern marshy regions, where thousands of ducks and water-hens abound. The mollusca are all species of eminently fresh-water genera, showing nothing very special. The crustacea, on the other hand, belong mainly to the Orchestiadæ, forms which thus far have not been found in fresh water at all: their nearest allies are nearly all marine (see Bull M. C. L., vol. iii. No. 16).

Although we have from the researches of several geologists, but of Darwin mainly, a pretty good general idea of the immense extent of territory which has been subject to a greater or less elevation along the whole west coast of South America, from the south coast of Ecuador to the eastern coast of Patagonia, this elevation appears to have culminated in Central Peru. Yet there has been nothing shown which would lead us to assume such an immense elevation of the land as 12,000 feet. It is very true that Darwin showed the most positive proof of elevation to a height of about 600 feet; while terraces, shingle-beaches, and other more or less distinct traces of the former level of the sea, he traced to a height of from 1,300–1,500 feet. I have been able to follow up these traces of elevation somewhat higher, having found at Tilibiche, at a height of 2,900 feet above the level of the sea, corals of genera closely allied to those now found living in the West Indies (see Bull M. C. L., vol. iii. No. 13). These corals were attached to rocks, in crevasses formed between them, much as we would find them attached at the present day in the cracks of rocks. This being near the northern extremity of the nitrate-fields of Peru, throws considerable light on the probability of these deposits having been of marine origin. In fact, the geography of the whole of the west coast of the Andes to the north of Chili seems to point to a former condition of things such as we now find on the west coast of Chili. The plains to the southward of Santiago, bounded by the coast range to the westward, and the Andes to the east, gradually pass to the condition of the coast now prevailing at Conception Bay, and south of it, — the coast range forming the archipelago, the Andes forming the coast range, and the plains of the more northern regions becoming changed to bays; the immense basins succeeding each other towards the north which form the so-called Desert of Atacama, the nitrate-beds, the llanos of the coast, the pampas of Peru, through which the rivers flowing to the west have cut deep valleys with more or less marked terraces, showing the different periods of ascent in the elevation of the continent. These plains are everywhere found, either between a coast range and the base of the eastern talus of the Andes, or extending from the summit of the shore terrace, if we may so call it, generally at a height of from 1,200 or 3,000 feet, sloping to the second terrace, with its base at an average height of from 6,000–7,000 feet, and then followed by a second and third more or less indistinct terrace until we reach the main elevated plateau or basin which lies between the eastern and western slope of the Andes. All these basins show more or less distinctly the trace of their former marine origin; so that, if we are to judge from the presence of strictly marine forms, the successive terraces developed on a magnificent scale on the west coast of the Andes, with the interlying basins, we have a fair presumption that the elevation of the Andes to their present height has taken place at a comparatively recent date, and during their upheaval the present nitrate district and saline deposits were left as large lagoons during a considerable period, to judge from the great thickness of the deposits found within their basins, all denoting the presence of a comparatively quiet inland sea.

Lake Titicaca itself must have, within a comparatively very recent geological period, formed quite an inland sea. The terraces of its former shores are everywhere most distinctly to be traced, showing that its water-level must have had an elevation of 300 or 400 feet at least higher than its present level. This alone would send its shores far to the north in the direction of Pucara, forming a narrow arm reaching up to S. Rosa. Lake Arapa is probably only an outlier of the ancient lake, as well as several of the small lakes, now at a considerable distance from the west shore. The immense plain of Cabanillas, extending north beyond Lampa to Juliaca, only 100 or 120 feet above the lake at its highest point, was one sheet of water. The terraces of the former shores are still very distinctly seen. The eastern shores did not probably differ greatly from the present outline, though the peninsula of Achacache was probably an island. The Bay of Puno must have been connected with the plains of Llave, and those back of Juli; while from the lower lake, back of Aygache, the lake formed huge inlets or deep bays, now represented only by the nearly dry river-beds flowing into the lake at Aygache, Corilla, and Guajui. The sluggish Desaguadero must have been a strait of considerable width, with large islands; and this long lake, connecting Lake Titicaca with Lake Aullagas, must have equalled in extent the upper lake; the upper lake, at that time, extending across the Isthmus of Yunguyu, leaving the Peninsula of Copacabana as a large island, connected with the lower lake by a broad pass between the hills to the west of Copacabana, and those to the west of Yunguyu. The plains, now laid bare at the northern and western shores of Lake Titicaca, give us an excellent idea the appearance the whole basin of the lake would present if entirely dry. The number of lakes and basins, great and small, which formerly covered the elevated plateau of the Andes, must have been very great; but we now find only here and there a small sheet of water. The former lakes are only represented by the more or less extensive pampas, forming basins at great altitudes, showing plainly that the whole of this district is receiving a much smaller waterfall than in former times, but probably not within historic times, if we take into consideration the position of some of the most ancient ruins of Bolivia (at Tiahuanaco), which are only about 75 feet above the present level of the lake. These ancient basins are thickly covered by huge bunches of rank grass, from which the llamas, alpacas, and vicuñas obtain their only sustenance at the immense heights where they seem best to prosper. It would be an interesting inquiry to ascertain the causes of the difference in the habitat between the other species of camels and the llamas, which do not thrive near the sea-coast.

In the lower lake, which is shallow, the temperature of the surface and that of the bottom varied extremely. From the number of observations taken, I can only state that it is very local, depending upon the prevailing wind and the condition of the sky.

The following soundings, taken from those of the upper lake, show the great uniformity of the temperature of the surface and bottom:—

Depth. Fath.	Surface.	Bottom.	Air.	Time.
5	55° F.	55° F.		7.40 A.M.
8	55	53	56°	10.15 A.M.
28	58	53		12.30 A.M.
18	59	54.5	55	4.30 P.M.
12	55	54.9	42	7.10 A.M.
24	56.5	56	53	9 A.M.
33	54.7	54.5	47	12.20 A.M., cloudy.
30	57.5	56.2	58.5	4 P.M., clear.
43	56.7	55	58	10.20 A.M.
47	55.9	54.9	67	11.05 P.M., sun very bright.
66	56.1	54.3	55	11.10 P.M., sunny.
74	57	54.5	60	2.25 P.M., sunny.
82	55.5	51		8 A.M.
85	56	54	43	6 A.M., rainy.
90	56	54	55	1 P.M.
100	55.3	54.3	44	7.10 A.M., raining hard.
103	56	51.5		6.15 P.M.
111	57.5	54.9	63	12.20 P.M., clear.
106	57	54.5		
112	54.9	54.5	44	7.10 P.M., raining hard.
113	57.5	55	61	10 A.M., clear.
114		55		
116	55	54.6	45	11.14 A.M., raining hard.
124	56.3	56	60	1.09 P.M., sunny.
125	55	54.9	45	8.05 P.M., sunny.
130	56	55		9.10 P.M.
136	57	54	55	10.30 A.M.
132	53	52		
149	55.3	54.5	47	11.40 A.M., cloudy.
150	55	54.5	48	10.25 A.M., cloudy.
151	55.4	55	49	12.25 P.M.
154	54	52		8.45 A.M.

The elevation of the lake above the Pacific has been taken from the surveys of the railroad engineers, obtained while laying the line from Arequipa to Puno. Professor James Orton inclines to the opinion that the whole basin of Lake Titicaca, with the high plateau to the westward, is gradually sinking, because the successive observations made from early times give a gradually diminishing height. Thus far, the few measurements taken can hardly be more than a chance coincidence, when we remember the uncertainty and great divergence attending all measurements of heights taken to within a comparatively very recent period. The experience of the topographers of the late geological surveys in the Rocky Mountains has been very similar; and yet we are hardly prepared for such a sweeping generalization as the sinking of the greater part of the Rocky Mountains from much more abundant data than those accessible from Lake Titicaca and its vicinity.

Along the eastern coast of Lake Titicaca, the mountains forming its former shores nowhere rise to any considerable height. The greatest elevations are found along the general line forming the western edge of the high plateau, to the south of which the lake is situated, from the Nevados of Tacorara to those east of Moquega, the Pichupichu, Chachani, Coropuno. A lower nearly parallel range extends about half-way between the line of the former and the axis of Lake Titicaca. This range, however, does not rise to more than 16,000 or 17,000 feet, and, sweeping to the northward at a distance of about one hundred miles to the north-east of the lake, forms the water-shed between the rivers leading to the headwaters of the Amazonas and those flowing into Lake Titicaca, the eastern sides of this great basin being formed by the northern extension of the huge range which culminates near the south-eastern shores of Lake Titicaca in the snowy giants of Guaina Potosi, Mamini, and Mampu. The range runs nearly northward from the head of the Bay of Achacache, forming the southern boundary of Caravaya on the north, and uniting with the northern water-shed of the great Titicaca basin. This eastern range of snowy mountains retreats from the shore of the lake about as far as the western intermediate range, and forms at the same time the line between the waters flowing to the Pacific and those belonging to the basin of the lake. The hills of the peninsula of Copacabana do not rise more than 800 to 1,000 feet above the level of the lake; and, to the south of the lake, low ridges form the dividing-lines of the torrents flowing from the heights between La Paz and Corocoro into the lower lake. The view from the crest of one of these ridges immediately to the eastward of Tiahuanaco is truly magnificent; and the panorama of snowy heights rising from 8,000 to 10,000 feet above the level of the lake is one of the most beautiful stretches of mountain-scenery it has been my fortune to see. Rising as these mountains do behind the islands of the lower lake as a foreground, with the low hills beyond Huarina on the opposite shore of the lake at the base of the snow-line coming down to within a couple of thousand feet of the shore, we have within a radius of thirty-five miles no less than six or seven peaks varying from 20,000 to 22,000 feet above the level of the sea. Looking over the peninsula of Copacabana extends the upper lake, with its sacred islands hardly visible on the horizon; while to the westward extend, as far as the eye can reach, the huge flat-topped hills, the dividing-ridges between the torrents flowing into the lake, which comprise the immense elevated plateau reaching a height of some 16,000 feet above the level of the sea, with an endless number of somewhat higher peaks rising slightly above this general elevation; while to the westward of Tiahuanaco the sharply-cut outline of the mountain-chain which forms the dividing-boundary between Bolivia and Peru shuts out the view in that direction. But while the outline of many of these chains is most graceful, and the grandeur of the Nevada de Sorata is not to be forgotten, the barrenness and utter desolation of the whole scene deprives it of much of its beauty. There is absolutely nothing green to rest the eye; the whole country is dry, arid, stony; here and there a patch of rank grass, upon which the vicuñas manage to eke out their existence; an occasional shrub, with a stem as large as one's little finger, only left because it has thus far escaped the eye of the Indian gathering the few shrubs remaining as the only firewood, which, with characteristic imprudence, he does not cut down to give it a chance to grow again, but pulls up roots and all, to get as much fuel for the present needs as possible.

The accompanying map illustrates the general hydrography of the basin of Lake Titicaca.


Soundings in fathoms
30 miles
10
10
10
Vilquechico
Moho
Conima
Julíaca
12553
Soto
Capachica
Amantani
Campanario
Escoma
Carabuco
Apinguela
Pulpito
Taquile
Pt. Kelima
Puno
12549
Chucuito
Ancoraimes
Achacache
Titicaca
Coati
Llave
Copacabana
Tiquina
S. Pedro
Huarina
Juli
Pomata
Yunguyo
Anapia
Sol
Carapata
Aygache
Taraco
Zepita
Desaguadero
Tiahuanaco
16°
70°
13200 ft.
17700 ft.
21.000 ft.
13000
14000
14300
12700
12620
Hydrographic Sketch
of
Lake Titicaca
by
Alex. Agassiz & S. W. Garman

XXV.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

No. X. — DISTRIBUTION OF MAGNETISM ON ARMATURES.

By Harold Whiting.

Presented, May 10, 1876.

The subject of the distribution of magnetism on armatures has not yet been carefully investigated; although the change of form of the curve due to the addition of an armature has been roughly determined. It appears, that, when an armature is added to one end of a magnet, some of the magnetism spreads over the nearest part of the armature. To prove this, and at the same time to get a general idea of the best way to investigate the subject further, I performed the following preliminary experiment. My apparatus consisted of a steel rod, half a metre long and about a quarter of an inch in diameter, and an iron rod of the same dimensions; also a small wooden bobbin wound with about a hundred and fifty coils of fine insulated wire, and having a hole in its axis just large enough to allow it to slide freely over the rods. A paper scale, graduated into centimetres and millimetres, was attached to each rod. The two ends of the coil of wire were connected with a very delicate galvanometer. The steel rod was magnetized.

The coil was now slipped in different parts of the rod, over a distance of two centimetres each time, and the deflections were noted. This deflection was made the ordinate of a curve, and the abscissa was taken equal to the distance of the centre of the coils at the central point of their motion.

Table I. gives the figures, which are, of course, only relative. The distances are given in centimetres.

TABLE I.

SIMPLE MAGNET. PRELIMINARY EXPERIMENT.

Distances (Cm.).	Deflections.	Distances (Cm.).	Deflections.
0.5	+ 9.6	29.5	—0.6
2.5	7.8	31.5	1.4
4.5	6 2	37.5	2.45
6.5	5.	40.5	4.2
8.5	4.1	42.5	4.9
10.5	3.7	44.5	6.7
12.5	3.0	46.5	8.6
15.5	2.0	48.5	9.0
19.5	1.1	49.5	10.0
23.5	0.35	1.	
25.5	0.23		
27.5	0.		

When the armature was added, the distribution on the magnet was as in Table II. *a*. Here, too, the numbers represent only relative values. Table II. *b* gives, in the first column, the distances; in the second, the permanent magnetism of the armature (nearly constant after once touching the magnet); in the third column, its magnetism when the magnet was attached; in the fourth, the difference of the second and third; in the fifth, the value corrected as afterward to be explained.

TABLE II.

MAGNET AND ARMATURE. PRELIMINARY EXPERIMENT.

a. THE MAGNET.

Distance.	Deflections.	Distance.	Deflections.	Distance.	Deflections.
0.5	+9.1	19.5	+1.25	34.5	—1.4
2.5	8.3	22.5	0.6	36.5	2.0
4.5	6.5	24 5	0.4	38.5	2.9
6 5	5.3	26.5	0.2	40.5	3.2
8.5	4.4	27.5	0.	42.5	4.
10.5	3.7	28.5	—0.2	44 5	4.5
12.5	2.9	30.5	0.5	46.5	5.
15.5	2.1	32.5	1.0	48.5	5.7

b. The Armature.

Distances from juncture.	Deflection due to permanent magnetism.	Deflection when bar was added.	Difference of last two columns.	Corrected values for ideal armature.
50.5	+ 0.15	—4.2	— 4.35	—4.28
52.5	— 0.05	3.7	3.65	3.65
54.5	0.15	2.2	2.05	2.05
56.5	0.2	1.8	1.6	1.6
58.5	0.2	1.2	1.0	1.0
60.5	0.2	1.0	0.8	0.8
62.5	0.2	0.75	0.55	0.55
65 5	0.15	0.6	0.45	0.45
69.5	0.065	0.3	0.24	0.25
74.5	0.045	0.18	0.18	0.18
80.5	+ 0.10	0.03	0.13	0.16
84.5	0.17	0.01	0.18	0.14
86.5	0.20	+ 0.08	0.12	0.13
92.5	0.26	0.05	0.11	0.12
97.5	0.20	0.06	0.12	0.11

The last three values of the curve of magnet, under *a* should be corrected so as to read,

Distance.	Deflection.
44.5	6.7
46.5	5.4
48.5	6.4

It is evident from this experiment, 1st, That the magnetism spreads over the armature.

2d, That the zero point is almost immovable. This was proved repeatedly with various magnets and armatures; and even the most delicate test possible — that of testing the change of distribution at the zero point, when the armature was suddenly removed, by the current induced in a helix — even this failed to show more than the very slightest change.

3d, That the whole farther end of the magnet is unaffected by the armature. This was tested and proved in the same way.

4th, That probably the permanent magnetism of the armature should be subtracted from the total magnetism of the armature when in contact with the magnet; and when the two are nearly equal, as a small error in observation will produce a large relative error in the result, any small irregularities should be removed from the curve. When, however, there is any quantity of permanent magnetism at the juncture, and of an opposite sign to that of the magnet, allowance should be made for a portion of this magnetism spreading over the magnet. The law by which this happens will be demonstrated by and by. It is the same, nearly at least, as if the magnet were soft iron. About half of this magnetism, therefore, spreads over the magnet. Unless this counter-distribution be taken into account, it will be absolutely impossible to obtain accurate results; for no bar of soft iron used as an armature will remain free from permanent magnetism, even if it were perfectly non-magnetic before.

I next investigated the change due to closeness of contact, and found that a bar with perfectly flat ends varied in the amount of magnetism it drew from a magnet ten to twenty per cent, according to the means taken to secure perfect contact of surfaces.

The amount drawn off varies with the length. Some idea of the proportion may be given by these numbers. 100 units being the amount drawn off by a metre bar from a metre magnet, a bar a metre and a half long would draw off about 135 units; half a metre long, 80 units; and 9 cm. long, about 30 units. A mass of iron in weight equal to 116 cm. of iron rod of the size used above draws off about 65 units; so that the length makes a much greater difference than the mass. When for a solid rod we substitute a bundle of wires of equal length and weight, there is no sensible difference in the amount of magnetism drawn off, as tested by the current induced in a helix.

The old apparatus was now laid aside. The new one differed in several respects. The bobbin was of brass; thickness outside, 5½ mm.; inside, 3 mm.; depth of cut was about 5½ mm.; and the diameter of the rods was 12 mm. The magnet and armature had a small hole bored in each end, and a small screw was fitted to draw them tightly together. The surfaces of the ends were made perfectly flat in a lathe. Two clamps served to limit exactly the motion of the bobbin to any distance desired. The magnets and armature were placed east and west on a table about eight metres from the galvanometer, whose deflections were observed with a telescope. Therefore both the induced magnetism of the earth was eliminated, and the magnet had but little effect upon the galvanometer.

Table III. gives the magnetism of magnet No. 1 reduced to absolute measure by the following formula: —

Let n = number of coils in helix.
n' = number of coils in earth inductor.
R = radius of earth inductor in centimetres.
K = the intensity of earth's magnetism $\left(= \text{about } \frac{1.7}{\cos 73°}\right)$,
A = deflection of galvanometer by helix.
B = deflection of galvanometer by earth inductor.
dL = the distance over which the helix was slipped.
M = the surface magnetism of the bar at the point to be measured, the unit being that quantity which will produce unit field at unit distance, then $M = \frac{A}{B} \frac{n'}{n} \frac{R^2 K}{dL}$ (for all points except very near the ends).

Table III. shows the magnetism of magnet No. 1, and armature in terms of K.

TABLE III.

a. The Armature.

Distances from juncture.	Permanent magnetism.	Magnetism when attached to magnet.	Difference of last two columns.	Values corrected for contra-distribution.*
98	+4.0	+3.0	+1.0	
92	4.5	2.97	1.7	
81¾	5.1	3.8	1.5	
71¾	6 2	4.5	1.7	
61½	7.3	4.9	1.9	
51	8.5	5.5	3.0	
41	13.9	8.3	5.6	
30¾	16.3	7.25	9.1	
20¾	18.8	0 12	18.7	
10½	21.2	—5.3	26.5	+24.0
5½	21.2	16.5	37.8	29.5
1¼	17.0	27.2	44.2	30.5

* That is the distribution of the permanent magnetism of the armature upon the magnet.

b. The Magnet.

Distances from juncture.	Magnetism corrected for contra distribution.*	Distances from juncture.	Magnetism corrected for contra distribution.*
2¼	56.	18½	45.5
3	57.	28½	29.7
5	54.5	39	15.
8	54.	49	0.
11¼	53.5	59	—22.
14¼	53.	74½	44.
13¼	52.	84	67.
16¼	50.	94	109.
15½	48.	98	162.

Table IV. gives the distribution for a hollow tube of soft iron (one metre in length) magnetized by a core of steel wires extending half way down the tube. The magnetism was obtained by halving the difference of the two values obtained before and after reversing the magnetic core.

TABLE IV.

HOLLOW TUBE WITH MAGNETIC CORE.

Distances (Cm.).	Magnetism.	Distances.	Magnetism.
2¼	—12.	49¼	5.85
10½	— 5.5	56	4.0
20¾	— 1.8	61	2.9
31	+ 1.05	71	1.35
41	4.2	81¼	0.52
44	5.5	91½	0.2
46	5.55		

Last of all, let us examine the case of two magnets joined by their opposite poles.

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* That is the distribution of the permanent magnetism of the armature upon the magnet.

Without going through the process of analysis, let me simply state what seems to me to be the truth.

Each magnet probably distributes upon the other as much magnetism as it would were a *steel* bar, without magnetism, in the place of the other magnet; and this amount is about one-half or two-thirds the amount that would be distributed on a bar of soft iron. The resulting distribution is simply the algebraic sum of its components.

Table V. gives the magnetism actually observed; and it is remarkable, that, if these curves are plotted, the very same line that represents the theoretical represents also the observed magnetic curve for this case. I would state that the curves were not chosen to suit the occasion, but are identical with the curve of the preliminary experiment, where the poor juncture or the shortness of the bar made up for the superior capacity of the soft iron.

Whether the theory be true or not, I leave it to be judged. It is at least useful in eliminating the contra-distribution inevitable in experimenting with soft-iron armatures; for, if the law holds so nearly in case of such large values, the error in small values must be inappreciable.

The law is as follows: *Find the curve of the armature when a perfectly non-magnetic bar of soft iron, of half the length of the magnet, is joined to it; then subtract algebraically this magnetism from the observed.*

TABLE V.

DISTRIBUTION OF TWO MAGNETS UNITED BY OPPOSITE POLES.

Magnet No. 1.		Magnet No. 2.	
Distances from juncture.	Magnetism.	Distances from juncture.	Magnetism.
0	+ 2 0	0	+ 2.
10	—29.0	10	36.
15	37.0	15	37.
20	37.0	20	36.
30	31.0	30	24.
50	1.5	50	— 2.5
98	151.0	98	130.

In the case of two similar poles being brought together, there is no perceptible change of distribution: the most delicate experiments failed to show any. Probably a change does, however, take place; but the resulting curve is so like the former curve, that the difference is imperceptible.

On the theory of the analogy of the magnetic lines of force to electric currents, these laws will, I think, be nearly, though not completely, fulfilled.

These laws, if true, and, if not, in so far as they are true, enable one to determine the shape which the curve would assume were the armature and magnet of one piece of metal; i.e., if the juncture was absolutely perfect.

Moreover, the same method enables us to draw the limiting values for different lengths of armature: for we have only to increase each abscissa of the curve of the magnet as the total length of magnet and armature is to that of the magnet alone, and to take the half-sum and half-difference as before, to find the curves on the magnet; then, drawing a curve in the same manner to represent another magnet of length of armature joined by a similar pole, the curves on the armature can thus be determined. We shall see, then, that a soft-iron armature acts like a steel armature of about double the length. Whether this is due to contra-distribution, or to a superior magnetic capacity, I leave to be determined.

The following experiments were devised to show the change in magnetic moment due to armatures. The experiments are rough; but they give far the best idea of the changes that take place in magnetic distribution. A magnet was placed upon the floor at a fixed distance from the galvanometer-needle, to the east of it, and pointing east and west. Then an armature was added, and the position of the centre of the magnet was marked upon the floor. Then the whole combination was removed to a distance, and the deflection was noted. Then the combination was brought back, with poles reversed, and was moved toward the galvanometer till the deflection was equal to the previous one.

This at once showed the increase of distance between the poles; for it must have been equal to the distance of the centre of the magnet from its former position, and the central point must have advanced half this distance. Having determined the position of the central point, the magnet alone was now turned upon it; and the ratio of the deflection of the magnet and armature to that of the magnet alone showed the change of magnetic moment.

The centre of the longest armature (150 cm.) advanced 18.25 cm., and the moment became half as much again. The centre of the metre armature advanced 14.5 cm., and its moment became a little over quarter as much again. The moment of the short (50 cm.) armature was increased one-sixth.

From this the distance of the poles of the magnet from the ends can be calculated; and it is about 12 cm. When calculated by the vibrations of a compass in two positions very near the end, it appeared to be 5 cm.: the latter method is probably, therefore, inexact, and will always give the distance too small. It is only at large distances that the magnetism of one end of a bar can be considered as acting at a point.

When the magnet was joined to the armature by a short piece of iron shaped like a U, so that it was parallel to the armature, the pole apparently retreated about 7 cm., and the moment decreased about one-tenth. When, however, a second U armature was added to complete the circle, the reduction of magnetic moment was scarcely perceptible, being less than $\frac{1}{34}$ of the total value. This may possibly be due to poor contact; but I was unable to obtain any different result, though I measured the distribution in various ways. Perhaps, when the armature is bent round so near the magnet, the resistance of the air to the line of force is so slight, that the adding of the second armature affects it but little. This, I think, would be the necessary consequence of the analogy of magnetic force and electric currents.

We see, then, that shunting, so to speak, the poles of a magnet with a soft-iron bar, diminishes the magnetic moment about one-sixth.

It follows, that, if a stronger magnet be shunted by a weaker one, the magnetic moment will be diminished in some way proportional to the difference of magnetization. This accounts for the fact that thick magnets are weaker than an equal weight of thin ones: 1st, because it is impossible, owing to the difficulty of tempering evenly, to obtain the maximum capacity for magnetism in all parts of the bar, and those parts which are weaker diminish the average magnetism per weight, and also diminish the strength of the stronger parts, acting like a shunt; 2d, because, in the common process of magnetizing a bar by rubbing the surface, the interior is less magnetized than the outside, and the core acts more or less like a shunt of soft iron.

If, however, a solid body is magnetized by a force acting on all parts alike, it will not act differently from a bundle of wires of equal length and weight, provided the material be the same. Therefore the bundle of iron wires alluded to above ought to act, as they did, like the solid bar. Fact and theory agree. I am now prepared to answer a question, from which, curiously enough, the whole of the present investigation sprang. I can answer decidedly that there will be no advantage in substituting a bundle of iron wires or plates for the solid core of the helix of a magnetic engine; but, as the helix will be farther off from the core, the induced current will not be increased, but diminished.

XXVI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

XI. — CHANGE OF ELECTRICAL RESISTANCE IN WIRES BY STRETCHING.

By George S. Pine.

Presented, May 10, 1876.

The electrical resistance of a wire of constant section and material is directly proportional to the length, and inversely proportional to the area of the cross-section. When the wire is stretched, its thickness or cross-section, as well as its length, undergoes a change. This investigation was undertaken to see whether the change in resistance is directly as the length, and inversely as the cross-section of the wire; or whether the copper or the iron, whichever the substance may be, is a better or a worse conductor.

Let l = original length of the wire.
l_1 = length at the end of the experiment.
r = original radius.
r_1 = final radius.
R = original resistance of the wire.
R_1 = final resistance.
v = volume of wire, — supposed constant.
λ = resistance of wire whose length equals its cross-section.

Suppose that λ does not alter. On this supposition, let us find the resultant resistance. We must compare this with the observed resistance to see whether our supposition is right; to see whether λ does or does not alter.

Supposing λ does not vary

$$R = \frac{\lambda l}{\pi r^2} \qquad\qquad R_1 = \frac{\lambda l_1}{\pi r_1^2}$$

$$\frac{R}{R_1} = \frac{\frac{\lambda l}{\pi r^2}}{\frac{\lambda l_1}{\pi r_1^2}} = \frac{l r_1^2}{l_1 r^2} \qquad (1)$$

The volume being unchanged by the stretching

$$v = \pi r^2 l \qquad \text{also} \qquad v = \pi r_1^2 l_1$$

$$r^2 l = r_1^2 l_1 \qquad \therefore \qquad r_1^2 = r^2 \frac{l}{l_1}$$

Substitute this value in equation (1), —

$$\therefore \qquad \frac{R}{R_1} = \frac{l r^2 l}{l_1 r^2 l_1} = \frac{l^2}{l_1^2}$$

From this we may conclude, that, if the original resistance is to the final resistance in a greater or less ratio than the square of the original length is to the square of the final length, the stress of the particles does alter the specific resistance of the wire. If the ratio of the resistances is greater than the ratio of the squares of the lengths, then the conductivity of the wire is improved.

In the following experiments I used a Thomson's mirror galvanometer with the arrangement of Wheatstone's bridge. I used a wooden bracket attached to a partition of the wall, about 2.5 metres from the floor. I put the wire through a hole in this bracket. and kept it from slipping by driving in a wooden peg. To guard further against slipping, the wire was wound tightly around a screw near the hole. Altogether there was from four to ten centimetres of wire that was not stretched, but whose resistance was taken account of. In the later experiments, this length was taken account of in calculating the resistances. To the lower end of the wire I bound a ring, and on this ring were hung the weights. I connected the ends of the wire with the box of resistance coils by means of thick wires. The resistance of these thick wires was found to be .036 ohms.

Experiment 1. — This experiment was made with copper wire .628 millimetres in diameter. It being the first experiment I made, all the phenomena were not observed. The original and final resistances, and the original and final lengths, I got pretty carefully; but I failed to note the intermediate lengths.

Original length was	1.647 metres.
Final length before breaking	1.857 ,,
Stretched 21 centimetres.	

	Ohms.
Original resistance with connections	.144
Resistance of connecting wires	.036
Original resistance	.108
Final resistance without connecting wires	.134

$\frac{l^2}{l_1^2} = \frac{2.713}{3.45} = .786 \qquad \frac{R}{R_1} = \frac{108}{134} = .804 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$

We should expect R_1 to have been .137. The wire broke under the weight of 16.3 lbs. The weights I used were in lbs., not grammes.

But we have not considered the whole length in considering the change in length; but we have considered the whole length in considering the change in resistance. If we add the same constant to l and l_1, say a, and l_1 is greater than l, then plainly

$$\frac{l^2}{l_1^2} < \frac{(l+a)^2}{(l_1+a)^2}.$$

But more than a may have been added to l_1.

Then, too, if the whole length had been under the stretching process, R_1 might have been greater than it was observed to be. So that the difference of .003 ohms might have been made up, had the whole length been under the stretching process.

In this experiment I measured the final diameter of the wire with the dividing engine, and found that it varied perceptibly in different parts; in one part the mean reading being .593 millimetres, and in another part .56 millimetres. From the deduction given above, it can be seen that we need only consider the lengths and the squares of the lengths. In the following experiments I did not consider the change in diameters.

Experiment 2.— In this experiment I used thin iron wire. 4, 6, 8, and 10 lbs. produced no change in the resistance of the wire, though the length increased slightly. Original resistance was 1.0536 ohms. At first, R was only 1.0584.

10 mm.	$R = 1.068$ ohms.
15 „	$R = 1.0704$ „
20 „	$R = 1.1256$ „
25 „	$R = 1.1304$ „
28 „	$R = 1.1404$ „
30 „	$R = 1.1472$ „

I did not observe the changes in length carefully. At this time, 2 lbs. was the smallest weight I had. On applying fourteen pounds, the wire stretched some; but, when I allowed the whole force to come on, the wire snapped near a place where it was wound. I applied the weight again, and the wire snapped near the middle.

Length of wire before applying 14 lbs. . . . . . . 1.633 metres.
Original length . . . . 1.58 „

$$\frac{l^2}{l_1^2} = \frac{2.496}{2.667} = .927 \qquad \frac{R}{R_1} = \frac{1.0536}{1.1472} = .916$$

Here $\frac{R}{R_1} < \frac{l^2}{l_1^2}$; and it would seem that finally iron has been made a poorer conductor by stretching. As to the intermediate states of the wire, nothing can be inferred. Later I performed another experiment with better results. It was with the same kind of wire. It would seem to show that the conductivity of iron is improved by stretching. I will call it

Experiment 2a. — These are the results: —

l	l^2	R
1.696	2.876	1.104
1.716	2.944	1.1064
1.736	3.014	1.1448
1.766	3.119	1.178

$$\frac{l^2}{l_1^2} = .922 \qquad \frac{R}{R_1} = .937 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$$

We should expect R_1 to have been 1.197.

Experiment 3. — In this experiment I used thin copper wire $\frac{11}{40}$ millimetre in diameter. 2 lbs. produced no change in the resistance, though the length increased 2 centimetres. These are the results: —

l	l^2	R
1.476	2.1786	.3816
1.5	2.25	.3816
1.566	2.452	.3912
1.576	2.484	.4032

It broke under weight 4.3 lbs., and I did not get the final results.

$$\frac{l^2}{l_1^2} = .936 \qquad \frac{R}{R_1} = .946$$

Here $\frac{R}{R_1} > \frac{l^2}{l_1^2}$.

It seems that the conductivity of the wire is improved.

I used the same kind of wire in another experiment, which I will call

Experiment 3a. — The wire stretched in all 31 centimetres, and broke under the full force of 4.3 lbs. The .3 lbs. is the weight of the iron ring.

	l		l^2	R	
	1.81		3.276	.4776	
	1.905		3.629	.5040	
	1.945		3.783	.5280	
	1.955		3.822	.5520	
	1.985		3.94	.5592	
l_o =	2.055	l_o^2	4.223	.6216	R_o
	2.09		4.368	.624	
	2.12		4.474	.6264	

$$\frac{l^2}{l_1^2} = .729 \qquad \frac{R}{R_1} = .769 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$$

See the curve representing the resistance in this experiment. There is a great and rapid change in the resistance when the wire has been stretched 20 centimetres.

$$\frac{l^2}{l_o^2} = \frac{1.81}{2.055} = .775 \qquad \frac{R}{R_o} = \frac{4776}{6216}\ .769$$

Here at this point $\frac{R}{R_o} < \frac{l^2}{l_o^2}$

Experiment 4. — In this experiment I used thicker copper wire, with the following results: —

l	l^2	R
1.70	2.89	.0636
1.72	2.958	.0636
1.75	3.07	.0648
1.757	3.086	.0648
1.825	3.327	.0684
1.85	3.43	.0768
1.875	3.515	.078

$$\frac{l^2}{l_1^2} = \frac{289}{3.5_15} = .822 \qquad \frac{R}{R_1} = \frac{636}{78} = .828 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$$

I tried the same kind of wire again. It stretched considerably before there was any change in the resistance. The original length was 1.65 metres. The final length was 1.82 metres. 23 lbs. broke the wire before I had time to observe the resistance; but, before applying the last pound, the resistance was .076 ohms. The original resistance was .072.

$$\frac{l^2}{l_1^2} = \frac{2.622}{3.312} = .792 \qquad \frac{R}{R_1} = .947 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$$

Experiment 4*b* was with the same kind of wire, with these results: —

l	l^2	R
1.595	2.544	.0648
1.635		.0648
1.665		.0648
1.715		.0648
1.765	3.116	.0648
1.855	3.44	.0820
1.945	3.783	.090
2.	4.	.1008
$\frac{l^2}{l_1^2} = .636$	$\frac{R}{R_1} = 0.642$	$\frac{R}{R_1} > \frac{l^1}{l_1^2}$

26 lbs. broke the wire.

In all these experiments, it is easy to see that the change in resistance at first is not at all proportional to the increase in length. At the close of some of the experiments, the resistance is almost as much as it ought to be; and perhaps, if there were no error in observation or calculation, the resistance at the breaking-point would be as much as the law would make it.

Experiment 5. — This experiment was made with copper wire not so thick as that used in the previous experiment. I measured the total length, and the changes in length; so that, although not the whole length is under the stretching process, the resistances given correspond more exactly to the lengths given.

l	l^2	R
1.71	2.924	.109
1.725	2.965	.1092
1.755	3.08	.1104
1.815	3.294	.1128
1.84	3.385	.1128
1.875	3.516	.114
1.9	3.61	.114
1.91	3.648	.114
1.95	3.8	.1356
1.99	3.98	.138
$\frac{l^2}{l_1^2} = .738$	$\frac{R}{R_1} = .791$	$\frac{R}{R_1} > \frac{l^2}{l_1^2}$

16 lbs. broke the wire. I performed a second experiment with the same kind of wire, and with essentially the same results.

Experiment 6. — I next took German-silver wire. The curve of observations here will be found to almost coincide with the straight line representing the law. This experiment is quite curious when contrasted with the others.

l	l^2	R
1.53	2.34	4.33
1.535	2.356	4.34
1.545	2.387	4.40
1.57	2.465	4.577
1.595	2.544	4.728
1.615	2.608	4.824
1.64	2.69	4.987
1.665	2.772	5.112
1.69	2.856	5.22
1.735	3.01	5.609

$$\frac{l^2}{l_1^2} = .777 \qquad \frac{R}{R_1} = .77$$

Experiment 6*a*. — German-silver wire again.

Original total length	1.70 metres.
Length to be stretched	1.60 ,,
Original total resistance	4.848
Resistance of connecting wires	.036
Resistance of 1.70 metres	4.812
Subtract $\frac{10}{170}$ of this	.283
Resistance of 1.60 metres	4.529

l	l^2	R
1.60	2.56	4.529
1.61	2.592	4.541
1.64	2.689	4.733
1.67	2.789	4.9226
1.70	2.89	5.1386
1.77	3.133	5.5226
1.815	3.294	5.813
1.85	3.42	6.0506
1.885	2.591	6.2858
1.99	3.96	6.9626

$$\frac{l^2}{l_1^2} = .646 \qquad \frac{R}{R_1} = .650 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$$

By examining the curve, it will be seen that it very nearly follows the law, and that the conductivity of the metal is but little altered.

Experiment 7. — This experiment was made with copper wire No. 18.

Original total length	1.62 metres.
Length to be stretched	1.57 ,,

	Ohm.
Original resistance with connecting wires	.3000
Resistance of connecting wires	.036
Resistance of total length	.264
Resistance of length not stretched	.008
Original resistance of length to be stretched . . .	.256

l	l^2	R
1.57	2.465	.256
1.58		.256
1.595		.256
1.6	2.56	.256
1.615	2.608	.2608
1.64	2.69	.2728
1.66	2.7556	.2776
1.69	2.856	.2776
1.725	2.9756	.2992
1.76	3.0976	.3016

$$\frac{l^2}{l_1^2} = \frac{2465}{3097} = .795 \qquad \frac{R}{R_1} = \frac{256}{3016} = .848 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$$

R_1 should have been .322 if the conductivity of the metal had not been altered.

Experiment 8. — Copper wire No. 22.

Original total length	1.57 metres.
Length to be stretched	1.53 „
Resistance with connecting wires	.3048
Resistance of connecting wires	.036
Resistance of total length	.2688
Resistance of length not stretched	.0068
Resistance of wire to be stretched	.2620

l	l^2	R
1.53	2.341	.262
1.55	2.—	.262
1.59		.262
1.62	2.624	.262
1.655	2.739	.3004
1.68	2.822	.3124

$$\frac{l^2}{l_1^2} = .829 \qquad \frac{R}{R_1} = .841 \qquad \frac{R}{R_1} > \frac{l^2}{l_1^2}$$

The wire broke under weight of 5.2 lbs.

R_1 should have been .3161 if there was no change.

Experiment 8*a*. — With copper wire of same size.

Original length	1.56	metres.
Length to be stretched	1.52	,,
Resistance of whole length	.2676	,,
Resistance of length not stretched	.0068	,,
Resistance of wire to be stretched	.2608	,,

l	l^2	R
1.52	2.3104	.2608
1.54	2.3716	.2608
1.56	2.434	.2620
1.58	2.496	.2620
1.6	2.56	.2836
1.63	2 65	.2956
1.655	2.706	.298
1.67	2.789	.310
1.69	2.856	.316
1.705	2.907	.3256

$$\frac{l^2}{l_1^2} = .794 \qquad \frac{R}{R_1} = .8$$

Wire broke under 5.2 lbs.

Experiment 9. — *Copper wire, the finest yet.*

Original total length	1.56
Length to be stretched	1.52
Original total resistance	.780
Resistance of connecting wires, &c.	.055

l	l^2	R
1.52	2.3104	.725
1.535		.725
1.55	2.4025	.725
1.565	2.444	.7298
1.59	2.528	.7538
1.61	2.592	.7766
1.64	2.6896	.8018
1.67	2.789	.8318
1.70	2.89	.8618
1.73	2.993	.8918
1.77	3.133	.9314
1.81	3.276	.971
1.855	3.441	1.006

$$\frac{l^2}{l_1^2} = .671 \qquad \frac{R}{R_1} = .7206$$

If there were no change, R_1 should have been 1.08 ohms. The wire broke under pressure of 2.6 lbs.

From the foregoing experiments, I conclude that the conductivity of German-silver wire remains unaltered by stretching; that the conductivity of iron wire is perhaps improved, and that the conductivity of copper wire is improved, that up to a certain point the wire can be stretched without increasing the resistance, or only increasing the resistance very little; that beyond that point the resistance increases very rapidly for a while, and then increases less rapidly. In most cases, after the wire has been stretched to the point where the resistance ceases to increase rapidly, the resistance appears to increase in such a way, that the ratio $\frac{l_1^2}{R_1}$ remains almost constant.

It appears, then, that copper wire can be stretched to some advantage; that, if it is stretched too much, some of the advantage gained is lost again. Experiments 3*a* and 8*a* are the only instances where the copper wire appears to have lost at any time the full amount of the advantage gained by stretching; but, even in these instances, the wire seems to gain advantage in regard to its conductivity as the stretching goes on.

Thin copper wire being in the process of manufacture, stretched to a great extent, the advantage gained by further stretching is less marked than with thicker wire. It is noteworthy that the wire becomes very brittle before it breaks, and assumes a definite structure like steel wire.

PROCEEDINGS.

Six hundred and eighty-first Meeting.

May 25, 1875. — ANNUAL MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read a letter from Mr. R. C. Winthrop, accepting his appointment as a delegate to the International Congress of Geographical Sciences; and, at his suggestion, Mr. J. I. Bowditch was appointed a second delegate to this Congress.

The Treasurer presented his report, which was accepted, and on his motion it was

Voted, To appropriate for the general expenses of the Academy, during the coming year, twenty-one hundred dollars ($2100).

The Chairman of the Rumford Committee presented his report, which was accepted; and, in accordance with its suggestion, it was

Voted, That an appropriation of fifteen hundred dollars ($1500) be made from the income of the Rumford Fund for the coming year, to finish the publication of Count Rumford's works.

Voted, That the Librarian and Treasurer of the Academy be authorized to sell to each Resident Fellow one, and one only, complete set of Rumford's Works, including the Life, for five dollars, and to settle on this basis the account of those Fellows who have already purchased the earlier volumes.

Voted, That ten complete sets of Rumford's Works, including the Life, be presented to Professor W. R. Nichols, as an acknowledgment of his services to the Academy.

Voted, That the sum of two hundred and ninety-one dollars ($291) be appropriated from the income of the Rumford Fund to cover the cost of publishing the papers on Light and Heat in Volume X. of the Academy's Proceedings.

Voted, That the sum of five hundred dollars ($500) be appropriated from the income of the Rumford Fund, as the said income will permit, to aid Professor John Trowbridge, of Cambridge, in continuing his researches on the improvement of the Magneto-electric Machine and Induction Coil.

Voted, That the Rumford Medal, for the present year, be awarded to Dr. John William Draper, of New York, for his Researches on Radiant Energy.

On the motion of the Corresponding Secretary, it was

Voted, That an appropriation of fifteen hundred dollars ($1500) from the general fund be made to defray the expenses of publication during the year.

Voted, To appoint a committee of five to revise the Statutes of the Academy. The President appointed Messrs. Cooke, Thomas, Washburn, Deane, and Norton, members of this committee.

Voted, To adjourn this meeting to the second Tuesday in June.

The annual election resulted in the choice of the following officers: —

CHARLES FRANCIS ADAMS, *President.*
JOSEPH LOVERING, *Vice-President.*
JOSIAH P. COOKE, JR., *Corresponding Secretary.*
EDWARD C. PICKERING, *Recording Secretary.*
EDMUND QUINCY, *Treasurer and Librarian.*

Council.

John B. Henck, Wolcott Gibbs, Charles W. Eliot, — of Class I.

Alexander Agassiz, John A. Lowell, Benj. E. Cotting, — of Class II.

George E. Ellis, Andrew P. Peabody, Francis Parkman, — of Class III.

Rumford Committee.

Morrill Wyman.
Wolcott Gibbs.
Josiah P. Cooke, Jr.
James B. Francis.
John M. Ordway.
Stephen P. Ruggles.
Edward C. Pickering.

Committee on Finance.

Charles Francis Adams, Edmund Quincy, — *ex officio.*
Thomas T. Bouvé.

The following Committees were appointed on the nomination of the President: —

Committee on Publication.

Alexander Agassiz.
W. W. Goodwin.
John Trowbridge.

Committee on Library.

Charles Deane.
Henry P. Bowditch.
William R. Nichols.

Auditing Committee.

Henry G. Denny.
Robert W. Hooper.

Six hundred and eighty-second Meeting.

June 8, 1875. — ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

The President announced the death of M. Charles de Rémusat, Foreign Honorary Member.

The Corresponding Secretary read a letter from M. Barrande, acknowledging his election into the Academy.

Voted, To adjourn the meeting in August to the second Tuesday in October.

The following papers were presented: —

"On the Hexatomic Compounds of Cobalt." By Dr. Wolcott Gibbs.

"On the Supposed Perchloride of Manganese." By Professor J. P. Cooke, Jr.

"On the Use of Field Instruments in Astronomy." By Professor T. H. Safford.

"On Photographing Spectrum Lines." By Dr. Robert Amory.

"On a Comparison of Prismatic and Diffraction Spectra." By Professor E. C. Pickering.

"On a New Method of Calibration." By Professor E. C. Pickering.

"On a New Instrument for Projecting Lissajou's Curves." By Professor E. C. Pickering.

On the "Theory of Discount in the Game of Billiards." By Professor Benjamin Peirce.

Professor William Watson presented a set of models illustrating his "Descriptive Geometry."

Six hundred and eighty-third Meeting.

October 12, 1875. — ADJOURNED STATED MEETING.

The VICE-PRESIDENT in the chair.

The Vice-President announced the death of Professor Joseph Winlock, and Mr. Chauncey Wright.

The following papers were presented: —

"On a New Property of Conic Sections." By Professor Benjamin Peirce.

"On the Method of Least Squares." By Professor T. H. Safford.

Mr. W. A. Rogers described some further investigations he had made on the lines of Nobert, and presented a paper by M. Trouvelot, "On Veiled Sun-Spots."

The following papers were presented by title: —

"On the Flora of Guadalupe Island." By Sereno Watson.

"Remarks on Magnetic Distribution." By Professor H. A. Rowland.

Six hundred and eighty-fourth Meeting.

November 10, 1875. — STATED MEETING.

The PRESIDENT in the chair.

Mr. W. A. Rogers was appointed Secretary *pro tempore.*

Upon the recommendation of the Council, the following gentlemen were elected members of the Academy: —

Andrew Crombie Ramsay, of London, to be a Foreign Honorary Member in Class II., Section 1, in place of the late Sir Charles Lyell.

Alfred M. Mayer, of Hoboken, to be an Associate Fellow in Class I., Section 3.

Frederick A. Genth, of Philadelphia, to be an Associate Fellow in Class II., Section 1.

Joseph LeConte, of San Francisco, to be an Associate Fellow in Class II., Section 1.

Othniel Charles Marsh, of New Haven, to be an Associate Fellow in Class II., Section 2.

Daniel C. Gilman, of Baltimore, to be an Associate Fellow in Class III., Section 2.

William Sellers, of Philadelphia, to be an Associate Fellow in Class I., Section 4.

Albert Nicholas Arnold, of Hamilton, N. Y., to be an Associate Fellow in Class III., Section 2.

Ira Remsen, of Williamstown, to be a Resident Fellow in Class I., Section 3.

Hiram F. Mills, of Lawrence, to be a Resident Fellow in Class I., Section 4.

Robert Thaxter Edes, of Boston, to be a Resident Fellow in Class II., Section 4.

Henry Adams, of Boston, to be a Resident Fellow in Class III., Section 3.

Professor Cooke announced that the fourth and last volume of Count Rumford's Works had been issued from the press.

Mr. R. C. Winthrop made the following Report: —

It has seemed to me proper, Mr. President, that I should make some brief report of what I did, and of what I left undone, under the commission with which the Academy honored me, some months ago, to represent them at the International Congress of Geography in Paris.

Agreeably to a suggestion which I ventured to make to the Secretary, on receiving my own appointment, Mr. Ingersoll Bowditch, then abroad, was afterwards associated with me in the delegation. But I am sorry to say that neither of us found it practicable to be in Paris during the week in which the sessions were held. For myself, I reached there only on the evening of the day on which they were formally closed. It was an occasion of public ceremonial, which I was sincerely sorry to have missed. I regretted much less that I was unable to attend the opening ceremonies, as they took place on Sunday; and, though I do not care to associate myself with too sanctimonious a sabbatarianism, I have always been offended, when abroad, by the habitual selection of Sunday, particularly in Paris, for spectacles and shows of all sorts. Such a course seems almost like an insult to Protestantism, and might well be the subject of remonstrance where the occasion is not of a local character.

I had reported myself, as a delegate from the Academy, previously to my arrival, and my name had been duly entered on the roll of the Congress. Nothing remained, however, for the members to do, except to make a visit to the Sewers of Paris, — a geographical exploration from which I was willing to excuse myself during the heats of August, — and to pay their respects to the Préfet of the Seine, at a formal reception arranged for that purpose.

This latter service I performed, and found a large and brilliant assembly at the palace of the Luxembourg, quite in Imperial style, notwithstanding the Republican element which has recently entered into the institutions of France. The staircase was lined with *gens d'armes* in uniform, a mounted police guarded the gateways, and one of the regimental bands played national airs within the palace. Nothing could have been more cordial and gracious than the welcome given me as a representative of the American Academy by the Préfet, M. Ferdinand Duval; and I had an opportunity of meeting not a few of the literary and scientific celebrities of France, as well as the delegates from other countries.

The next day I proceeded, with my card of membership, and under the escort of my accomplished friend, Colonel Perraud, to visit the *Exposition Géographique*, which had been arranged in those parts of the palace of the Tuileries which had escaped the torches of the Commune. A marvellous and most multitudinous exposition it was, and one which reflected the highest credit on the Geographical Society of France, under whose auspices it was prepared. I could not have believed it possible that any thing so dry, and so little æsthetic, as geography, could furnish the materials for so really interesting and brilliant a show. It was, indeed, an exhibition of many other things besides such as might be supposed to belong to geography proper. Geology, archæology, ethnology, antiquities of every sort, historic and pre-historic, were gathered there, side by side with maps and memorials of the most recent researches of modern travellers and geographers.

My eye lighted, for instance, on a photographic *fac-simile* of the "Mappamondo di Frà Mauro" of 1459, and on copies or originals of not a few other maps, on which there was no America. It was a relief to turn from these and see, as I did, the beautiful chart, published by our Coast Survey, of Boston Harbor, hanging at the very entrance of the little American department.

I remember seeing, too, the War Map used by the heroic Charles XII. of Sweden, and not far off the manuscript notes and maps of the not less heroic Livingston and Speke and other recent explorers of Africa.

A cast of the wonderful Meteorite of Greenland, weighing (the original) twenty thousand kilos, if I remember right, occupied a whole corner of one apartment. *Fac-similes* of Domesday Book and of the black-letter Prayer Book of 1636 attracted my eye in the English division.

This will give a sufficient indication of the somewhat heterogeneous things which were gathered together from all quarters under the banners of geography, recalling that comprehensive, all-embracing description of Cicero: "Omnes etenim artes quæ ad humanitatem pertinent, habent quoddam commune vinculum, et quasi cognatione quâdam inter se continentur."

The archives of all countries, and the museums of all learned societies, had indeed been made tributary, without reserve, to this exposition; and things old and new had been brought forth from private cabinets and public collections to enrich and adorn it.

But I must not leave the impression that Geography proper, so to speak, was without its full representation. Such an array of globes and maps and photographic illustrations of earth and sea and sky could never have been congregated anywhere before. The Russian department was exceedingly rich, and surpassed all others in the number and perfection of the geographical works with which it was crowded. The Prussian or German department was hardly less striking; while the Austrian, Spanish, Portuguese, Italian, Danish, Norwegian, Dutch, Belgian, and Swiss departments contained many most interesting and valuable contributions. England was hardly there in full force, and the American department was small and poorly supplied.

When I alluded to this, however, as I did with regret, the Préfet of the Seine, with true French politeness, replied, "Yes, but we know you are fitly and fully engrossed with your grand Centennial Exposition at Philadelphia next year, which is well worthy of all your attention; and we shall all be interested in its success."

I lay upon the table a printed Catalogue of this remarkable Exhibition, with a few other pamphlets relating to it, which may give the Academy a better idea of its character than I have been able to convey in these cursory remarks.

Before resuming my seat, however, I may be pardoned for alluding to the monument of Count Rumford, which I visited in company with the American Minister, Mr. Washburne. It received some not very considerable damage from a shell which struck it, or exploded near it, during the siege of Paris. It was understood, before I left Paris, that this Academy had passed a resolution for its repair, and such a measure would be a graceful act to be performed by this or some other American instrumentality. Our Minister was anxious to superintend such a repair, if authority should be given him to do so; and I promised to bring the subject to the renewed consideration of the friends and guardians of Count Rumford's memory.

Professor Cooke presented the report of the committee appointed to revise the Statutes of the Academy, and it was

Voted, To lay this report on the table, and make it the special subject of an adjourned meeting; it was also

Voted, That the Corresponding Secretary be requested to print the report, and distribute it among the Resident Fellows.

Voted, To adjourn this meeting, at its close, to the second Tuesday in December.

The following papers were presented: —

"On the Flora of Guadalupe Island." By Sereno Watson.

"On the Proper Motion of η Draconis." By W. A. Rogers.

Six hundred and eighty-fifth Meeting.

December 14, 1875. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from Messrs. Arnold, Genth, Mayer, and Mills, accepting their election as Fellows of the Academy; also, a letter from Mr. Parkman, declining his election as a member of the Council.

Mr. R. C. Winthrop was elected a member of the Council in place of Mr. Parkman.

The Corresponding Secretary read a petition from the Trustees of the Boston Public Library to the General Government, asking aid toward the publication of a Topical Index of the United States Documents; and it was

Voted, To authorize the President to sign this document in behalf of the Academy.

Dr. Gibbs presented a memorial petitioning Congress to remove the duty on foreign scientific books not in English, Latin, or Greek; and it was

Voted, to authorize the President to sign this memorial.

The report of the committee on the Revision of the Statutes was taken from the table, and its recommendations discussed. But, in accordance with the provisions of the statutes, action was deferred until the next stated meeting.

The following papers were then presented : —

"On the Periodic Changes in Right Ascension." By Mr. W. A. Rogers.

"On the Tempel Nebula in the Pleiades." By Mr. Trouvelot.

"On the Planet Saturn." By Mr. Trouvelot.

"On a New Form of Bunsen Battery." By Dr. Wolcott Gibbs.

"On the Milk Supply of Boston." By Mr. S. P. Sharples.

"On a New Genus of Harpagonella." By Dr. Asa Gray.

Six hundred and eighty-sixth Meeting.

January 11, 1876. — MONTHLY MEETING.

The PRESIDENT in the chair.

The following papers were presented : —

"Improvements in Inland Navigation Resulting from the Introduction of a New System of Movable Dams." By Professor William Watson.

"Description of an Apparatus to Measure Directly the Strain to which the Different Bars of an Iron Lattice Girder are exposed." By Professor William Watson.

"On the so-called Etheric Current." By Professor John Trowbridge.

"On some New Methods of Topographical Surveying." By Professor E. C. Pickering.

Six hundred and eighty-seventh Meeting.

January 26, 1876. — STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from Messrs.

LeConte, Remsen, Edes, and Gilman, accepting their election as Fellows of the Academy.

On the motion of Professor Washburn, it was

Voted, To discharge the committee on Expert Evidence.

The following gentlemen were elected members of the Academy: —

Charles Edward Hamlin, of Cambridge, to be a Resident Fellow in Class II., Section 3.

Edwin Lawrence Godkin, of Cambridge, to be a Resident Fellow in Class III., Section 3.

Thomas Dwight, Jr., of Boston, to be a Resident Fellow in Class II., Section 3.

Conte Federigo Sclopis di Salerano, of Turin, to be a Foreign Honorary Member in Class III., Section 1, in place of the late Charles de Rémusat.

The proposed amendments to the Statutes and Standing Votes of the Academy, by rule laid over from the last stated meeting, were acted on seriatim. With some amendments they were all adopted, and are incorporated in the new draft of the Statutes and Standing Votes printed at the end of this volume in connection with the Report of the Council.

Professor Watson presented the following papers: —

"A Description of the New Machinery and Processes employed to Obtain a Supply of Water for the Inland Navigation of the Champagne District of France."

"Improvements in the Construction of River Locks, and the Saving made in the Prism of Lift by the Use of Oscillating Liquid Columns."

The following papers were presented by title: —

"On the Effect of Thin Plates of Iron as Armatures to Induction Coils." By Professor John Trowbridge.

"On the Action of Methyl Iodide on Plumbic Urate." By Professor H. B. Hill.

A communication from the Boston Society of Civil Engineers on the introduction of the metric system of weights and measures, was referred to a committee consisting of Messrs. Pickering and Watson.

Six hundred and eighty-eighth Meeting.

February 9, 1876. — Monthly Meeting.

Professor Peirce in the chair.

The Corresponding Secretary announced that the Rumford Medal would be ready for presentation to Dr. Draper at the next meeting. He also called attention to the Statutes as revised, copies of which he presented in print.

The following papers were presented: —

"On the Effect of Thin Plates of Iron as Armatures to Induction Coils." By Professor John Trowbridge.

"On a New Form of Mirror Galvanometer." By B. O. Peirce.

"On the Solar Motion and Stellar Distances." By Professor T. H. Safford.

"On some New Forms of Iron Viaducts." By Professor William Watson.

"On two New Machines used in the Construction of Tidal, Coast, and Harbor Works." By Professor Watson.

"On the Occurrence of Odoriferous Glands in the Walking-stick." By Professor S. H. Scudder.

"On the Equal Roots of the Principal Equations of the Circular Perturbations of the Planets as not affecting the Stability of the System." By Professor Benjamin Peirce.

Six hundred and eighty-ninth Meeting.

March 8, 1876. — Stated Meeting.

The Academy met at the house of Mr. John A. Lowell.

The President in the chair.

The Corresponding Secretary read letters from Messrs. Ramsay, Selopis, Godkin, and Adams, accepting their election as members of the Academy.

Voted, To adjourn this meeting at its close to the second Wednesday of April, and to postpone the *stated* business of the meeting until then.

The Chairman of the Rumford Committee then introduced the *special* business of the evening, and handed to the President the Rumford Medals (in gold and silver), on each of which had been engraved the following inscription: "Awarded by the American Academy of Arts and Sciences to John W. Draper, for his Researches on Radiant Energy. May 25th, 1875."

In presenting the medals, the President said: —

Gentlemen of the Academy, — The foundation of this Society, you all know, dates back but four years less than a century. It followed close upon the adoption of the form of government of the State itself. Further than this privilege of a corporation, I am not aware that the State has since bestowed any aid to it whatever. During the long period that has intervened, the individual members have steadily and honestly contributed their labors and their money to the advancement of science and of the arts, the evidence of which is to be found as well in the collections of the library as in the long series of their published transactions. We have not been so lucky as to earn the favor of the generous and wealthy at all in the proportion given to some other institutions of the same general character. In point of fact, we have to ascribe our success more to our own energies than to the assistance of patrons. This is no bad sign for the future. The Academy was never in more healthy and vigorous condition than at this moment. The meetings are constantly attended by numbers who appear to give or to receive with interest the many valuable contributions to knowledge which ultimately take their place in the formidable volumes open to the inspection of the world.

Yet it is not to be understood from what I have said that the institution has been altogether without liberal assistance from several sources. The most remarkable instance of a benefaction was perhaps the earliest, that of Benjamin Thompson, better known under the name of Count Rumford, who, eighty years ago, presented to the Academy the sum of five thousand dollars, to be devoted to the stimulation of the study of the various phenomena connected with light and heat, by the presentation of medals of value as honorary rewards to successful research. It is to the credit of the Academy, in these degenerate days, to find that its administration of this property has fully justified the confidence of the donor, the original sum having increased more than fourfold over and above the cost of the medals which have from time to time been awarded to successful investigation of the great subjects proposed for study and examination.

It now becomes my agreeable duty to announce the fact that, after a careful review of the meritorious services of Professor Draper in this great field of inquiry, the committee having the subject in their charge have, for reasons given by them, recommended through their Chairman, that the medals prescribed in the deed of trust should be presented to him as having fully deserved them. It falls to my lot only to recapitulate in brief some of these reasons.

In 1840 Dr. Draper independently discovered the peculiar phenomena commonly known as Moser's images, which are formed when a medal or coin is placed upon a polished surface of glass or metal. These images remain, as it were, latent, until a vapor is allowed to condense upon the surface, when the image is developed and becomes visible.

At a later period he devised the method of measuring the intensity of the chemical action of light, afterwards perfected and employed by Bunsen and Roscoe in their elaborate investigations. This method consists in exposing to the source of light a mixture of equal volumes of chlorine and hydrogen gases. Combination takes place more or less rapidly, and the intensity of the chemical action of the light is measured by the diminution in volume. No other known method compares with this in accuracy, and most valuable results have been obtained by its use.

In an elaborate investigation, published in 1847, Dr. Draper established experimentally the following important facts: —

1. All solid substances, and probably liquids, become incandescent at the same temperature.

2. The thermometric point at which substances become red-hot is about 977 Fahrenheit degrees.

3. The spectrum of an incandescent solid is continuous; it contains neither bright nor dark fixed lines.

4. From common temperatures nearly up to 977° Fahrenheit, the rays emitted by a solid are invisible. At that temperature they are red, and the heat of the incandescing body being made continuously to increase, other rays are added, increasing in refrangibility as the temperature rises.

5. While the addition of rays, so much the more refrangible as the temperature is higher, is taking place, there is an increase in the intensity of those already existing.

Thirteen years afterward, Kirchhoff published his celebrated memoir on the relations between the coefficients of emission and absorption of bodies for light and heat, in which he established mathematically the same facts, and announced them as new.

Dr. Draper claims, and we believe with justice, to have been the first to apply the daguerreotype process to taking portraits.

Dr. Draper applied ruled glasses and specula to produce spectra for the study of the chemical action of light. The employment of ruled metallic specula for this purpose enabled him to avoid the absorbent action of glass and other transparent media, as well as to establish the points of maximum and minimum intensity with reference to portions of the spectrum defined by their wave lengths. He obtained also the advantage of employing a normal spectrum in place of one which is abnormally condensed at one end and expanded at the other.

We owe to him valuable and original researches on the nature of the rays absorbed in the growth of plants in sunlight. These researches prove that the maximum action is produced by the yellow rays, and they have been fully confirmed by more recent investigations.

We owe to him, further, an elaborate discussion of the chemical action of light, supported in a great measure by his own experiments, and proving conclusively, and, as we believe, for the first time, that rays of all wave lengths are capable of producing chemical changes, and that too little account has hitherto been taken of the nature of the substance in which the decomposition is produced.

Finally, Dr. Draper has recently published researches on the distribution of heat in the spectrum, which are of the highest interest, and which have largely contributed to the advancement of our knowledge of the subject of radiant energy.

And now, in the absence of Dr. Draper, unable at this inclement season to execute a fatiguing journey, it gives me pleasure to recognize you, Mr. Quincy, as his worthy and competent representative.

I pray you, in receiving these two medals on his behalf, in accordance with the terms of the original trust, to assure him, on the part of the Academy, of the high satisfaction taken by all its Fellows in doing honor to those who, like him, take a prominent rank in the advance of science throughout the world.

Mr. Quincy, on receiving the medals, said: —

Mr. President, — In the name and on the behalf of Dr. Draper I have the honor to receive the Rumford Medals in gold and silver, which the Academy has been pleased to award to him, and I will have them safely conveyed to him to-morrow, together with the assurances of the satisfaction of the Academy in this action which you wish me to communicate to him. In common with yourself, Sir, and all the Fellows present, I regret that that eminent person is unable to attend this meeting and receive the medals himself. And, personally, I regret the absence of Dr. Wolcott Gibbs, who had promised to perform this grateful service for his friend, and who would have been able to make a more suitable reply to the able discourse with which you have accompanied the presentation of the medals, and to have done more justice to the claims of Dr. Draper to this distinction than I can pretend to do. Dr. Gibbs having also been unavoidably prevented from being present this evening, I have now the honor to read a communication from Dr. Draper to the Academy, in acknowledgment of this testimony to his services to science.

Mr. Quincy then read the following letter: —

To the American Academy of Arts and Sciences.

Your favorable appreciation of my Researches on Radiations, expressed to-day by the award of the Rumford Medal, the highest testimonial of approbation that American science has to bestow on those who have devoted themselves to the enlargement of knowledge, is to me a most acceptable return for the attention I have given to that subject through a period of more than forty years, and I deeply regret that through ill-health I am unable to receive it in person.

Sir David Brewster, to whom science is under so many obligations for the discoveries he made, once said to me that the solar spectrum is a world in itself, and that the study of it will never be completed. His remark is perfectly just.

But the spectrum is only a single manifestation of that infinite ether which makes known to us the presence of the universe, and in which whatever exists — if I may be permitted to say so — lives and moves and has its being.

What object, then, can be offered to us more worthy of contemplation than the attributes of this intermedium between ourselves and the outer world?

Its existence, the modes of motion through it, its transverse vibrations, their creation of the ideas of light and colors in the mind, the interferences of its waves, polarization, the conception of radiations and their physical and chemical effects, — these have occupied the thoughts of men of the highest order. The observational powers of science have been greatly extended through the consequent invention of those grand instruments, the telescope, the microscope, the spectrometer. Through these we have obtained more majestic views of the nature of the universe. Through these we are able to contemplate the structure and genesis of other systems of worlds, and are gathering information as to the chemical constitution and history of the stars.

In this noble advancement of science you, through some of your members, have taken no inconspicuous part. It adds impressively to the honor you have this day conferred on me, that your action is the deliberate determination of competent, severe, impartial judges. I cannot adequately express my feelings of gratitude in such a presence, publicly pronouncing its approval on what I have done.

I am, gentlemen, very truly yours,

John W. Draper.

Professor Watson gave an account of an excursion upon the Marne, with a description of the drum-weirs and river-gates for inland navigation.

Professor Cooke exhibited the radiometer of Professor Crookes, and gave the results of some experiments he had made with it.

Professor William Everett presented a communication on the sources of the Nile. He first called attention to the fact that the wonderful extension of our knowledge in the last few years on this subject had come from explorations directed *from the south*, rather than from the direction of Egypt. In connection with these expeditions, attention had again been directed to earlier discoveries. The veracity of the Portuguese explorers had been attested, and the value of some of the very earliest accounts reasserted. Dr. Livingstone especially had dwelt with great confidence — probably too great — on Herodotus's view of the Nile sources. But a still earlier writer than Herodotus had not received due attention. In the Prometheus of Æschylus, lines 800–815, the wanderings of Io are described with some vagueness, it is true, but in terms which appeared to Professor Everett to indicate a journey to the extreme east, afterwards tending to the south, and approaching Africa from the south-east by a certain *Ποταμὸς Αἰθίοψ*, which he believed to be the Zambesi. The course is then directed along the shore of this, as in Livingstone's second expedition; the central plateau is then entered, as in his last; and the upper falls of the Nile are visited, — as by Speke and Baker, — where it descends *Βυβλίνων ὀρῶν ἄπο,* which Professor Everett thought indicated the vast reaches overgrown by the Byblus reed, so prominently noticed by Sir Samuel Baker.

The date of the Prometheus is approximately 472 before Christ.

Attention was also called to the verifications of the Homeric geography, given by Mr. Gladstone in 1858, and since more accurately worked out in Germany.

Six hundred and ninetieth Meeting.

April 12, 1876. — Adjourned Stated Meeting.

The Vice-President in the chair.

The Corresponding Secretary read letters from Messrs. Hamlin and Marsh, accepting their election as members of the Academy; also, a letter from Mr. E. A. Thompson, of North Woburn, asking aid in securing the house of Count Rumford for public purposes. It was

Voted, To present to the North Woburn Literary Association a copy of the "Life and Works of Count Rumford."

The following gentlemen were elected into the Academy: —

John Langdon Sibley, of Cambridge, to be Resident Fellow in Class III., Section 2.

Henry A. Rowland, of Baltimore, to be an Associate Fellow in Class I., Section 3.

Balfour Stewart, of Manchester, to be a Foreign Honorary Member in Class I., Section 3.

On the recommendation of the Rumford Committee, it was

Voted, To allow the Associate Fellows to purchase copies of the "Life and Works of Count Rumford" at the same rate as the Resident Fellows.

The committee appointed to consider the memorial of the Boston Society of Civil Engineers, regarding the introduction of the metric system, reported, recommending that the President be authorized to sign this memorial. After considerable discussion, it was

Voted, To indefinitely postpone this subject.

The following papers were presented: —

"On George B. Grant's Calculating Machine." By William A. Rogers.

"On the Methods and Precision of Meridian Observations." By Truman H. Safford.

"On a New Form of Induction Apparatus." By Henry P. Bowditch.

"On the Binary System of Arithmetic." By Benjamin Peirce.

Six hundred and ninety-first Meeting.

May 10, 1870. — Monthly Meeting.

The President in the chair.

The Corresponding Secretary read a letter from Mr. J. L. Sibley, acknowledging his election into the Academy.

The Corresponding Secretary presented the Annual Report of the Council, which was accepted, and is hereto appended.

The following papers were presented: —

"Some Formulæ relating to the Motions of Planets and Comets." By T. H. Safford.

"On the Three Brombenzylbromides." By C. L. Jackson.

"On Telegraphing Musical Sounds." By A. G. Bell.

"On the Perturbations of Uranus by Neptune." By Benjamin Peirce.

Professor Pickering presented the following papers: —

"On the Intensity of Sound." By W. W. Jacques.

"On the Diffraction of Sound." By W. W. Jacques.

Professor Trowbridge presented the following papers by title: —

"On the Change in Conductivity of Copper Wires resulting from Stretching." By G. S. Pine.

"On the Distribution of Magnetism on Armatures." By Harold Whiting.

Dr. Robert Amory exhibited some photographs which he had taken of the Solar Spectrum, in which the D line was for the first time distinctly represented.

REPORT OF THE COUNCIL.

Since the last Report, May 11, 1874, the Academy has lost by death twelve members, as follows: five Fellows, John Henry Clifford, Horatio B. Hackett, Joel Parker, Joseph Winlock, and Chauncey Wright; three Associate Fellows, Horace Binney, Sir William Logan, and William Sweetser; four Foreign Honorary Members, Gabriel Andral, Gino Capponi, Charles de Rémusat, and Sir Charles Wheatstone. During the year, the Council have also, and for the first time, received notice of the death of Eyries, the Duke di Serradifalco, and De Macedo, three Foreign Honorary Members whose decease took place several years since.

JOHN HENRY CLIFFORD.

The Honorable John Henry Clifford was born at Providence, Rhode Island, on the 16th of January, 1809, and was graduated at Brown University in 1827. He studied law in Massachusetts, was admitted to the Bar of Bristol County in 1830, and was a resident of New Bedford until his death. In 1835, he entered the Legislature of Massachusetts, as a Representative of New Bedford, and was a member of the committee for the revision of the Statutes. In 1839, he was appointed District Attorney for the Southern District of Massachusetts, and served the Commonwealth in that capacity for ten years. In 1845, he was elected to the Senate of the State; and, in 1849, he became Attorney-General of the Commonwealth, and was continued in that office for four years. During this period, he acquired wide distinction for his management of the prosecution and conviction of Professor Webster. In 1853, he was elected Governor of Massachusetts, and discharged the duties of that office with great ability. He declined a re-election, however, and again assumed the office of Attorney-General, by the appointment of Governor Washburn, and afterwards by the election, successively, of the Legislature and of the people. In 1862, he re-entered the Senate of Massachusetts, and was President of that body. In 1867, he accepted the position of President of the Boston and Providence Railroad Company, and devoted himself mainly to business pursuits for the remainder of his life.

In 1874, the appointment of United States Minister to Russia was offered to him by President Grant, and afterwards that to Turkey; but he declined them both. He was for many years one of the Overseers of Harvard University, and President of that Board; and, as one of the Trustees of Mr. George Peabody's great Education Fund for the Southern States, he had become known far beyond the limits of his own State.

In 1875, he made a visit to Europe for the benefit of his own health and that of his family; but soon after his return home he was struck down by fatal illness, and died on the 2d of January, 1876, in the sixty-seventh year of his age.

Governor Clifford was a man of marked ability, and in every station which he held he exhibited peculiar capacity for public usefulness. Few men of our time have left their names on the records of Massachusetts more distinctly or more enviably. He was genial, warm-hearted, public-spirited, patriotic, and greatly endeared to his friends in all parts of the country. His death was the occasion of widespread sorrow, and his memory will long be cherished as that of a Christian gentleman, whose character and whole career had reflected the highest honor on New England.

HORATIO BALCH HACKETT.

Horatio Balch Hackett died very suddenly in Rochester, N.Y., November 2, 1875. He was born in Salisbury, Mass., in the year 1808. He fitted for Amherst College at Phillips Academy, in Andover, where he distinguished himself as a scholar; and his oration, on leaving that institution, was of such marked merit, that it led one of the Trustees to offer to defray the expenses of his college course. He entered Amherst College in 1826, and was graduated with its highest honors in 1830. He completed the regular course of theological studies in Andover in 1834, after which he went to Germany, and studied for some time at Halle and Berlin. On his return, he spent one year as a

Tutor in Amherst College, and was then chosen Professor of Ancient Languages in Brown University, in Providence, R I. After four years (1835–39), he was invited to fill the chair of Biblical Literature in the Newton Theological Institution. He occupied this position until 1869; and, after spending one year in the service of the American Bible Union, he accepted the appointment of Professor of Biblical Literature in the Rochester Theological Seminary, which position he occupied at the time of his death. He was also for several of the last years of his life a member of the American Committee for the revision of the English Scriptures.

In 1851–52, Dr. Hackett travelled in Italy, Egypt, Palestine, and other countries. In 1858–59, he resided several months in Athens, for the purpose of studying Modern Greek, as auxiliary to the interpretation of the New Testament.

As a scholar, he was both comprehensive and exact. As a teacher, he combined in rare union the minutest accuracy in details with the most fervid enthusiasm. His love of truth was intense, his devotion to sacred literature absorbing, his industry unsurpassed, and his mind remarkably free from theological and other prepossessions. His comprehensive and exact classical scholarship was coupled with an unusual mastery of pure, perspicuous, and picturesque English, and his modesty was equal to his learning.

His published works are an edition of Plutarch's "De Sera Numinis Vindicta," with notes, Andover, 1844, afterwards republished with additional notes, as the joint work of himself and Professor Tyler, of Amherst; a Translation of Winer's Chaldee Grammar, with additions, 1845; a Hebrew Reader, 1847; a Commentary on the Book of Acts, 1851, republished with considerable enlargement in 1858; Illustrations of Scripture, suggested by a Tour through the Holy Land, 1855, which has passed through several editions, and been reprinted in England and Scotland, and is his principal work; Memorials of the War, a volume comprising brief notices of Christian heroes who fell in the service of their country during the civil war; the Epistle of Paul to Philemon, a new Translation with notes for the American Bible Union; an American Edition of Smith's Dictionary of the Bible, with many additions and improvements, of which Dr. Ezra Abbot, of Cambridge, was a joint editor; and, lastly, many valuable articles contributed from time to time to the Christian Review, and the Bibliotheca Sacra.

JOEL PARKER.

The limited space within which the Academy is obliged to confine the notices of its departed members, in the published volumes of its Proceedings, gives but little opportunity to do justice to the memory of the Hon. Joel Parker, of Cambridge, whose death occurred August 17, 1875, at the age of eighty years.

He became a Fellow of the Academy February 1, 1853.

He was born in Jaffrey, N.H., January 25, 1795, the youngest of nine children of the Hon. Abel Parker, who was for many years Judge of Probate for the County of Cheshire. He was prepared for Dartmouth College at Groton Academy, and graduated in 1811, being then less than seventeen years of age. Among his classmates were Amos Kendall, and Chief Justice Shepley, of Maine. He was admitted to the Bar of Cheshire County in October, 1817, and entered upon the practice of the law in Keene, which, with the exception of about a year, was his place of residence till his removal to Cambridge, in 1848. After a career of distinguished success at the Bar, and a service of two years in the Legislature of that State, he was appointed a Judge of the Superior Court of New Hampshire in 1833, and to the place of its Chief Justice in 1838. He held judicial office with great acceptance to the Bar and the public till 1848, when, having been invited to the Royall Professorship in the Harvard Law School, he resigned his place upon the bench, and entered upon the duties of his new appointment. He held this office till 1868, when he resigned it, and from 1868 to 1874, without changing his residence, he gave courses of lectures as a Professor of Law to the Senior Class in Dartmouth College, upon the Constitution of the United States. He also lectured upon the same subject to the members of the Columbian Law School in Washington. He was a professor of Medical Jurisprudence in the Medical School of the last-named institution from 1847 to 1857. He had previously lectured on the same subject in 1851 in the Boylston Medical School, and in the Medical College in New York. His public services, after removing to Cambridge, aside from his duties as a professor and lecturer, consisted of a membership of the Constitutional Convention of Massachusetts in 1853, and an active part in the revision of the statutes of that State, to which he was appointed in 1855. Among the indications of the estimate in which he was held as a jurist and scholar, may be mentioned the degree of LL.D., which was conferred upon him by his *Alma Mater* in 1837, and by Harvard College in 1848. He was also a member of the Massachusetts Historical Society.

Though a close and earnest student all his life, and constantly busy with his pen, unfortunately for the permanency of his fame as an author, he left no considerable work upon any one topic, which is the more to be regretted, when what he did leave shows such unquestionable ability to do ample justice to any subject which he might have undertaken. His legal opinions, as a judge, extend through thirteen volumes of the New Hampshire Reports, and will be lasting memorials of his learning, diligence, judicial acumen, and independent judgment. Many of them were upon new and important questions, and evince a remarkable skill at analysis and profound discrimination, which were marked characteristics of his mind. Among them will be found the memorable discussion of certain questions growing out of the construction to be given to the word "lien," made use of in the United States Bankrupt Law of 1841, upon which Judge Story had given able and elaborate opinions, which he proposed to enforce in opposition to those entertained by Chief Justice Parker. It is sufficient for the purposes of this notice to say that, upon the final determination of these questions by the Supreme Court of the United States, the positions assumed by Judge Parker, and which he was equally resolute with his distinguished antagonist to maintain, were fully sustained. His publications, aside from his judicial opinions, consisted of lectures, addresses, literary and historical, and essays and discussions upon questions of constitutional law, which, if collected, would form a large volume replete with learning and profound thought, suited as well to the future as to the then condition of the country which called them out. No one who should read them would need to be told that he was not only a bold and independent thinker, but that he never temporized in his course where he thought public duty led the way.

If, now, we pass from a consideration of his public life to the qualities for which he was distinguished within the precincts of his own home, it may be remarked that his wife, who survives him, was the daughter of Elijah Parker, Esq., his former professional partner. They had three children, of whom a son and a daughter now survive him. With all his habits of close and severe thought and study in the performance of his official duties, he was eminently domestic in his tastes and occupations. He loved to make his home pleasant by its surroundings. He indulged in the culture of flowers, the reading of his favorite poets, and the free and familiar converse with his family and friends, characterized, as it often was, by a vein of genial and playful humor which broke down every thing like stiffness or reserve in his intercourse in domestic life.

As a judge, he was courteous, patient, and willing to listen attentively, and to weigh candidly whatever was addressed to his judgment, bringing to his conclusions the processes of close reasoning and careful analysis, which were among the leading characteristics of his mind.

As an instructor in law, he was thorough in his preparation, clear in his statements, without any attempt at rhetoric or fine composition, leaving upon the minds of his pupils definite and lasting impressions of the propositions which it was his purpose to enforce. Hundreds, who are now among the leading minds at the American bar, would bear willing testimony to his fidelity as a teacher, as well as the courtesy and urbanity which marked his intercourse with those who sought his instruction or counsel.

In the social intercourse of life, he was dignified without coldness, often playful, but never frivolous, with easy and agreeable manners, and a mind well stocked with general information and ready resources. He was not hasty in forming his opinions; but, when formed, he had no hesitancy in avowing and maintaining them. So far as these related to questions which grew out of the unhappy civil war in which the country was engaged, it is enough to say that he stood boldly and manfully for the Constitution in its integrity, by applying to it a higher test than the expediency of the hour.

With such qualities of mind, and such habits of keen and careful observation and investigation as he brought to every subject with which he engaged, he would have been eminent in any of the departments of science into which the Academy is divided. Horticulture was with him a study and a delight; but his pursuits were chiefly connected with literature, and the profession he had chosen.

He was much at home with the early history of New England and her institutions, and contributed several valuable articles upon subjects connected with these, which are among his published works.

He was true to the last in his fidelity to his Alma Mater. He was of her Board of Trustees from 1843 to 1860; and, at his death, remembered her together with the interests of the science to which his life had been devoted, by a liberal benefaction for founding a law school in that institution.

Although enough has been shown to claim for Judge Parker an honorable place among the men who have helped to mark the passing century, it is a fitting tribute for the Academy to pay to the memory of one of her distinguished sons, to place upon her own record some of the grounds upon which, when living, he commanded the respect and esteem of his associate Fellows.

JOSEPH WINLOCK.

Professor Joseph Winlock was born in Shelby County, Kentucky, on February 6, 1826. He died, suddenly, at Cambridge, Mass., in all the strength of his manhood, and at the height of his usefulness, on June 11, 1875. The day before that of his death, he was at his usual work, with no warning of his impending fate except from a sense of increasing lassitude which he had felt for several weeks.

His grandfather, a Virginian by birth, was General Joseph Winlock, who joined the American army, at the outbreak of the Revolution, when he was only eighteen years of age. He served at first as a private, and was afterwards promoted to the rank of ensign, lieutenant, and captain. He was engaged in the battles of Germantown, Brandywine, Monmouth, &c., and was with Washington at Valley Forge. In 1787, he married Miss Stephenson of Virginia, and settled in Kentucky, where he was employed in surveying and entering land. He was sent to the Convention which framed the Constitution of Kentucky, and, afterwards, for some years to the State Senate. He commanded the troops of the State which were ordered out to intercept the expedition of Aaron Burr in 1806. In the War of 1812, he held the rank of Brigadier-General, and went with three regiments to Vincennes.

His son, Fielding Winlock, the father of Professor Winlock, was born in Kentucky on May 4, 1787. He studied law, at first in the office of Felix Grundy, and, after Mr. Grundy's removal to Nashville, in the office of Henry Clay. During the preparations for the War of 1812, he was clerk of the committee of the State Senate on military affairs, performing also many of the duties of Adjutant-General. He left this position to serve in the army as aid to his father, and, in the campaign which ended with the defeat of Proctor and Tecumseh, on General Shelby's staff. After the war he held, at different times, various places of honor and trust, and died at the advanced age of eighty-five.

Professor Winlock was educated at Shelby College, Kentucky, where he graduated in 1845. At this early age his tastes and acquirements were conspicuous; and he received immediately the appointment of Professor of Mathematics and Astronomy in that institution. He devoted his first savings to the purchase of a set of the *Astronomische Nachrichten;* and, in order to be able to read it, he rose early in the morning to talk German with a rude laborer upon his father's farm, before the day's work began. Fortunately for himself and for science, he attended the fifth meeting of the American Association for the Advancement of Science, which was held at Cincinnati in the spring of 1851. It is not among the least of the advantages of this association that it brings into notice young men of promise who might otherwise live and die in obscurity, revealing to themselves as well as to others, by comparison, their rare intellectual endowments. In this case, the chief of American mathematicians recognized, in the Kentucky professor, one who had mastered and enjoyed his own highly condensed treatises, however distasteful they may have been to commonplace students and teachers. This happy conjunction of kindred minds resulted in bringing Mr. Winlock to Cambridge in 1852. Cambridge was, at that time, the headquarters of the American Ephemeris and Nautical Almanac; a great work, ordered by Congress in the Act of March 3, 1849, and placed under the superintendence of Lieutenant (now Admiral) C. H. Davis. Mr. Winlock joined the able corps of computers, on whose ability and fidelity the life of the Almanac depended, and remained in this service until 1857, when he was appointed Professor of Mathematics in the United States Naval Observatory at Washington. He had been in this new position for only a short time when he was made Superintendent of the Ephemeris and Almanac, and returned to Cambridge.

He vacated this post in 1859, and removed to Annapolis, where he had charge of the mathematical department in the United States Naval Academy. Soon after the removal of the Academy to Newport, in consequence of the war of secession, he was again made Superintendent of the Ephemeris and Almanac, and lived in Cambridge. During his long though interrupted connection with this national work, which has contributed largely to the cultivation as well as to the credit of mathematics and astronomy in this country, he made many valuable contributions to it, among which his carefully prepared Tables of Mercury was the most important.

In 1866, with no effort on his part, he received the appointment of Phillips Professor of Astronomy in Harvard College, and Director of the Observatory. To his titles was afterwards added that of Professor of Geodesy in the Lawrence and Mining Schools of the College. While he was Professor at Shelby College, he had made himself familiar with the construction and manipulation of the equatorial telescope. An excellent Merz instrument of this description, having a focal length of 9½ feet and an aperture of 7½ inches, was the property of that institution, and was afterwards borrowed by Mr. Winlock, and mounted at Cambridge, for a time, for his private use. With this exception, his scientific labors had been exclusively in the way of the higher mathematics, either as teacher or computer. It was not until he was relieved from the work of routine, and became Director of the Observatory at Harvard College, that he had an opportunity to develop and manifest his remarkable mechanical ingenuity and genius for invention. An ample and deserved tribute is paid to the memory and the services of the two lamented Bonds (the father and the son), when it is remembered that their lives, consecrated to astronomy, founded the Observatory, and won for it the sympathy and support of the community. Affection for them, and respect for their disinterested zeal, inspired the liberal endowments which strengthened its early growth. Because the men were there, the institution was born and lived. The buildings and equipments of the Observatory, under its first directors, put to shame many similar establishments in Europe. The possession of a magnificent refractor, equatorially mounted, approached by a skilfully devised observer's chair, and accommodated under an immense dome which was moved with marvellous ease, contrasted favorably with deficiencies in instruments and machinery at older observatories, and gave to the one at Cambridge, at once, a name and a rank among the best in the world. With delicacy and disinterestedness of feeling, eminently characteristic of Mr. Winlock, his first thought, on assuming the duties of Director, was for the reputation of his predecessors, with which the reputation of the Observatory was intimately associated. As rapidly as the resources of the Observatory permitted, he provided for the reduction and publication of their unfinished work. Thus the Annals of the Observatory have been enriched by a volume on Sun-Spots, and others on a catalogue of Zone-Stars. Another is yet to appear containing a catalogue of Polar and Clock Stars.

But it was impossible for the Observatory to maintain its high standing and remain stationary, while the old observatories elsewhere were remodelled, refurnished, and prepared to start upon a new career; and young observatories, richly appointed, were springing up in both hemispheres. The inventory of instruments, at the disposal of the Bonds, comprised the large equatorial, a five-foot equatorial, a four-foot transit-circle, a Bond clock and chronograph, two chronometers, and a set of Lloyd magnetometers for obtaining the elements of the earth's magnetism. During the nine years of Mr. Winlock's vigorous administration, the instrumental appliances of the Observatory were strengthened in all directions. A seven-foot equatorial by Clark, another Bond chronograph, a Bond standard-clock with break-circuit attachment for transmitting time-signals, a Frodsham sidereal clock, a Frodsham *break-circuit* sidereal chronometer (the original device of Mr. Winlock), a mean-time chronometer, a thermometric chronometer, a photographic telescope of long focus, a Russian transit, made in the workshop of the Pulkowa Observatory, a Zöllner astrophotometer, a large Ruhmkorff coil, various spectroscopes and self-recording meteorological instruments, — all this rapid increase of resources, while it added to the power, greatly multiplied the responsibilities of the Director. The costly transit-circle, though constructed upon the best models and by the most excellent artists, had always proved a failure and a disappointment; as Mr. Bond supposed, from fatal injuries which it received in its transportation. Though it was useful as a transit-instrument, implicit reliance could not be placed in it as a circle. The consequence was, that the great equatorial was too frequently called away from its legitimate work to do the duties which belonged properly to the circle. Mr. Winlock was not long in inspiring the friends of the Observatory with that large measure of confidence in his capacities and his sound judgment which prompted them to contribute over $12,000 for the purchase of a new meridian circle. In the autumn of 1867, Mr. Winlock went to Europe, and spent four months in visiting the principal observatories, and acquainting himself with the latest improvements in instruments, and especially in circles. Having studied the advantages and the defects in the highest class of meridian instruments, he blindly copied no one of them; but suggested valuable modifications, with the view of securing greater stability, increased precision of movement, and the most complete facility of observation. The improvements which he suggested were warmly approved and promptly adopted by the artists whom he preferred, Troughton and Simms of London; his modifications of the old construction have been fully justified by the results since the new circle has been put to work, and other astronomers have given the best indorsement by copying them. The eminent astronomer and mathematician, J. C. Adams, now President of the Royal Astronomical Society, ordered a circle from the same artists and of the same pattern for Cambridge, in England. In November, 1870, when the new instrument was ready for use, Mr. Winlock turned it upon the zone of stars between 50° and 55° of north declination. When the whole field of observation was divided between the different members of the *Astronomische Gesellschaft*, this was the share which fell to the Observatory of Harvard College. Already 15,000 observations have been made upon the zone-stars, and in two years more the great work will be completed. In 1867, Mr. Winlock had directed a series of observations with the old meridian circle for the purpose of obtaining an extended list of accurately placed time-stars. The utility of a larger catalogue of time-stars had been evidenced in the operations for the determination of longitude conducted by the United States Coast Survey, of which Mr. Winlock was consulting astronomer. These observations, which assigned exact places to stars only two minutes apart in right-ascension, but differing widely in declination, were finished in December, 1868, and have been reduced and printed. In 1871–72, the same stars were reobserved with the new circle, and again for the third and fourth times in 1874 and 1875. An additional set of stars is required for the instrumental constants, expressing errors in azimuth, collimation, level, &c. For this purpose 5,000 observations were made with the new circle in 1873 and 1874, intended to serve as the basis of an improved catalogue of polar stars, and they are now ready for publication. Therefore, no time has been wasted in reaping the full benefits of the new instrument, although the 30,000 observations already made with it are only the first-fruits of the happy devices of Mr. Winlock. These materials, to which must be added a catalogue of new double-stars, dissected by the great refractor, and a most laborious and exhaustive work upon stellar photometry, will magnify the forthcoming volume of the Annals of the Observatory, and be a worthy monument to the skill and perseverance of the Director and his gifted and faithful coadjutors.

In 1869, Mr. Winlock was instructed by Professor Benjamin Peirce, then Superintendent of the United States Coast Survey, to proceed to Kentucky at the head of a party destined to co-operate with officers of the survey in observing the total eclipse of the sun, on the 7th of August. Mr. Winlock gave his attention, particularly, to the physical aspects of the eclipse, examining the photosphere and the chromosphere with the spectroscope, and taking eighty photographs of the eclipse, in all its phases, seven of them during totality. It was his habit to think out every subject which engaged him for himself; and, when he acted, he seldom followed in the wake of other men. He found good reasons for rejecting the method of photographing which had been tried in Spain on occasion of the total eclipse of 1860, and which other American astronomers were preparing to imitate in 1869. As he wished, most of all, to secure a good picture of the corona, he placed the sensitive plates at the focus of the object-glass, thereby economizing the light, and avoiding the distortion by the eye-piece. His success was highly satisfactory. In the best of the pictures, he immediately recognized the fact that the corona was broader in the direction of the sun's equator than along the axis. He had arranged for obtaining numerous views of the partial phases of the eclipse, in the hope of extracting from them valuable information as to the use of photography in observing the transits of Venus. To this end, he was afterwards authorized by the Superintendent of the Coast Survey to engage Messrs. Alvan Clark and Sons to construct a micrometer, adapted to the nice measurement of distances and positions on the photographic plates. The Annals of the Observatory will contain a description and engraving of this micrometer, and an account of the measures made with it, with various representations of the eclipse copied from the photographs.

At this time, no one except Mr. Winlock had succeeded in obtaining a photograph of the corona during any solar eclipse. Although his photographs were only $\frac{3}{4}$ of an inch in diameter, they seemed to promise measurements, made under a microscope, which would compare favorably with the best that could be furnished by meridian instruments. A larger image would be still better; but this required a telescope of formidable length, and difficult to manipulate. To surmount this obstacle, Mr. Winlock conceived the idea of a horizontal telescope, to be fed by the light from a heliostat. He was convinced that a transparent reflector would be better than a silvered mirror, as it would weaken the light, and supersede the necessity of making the time of exposure inconveniently short. Moreover, as the instantaneous action of the light was often sufficient, the heliostat was unnecessary. Soon after his return from Kentucky he gave an order to the Messrs. Clark and Sons for a lens of four inches in aperture and forty feet in focal length, which, after some preliminary trials at their shop, was ready for use at the Observatory in July, 1870; and, since then, has been in constant employment for procuring photographs of the sun. The lens is mounted upon one pier, the reflector upon another, and the camera upon a third pier. The tube used for excluding the daylight is disconnected from the essential parts, so as not to disturb their stability.

At the request of the Superintendent of the United States Coast Survey, Mr. Winlock organized and directed one of the parties sent to the south of Europe to observe the total eclipse of the sun on December 22, 1870. He selected Jerez de la Frontera, near Cadiz, as a favorable station, and was assisted by one experienced officer of the survey, by several eminent astronomers and physicists, and by one of his own staff at the Observatory. Among the physical and astronomical instruments which he prepared for this expedition was a lens of $32\frac{1}{2}$ feet in focal length, to be used in the manner just described for instantaneous photographs. At this time, Mr. Winlock's method was widely known and highly appreciated, and every party which went into the field to observe this eclipse had decided to dispense with an eye-piece, and photograph in the focus of the object-glass. Unfortunately all the parties, European and American, failed, by reason of bad weather, in obtaining a picture of the corona, except the party in Spain; and there, also, the sky was not favorable for the best results. All the observers who went to India to photograph the total eclipse of 1871 preferred the same method, and were successful. Lord Lindsay applied it at the Mauritius in connection with the horizontal telescope. A telescope of long focus is not a new thing; a telescope placed upon the ground is not a new thing; there is no novelty about the heliostat; more than one person may have discovered the advantage in photographing which belongs to telescopes of great focal length. Nevertheless, the adaptation to photographic purposes of a telescope of long focus, fixed horizontally, and used without an eye-piece or a heliostat, is original, and whatever merit there is in it belongs to Mr. Winlock.

In a former generation, an eclipse of the sun excited the interest of astronomers, as furnishing the means of verifying or correcting the dynamical theory, or giving differences of geographical longitude. It is the consolation of science, that as fast as old fields are exhausted new ones call loudly for cultivation. As soon as one question is settled and curiosity flags, another problem springs into life and a fresh interest is born. The old ambition to fit out a comet with its orbit has yielded to the passion for knowing more about its physical changes and constitution. Now that the law of gravitation asserts an unchallenged supremacy in the solar system, the complex structure of the sun and the origin of the solar radiations claim a share of the astronomer's attention. In this way physical astronomy has acquired a new meaning; and a physical as distinguished from an astronomical observatory, either under the same or an independent superintendence, is one of the necessities of to-day's astronomy. It has been largely in the interest of physical astronomy, in this new sense, that observers have traversed continents, crossed oceans, and taken up their quarters in desolate islands, wherever a total eclipse of the sun or the transit of Venus has invited them. Where special physical observatories have not been started, the old observatories must assume their work, but not to the prejudice of the preferred duties of an astronomical observatory. Mr. Winlock gave a liberal portion of his time to celestial spectroscopy, and stocked the Observatory with the requisite instruments, and of the best class. These little instruments divided with the larger ones the benefits of his inventive spirit. In his two eclipse expeditions, he provided abundantly for the spectroscopic examination of the sun's surroundings, catching the sun itself in the reversal of the lines, and witnessing other interesting transformations. The secret of his success lies in the direction of his rule of having a definite idea of what he wished to do, and the best way of doing it, before going into the field. He went to Spain with the purpose of studying especially that fainter portion of the sun's corona which is outside the limits of the best photography. His experience in the Kentucky expedition had taught him that much valuable time is lost in the brief duration of totality, when the position of the dark or bright lines is registered by means of a scale which must be read and recorded at the time. To meet this difficulty, he invented the simple expedient of graving corresponding lines upon a silver plate, previously graduated by a few standard spectral lines. The differences could be leisurely measured at some future time. This improvement was promptly adopted by the English astronomers, and applied by them to the eclipse of 1870. Mr. Winlock was of opinion that his contrivance would be useful in observing the spectra of comets and nebulæ, and wherever the lines were faint. It might also be convenient for finding declination with meridian instruments. Another device was the use of a mirror to reflect the slit, and enable the observer to place it upon any part of the sun's image without the help of an assistant.

In January, 1854, the Hon. R. C. Winthrop, Chairman of the Committee of the Board of Overseers of Harvard College, appointed to visit the Observatory, reported that the Observatory time was sent to Boston for the regulation of marine chronometers, for the arrangement of railroads, and for the general convenience of the people through a large part of New England. He adds: "The importance of such a system to the business operations of the community can hardly be over-estimated." At this time the signals were sent to Boston by way of Watertown, Brighton, and Roxbury, a circuitous line of twelve miles in length, and the wires were often broken. In 1856, a loop connected the Observatory with the Fitchburg line, and was owned by it until 1862. This has, of course, been available for the occasional transmission of time; but it was designed for the determination of differences of geographical longitude, in connection with the United States Coast Survey; a service which began under the administration of the first Director, and has been continually expanding, until it has taken into its embrace the Pacific coast and the western shore of Europe. In 1866, the necessities of the Coast Survey demanded that the loop should be renewed between the Observatory and the main lines of the country; and this was done at the expense of the survey. From its foundation, the Observatory, in one way or another, had furnished exact time to the community gratuitously; for which, elsewhere, observatories receive a liberal compensation. In 1872, Mr. Winlock introduced improvements which have made this service more widely and constantly useful, and at the same time remunerative. A contract was made for a special wire between Cambridge and Boston, which should not be diverted to any other business. An attachment to the mean-time clock of the Observatory interrupts the voltaic current once in each two seconds, omitting the last break of every minute, and the last thirteen breaks of every five minutes, so that there can be no mistake as to the identity of any second or minute. Branch wires unite the City Hall of Boston, the telegraph offices and railroad depots, and the principal clock and watch factories and warehouses with the first wire. In some places, an electro-magnetic clock is used, controlled by the Observatory clock; but a cheap vibrating armature is all which is necessary, and is generally employed. The superiority of the new system is here: clocks, watches, and chronometers can be compared with the best standard time, not merely once a day, but at any moment; and the public have appreciated and rewarded it. In one sense, it may be always said that time is money. In this instance, the Observatory time has opened so good a market that it has yielded a yearly income of $2,000.

In 1872, Mr. Winlock began to prepare a series of astronomical engravings, which should represent, with sufficient accuracy, the most interesting objects in the heavens, as they appear in the powerful instruments of the Observatory. This work was intended for the benefit, not of astronomers, to whom the "Annals" are accessible, and precise measurements are indispensable, but of a larger class of readers, who, without pursuing astronomy as a specialty, are interested in following its progress and achievements. Thirty-five large plates, beautifully executed from the most carefully prepared drawings and photographs, were completed at the time of Mr. Winlock's death, and wait only for a few pages of letter-press to be ready for publication. They will gratify the scientific public with admirable representations of the planets, Mars, Jupiter, and the ring-encompassed Saturn; of the sun's spots, protuberances, and corona; of the moon's craters and geography; of seven of the most famous clusters and nebulæ; of

Donati's comet of 1858, and Coggia's comet of 1874, in some of their wonderful transformations.

In August, 1874, Mr. Winlock was appointed by Secretary Bristow chairman of the commission established by Act of Congress for making inquiries into the causes of steam-boiler explosions. He entered into this investigation with remarkable energy; carefully analyzed the various theories which had been suggested to explain this class of accidents; and ended with devising a number of ingenious experiments calculated either to confirm or refute them in detail. The arrangements were nearly completed for making these experiments at Sandy Hook and at Pittsburgh, when death put an end to his labors.

In the early part of his active career, Mr. Winlock was known and trusted as an accomplished teacher and an excellent mathematician; well versed in theoretical astronomy, and capable of applying it in laborious and responsible calculations. These qualifications pointed him out as a proper person to be made director of an observatory. With his new opportunity, he developed other talents, which, if not indispensable, were none the less valuable in his changed condition. It might have been expected that his clear mathematical mind would easily comprehend the physics and the geometry of the instruments whose usefulness he was to guide, and seize upon any defects which might exist in their construction. In devising remedies for these defects, as simple as they were sufficient, he displayed an originality in his mechanical ideas, and a spirit of invention, which left nothing wanting to fill out the measure of a consummate director. Without any passion for innovation, or any conceit of his own methods, he was not afraid to leave an easy and well-worn path, or disturb the most time-hallowed routine, if he could give good reasons for the change. The life of an assistant at an observatory, obliged to work while other men sleep, exposed to the caprices of the clouds, made nervous by the irregularity of his hours, the nice handling of his instruments, and the delicacy of the work expected of him; disappointed at the critical moment in realizing the fruits of anxious days of preparation, — such a life is dependent, in no small degree, not only for its happiness, but its endurance even, upon innumerable and indescribable little facilities for observation, which individually are not worth the mention, but which in the aggregate tell distinctly upon the success and the comfort of the profession. In his many innovations, of which every room and each instrument in the Observatory is a witness, Mr. Winlock was not misled by any theoretical abstractions, but moved always within the limits of practical good sense.

In his administrative capacity, which was tested in the Nautical Almanac, at the Observatory, and on two eclipse expeditions, Mr Winlock evinced a disinterestedness, a strength, and a tranquillity of mind, which commanded the respect and won the affection of his associates. His leadership was nowhere asserted, but everywhere acknowledged. A man of few words, but of much thought; of no pretensions, but of great performance, — he did his own part patiently and well, and by his example inspired others to do theirs. The magnitude and the variety of work embraced in his programme, none of which suffered by default, certify to the prudence and the vigor with which his forces were selected and marshalled.

In his private life, Mr. Winlock was exceptionally quiet and retiring. But little inclined to general society, he was full of hospitality. His happiness was not complete without a few very intimate friends; and he had no enemies. He was remarkably silent before strangers; but no one talked more or better in the circles which he loved. Indisposed as he was to take up his pen, when he wrote his words were as transparent as his thoughts. Modest and without self-assertion, he had as much as any other man the courage of his own opinions. Slow to put himself forward, he was genial and accessible; giving his time and his instruction freely to all who asked; never hoarding up a discovery for his own exclusive benefit, but sharing with all his last thought and his newest invention. He was keenly alive to the ridiculous; but there was no ill-nature in his criticisms. Pretence and charlatanism in science amused him; but they did not destroy his equanimity. Without any selfish aims, he took no security for his own discoveries and inventions; so that others, less scrupulous than he was, too often entered into his labors. His friends sometimes wished that his ambition had been more aggressive; but perhaps he was wiser, in the simplicity of his character and the purity of his motives, than the men of this generation. The discoveries and inventions which he did not claim for himself will be vindicated for him.

In an age of bribery and corruption, every example of honor and fidelity in the execution of a public trust is to be cherished. In an age, when superficiality is preferred to depth, when the aspirants for scientific distinction sometimes forget to be just, and even the stars of heaven are obscured by the dust of earth, every life consecrated to honest study, not deflected from its high path by the love of popular applause, silent in its own strength, as the planets whose courses it follows, is a blessing and a legacy to mankind. In an age, when priority of discovery often counts for more than the advancement of human knowledge, and the value of inventions is read only on the patent-rolls, the seeds which are scattered broadcast by the roadside and not selfishly garnered in some private granary, though the sower may have no sense of his own merits, will make the harvest of future science. The deep impression which a quiet, unobtrusive, self-poised career, like that of Mr. Winlock, makes upon the community, can never be known until it is finished. And then we see the beautiful spectacle of all — friends and strangers, those who knew him best, and those who seemed to know him but little — spontaneously offering the tributes of gratitude and affection which they would have refused to the noisy claimant. This is the best hope and the highest reward of science.

CHAUNCEY WRIGHT.

Chauncey Wright, who died suddenly at Cambridge on the 12th of September, 1875, was born at Northampton, September 20, 1830, and was graduated at Harvard College in 1852. He was an accomplished and able mathematician, and was a member of the Academy in the mathematical section; but it was in the direction of philosophy that his original, profound, and accurate thought had its most congenial exercise, and found frequent public expression through various journals and reviews. After the publication of Darwin's *Origin of Species*, his attention was chiefly devoted to the discussion which then received so powerful an impulse; and he is, probably, most widely known as a participant in that discussion. One of his articles, which appeared in the "North American Review," was considered so important a contribution to the literature of this school, that it was republished in pamphlet form in England, — a compliment the more noteworthy, because it was paid to one who was not a professed naturalist. Mr. Wright took much interest in this Academy, and was for several years its Secretary. He exerted an important and peculiar influence in scientific and literary circles, and one which, there is every reason to believe, would have become wide and commanding, if his life had been spared. We cannot hesitate to say that his loss is one of the most serious that the Academy and the whole educated community have this year to deplore; and we are glad to learn that his friends are preparing a republication of his writings, now scattered through the volumes of periodicals, and will join to it an account of his life and mental characteristics.

HORACE BINNEY.

HORACE BINNEY was born in Philadelphia, on the 4th of January, 1780, and died in that city on the 12th of August, 1875, having more than half completed his ninety-sixth year. Though Philadelphia saw his birth and death, and witnessed his honored public and private life for three quarters of a century, Massachusetts furnished the sound stock from which his paternal ancestry sprung. The first Binney of his race emigrated to New England in 1680. He came from Hull, in England, and was one of the founders of the worthy little town of the same name on our coast, looking towards Nantasket Roads, distinguished for many years as the seat of the smallest constituency entitled to representation in the country, vying in that particular with Old Sarum itself, until the ruthless hand of reform swept away its Lilliputian franchise. The sea offered an obvious career to the inhabitants of the miniature township; and, accordingly, early in the last century we find the grandfather of Mr. Binney sailing out of Boston, as master of a vessel, and afterwards established there in trade. His son, Barnabas Binney, made a step forward in life, being one of the first thirty graduates of Brown University, taking his degree in 1774. He received whatever medical education the country then afforded at Philadelphia, and, on the breaking out of the war, he took service as a surgeon in the Massachusetts line, from which he was afterwards transferred to that of Pennsylvania. Dr. Binney settled in Philadelphia, and married Mary Woodrow, of a good Scotch-Irish family, in 1777. He is described as having been a man of unusual intellectual power, uncommonly well-read, of great strength of principle and force of character. His wife strongly resembled her husband in all the material qualities of his mind and character, and was in every respect a helpmeet for him.

Whatever qualities of mind and tendencies of disposition Mr. Binney may have derived from his father, they came to him by inheritance only, as Dr. Binney died in 1787, when his son was but seven years old. His mother, however, was equal to the charge of his education, the beginnings of which were had at schools in Philadelphia and its neighborhood. In the year 1791, when her son was eleven years of age, Mrs. Binney entered into a second marriage with Dr. Marshall Spring, of Watertown, in this State, a connection which was in every way favorable to the happiness and improvement of the young boy. His mother survived her second marriage only two years, dying in

1793, just after his admission to college. Left thus on the very threshold of life, at thirteen, without father or mother to advise and direct him, he gave the best possible proof of his reverence for their memory, by his devotion to the opportunities of improvement which lay before him. In 1797, he took his degree at the head of his class, though but seventeen years old. Among his classmates were that eminent scholar, the Rev. Dr. William Jenks; Dr. John Collins Warren; Judge Daniel Appleton White; Professor Asahel Stearns, the immediate predecessor of Judge Story in the Law School of the University, all of them Fellows of the Academy; and Chief Justice William Merchant Richardson, of New Hampshire. Mr. Binney bore this testimony, long afterwards, to the advantages he had derived from his academic education: "The unfading art which I acquired at college was that of study; and, if the acquisitions I then made are faded or fallen from the surface, the art or faculty of study has never left me." A just recognition of the truth that the function of a University is to train, even more than to store, the young mind.

When young Binney first began to consider what should be the serious business of his life, it is not surprising that he should have first inclined towards the profession of medicine. His father and his step-father having been both of them in that line of life, his thoughts naturally turned themselves in that direction. Dr. Spring, however, discouraged this inclination; and he applied for admission to the counting-house of an eminent firm of merchants in Philadelphia, with the idea of devoting himself to trade. Fortunately for his future, there was no room for him there; and, as a last resort, he turned to the law, and entered the office of Jared Ingersoll, an eminent lawyer of that day. Having once made his choice of the law as the business of his life, he applied the whole force of his mind, with all the power of application his previous discipline had given it, to mastering the science and learning the methods of its reduction to the business of life. His devotion to that jealous mistress was absolute; and he allowed himself to be diverted from it by none of the seductions of pleasure or of society. In 1800, when but a little past his twentieth year, he was admitted to the bar, and entered upon that probationary novitiate through which all young lawyers have to pass. The enforced leisure of waiting, however, was sedulously improved by continued study and regular attendance upon the courts, to fit him for the success which awaited him.

That success was not very long delayed. We have no room within the limits permitted us here to go into the particulars of his beginnings and his progress. His gains could not have been insignificant during the first ten years of his professional life, since at the end of them, when he was but thirty years old, he was able to build the large and elegant house in Fourth Street, in which he lived for the remaining sixty-five years of his life. Indeed, he had but small reason to complain of neglected merit, when, at seven or eight and twenty, he was dividing the best business of Philadelphia with men much his seniors, and who enjoyed a national reputation for eminence in the law. At thirty-five, according to the authentic testimony of Mr. Justice Strong, of the Supreme Court of the United States, given in the Eulogium on the Life and Character of Mr. Binney, delivered last January,—at thirty-five he was "in the possession of all that the profession of the law could give to its professor, whether of reputation or emolument." And, during those years of active practice, he prepared six volumes of Reports, condensing the decisions of the Supreme Court of Pennsylvania, from 1799 to 1814, of which Judge Strong says: "When they came from his hands, they left nothing to be desired. They must always be regarded as the work of an accomplished lawyer." He was a model lawyer in the earnest attention he gave to the business intrusted to him, and in his devotion to the interests of his clients. He was not to be turned aside from his practice at the bar by any of the usual allurements of ambition, not even of promotion to the highest distinctions of the law. While yet in the prime of his life, he twice declined offers of a place on the Supreme Bench of his own State, and at least once of one on that of the Supreme Court of the United States.

Mr. Binney refused to be tempted to leave his profession by the fascinations of political life. A single term in the State Legislature in his youth, and one in Congress towards the close of his active professional career, were all the deviations he made from his chosen path through life into that enchanted ground. And his consenting to serve his city in the twenty-third Congress was induced by the pressure of a great question, the right decision of which should have depended on the judicial voice of law, and not on the passionate outcries of partisan politics. It was at the time of the war declared by President Jackson against the Bank of the United States, which he waged as against a tribe of savages which he was bound to extirpate *per fas aut nefas*. Or, to use his own figure of speech, as against "a monster," of which it was reserved for him, as the appointed champion, to rid the land with whatever weapon came uppermost. Mr. Binney maintained the reputation he had gained at the bar in the new field of parliamentary debate; but he only appeared in it on great occasions, to the height of which he always rose. The removal of the deposits of the Treasury from the United States Bank by General Jackson, in open defiance of law, and the threatening state of our relations with France, caused by the passionate violence of language of that headstrong magistrate, were the chief subjects which called forth Mr. Binney's eloquent resistance. At the adjournment of that Congress he retired from the political arena, determined never to enter it again.

From Washington he returned to the practice of his profession, in which he continued actively engaged for about ten years longer. Then he withdrew from the conflicts of the bar; but for several years longer acted as Chamber Counsel, and gave opinions in cases of legal difficulty, which were not unseldom accepted as final judgments by the parties in interest. His last appearance at the bar was when the attempt was made in 1844 to invalidate the will of Stephen Girard, as an attack upon Christianity. Mr. Binney was matched against Mr. Webster, who brought all the power of his thunderous eloquence to defend the Christian religion against this assault of the French infidel banker. Mr. Binney confined himself to a lucid exposition of the law of charitable bequests and its application to this case. The Supreme Court of the United States unanimously went with the lawyer and not with the orator, and maintained the validity of the will. It was a fitting occasion for the last words in court of a great lawyer. But, though Mr. Binney kept himself thus free from entanglement with politics, and gave himself with this entire dedication to the law, it was not because he did not take a deep interest in political questions. He always gave the weight of his private and personal influence on the side he deemed the right one. His academic and professional education falling in the midst of the excitements of the French Revolution, and at the time of the birth of the political parties which sprung from that tremendous event, Mr. Binney began life as a Jeffersonian Democrat. His guardian, Dr. David Jackson, in whose family he lived, was one of the strongest opponents of the administration of Washington; and every domestic influence must have been on that side. But when he began to examine opinions and practices for himself, as his mind developed itself, he joined the Federal party from conviction of the truth of its principles and the purity of its purposes; and he remained faithful to it through evil report and good report, as long as it had a name to live. When the war of the Rebellion broke out, Mr. Binney, though more than eighty years of age, stood by the Union with the energy and devotion of the youngest patriot. He sustained the action of President Lincoln in its most stringent manifestations, though not without qualifications and remonstrance, after the worst of the danger was over, against the possible abuses of extraordinary powers. When Mr. Lincoln suspended the privilege of the writ of *habeas corpus*, by proclamation, without the consent of Congress, — action which excited general doubt and widespread opposition, — Mr. Binney came to the rescue, and sustained the action of the President in three pamphlets, of which Judge Strong says that "they will never cease to be regarded as models of acute reasoning applied to Constitutional law."

From the accounts given of it by those accustomed to hear him in court, Mr. Binney's forensic delivery was of the highest, because of the most fitting, description. Without aiming at flights of oratory, his speech was always exactly adapted to the needs of the trial. Though forcible and energetic, vehement even on occasion, his style was generally the calm, unimpassioned expression of the logic of the facts and the pure reason of the law of the case. Fluent without haste, deliberate without hesitation, exact in apprehension, and accurate in expression, never missing or mistaking a word, his sentences fell on the ear of judge or jury with beautiful completeness, and kept the attention awake by the grace of their style as well as by the distinctness of their meaning. His published writings, though too few, are marked by the same clearness, force, and elegance of style that distinguished his speech. His discourses on the Lives and Characters of Chief Justice Tilghman, of Pennsylvania, and of Chief Justice Marshall, of the United States, are models of that most difficult branch of oratory which deals with the characteristics of the dead. The delicacy of touch, the accuracy of discrimination, the nicety of analysis, the distinctness of characterization, with which he places the eminent qualities of those great magistrates before the mind of the reader, the whole warm with personal affection and radiant with generous admiration, show to what distinction he might have risen in literature, had he given himself to its pursuit.

In 1850, at the age of seventy, Mr. Binney retired absolutely to private life, and addressed himself to the vocation — so difficult to the most of men, so beautiful when it is well discharged — of growing old gracefully. How perfectly and how beautifully he did this, all can say who have ever had the happiness of seeing the handsome old man, his white locks crowned with the black velvet skull-cap he usually wore, in his delightful home, and of enjoying the pleasure of his affluent talk, set off and enhanced by the charm of his majestic presence. The society of Mr. Binney had none of the drawbacks, from some of which extreme old age is rarely exempt. Besides having the perfect possession of his memory, and the same command of language as in his prime of life, he was in the full enjoyment of all the special senses. Though the weight of more than ninety years had abated his natural force, yet was his eye not dim, and it was a faithful and untiring servant to the end. And what is even more rare in the very old, his hearing was as perfect at ninety as at nineteen. There was, therefore, in his case, none of the painful consciousness of effort on the part of speaker and of hearer, which generally lessens the pleasure of conversing even with the most interesting and intelligent of old men. Indeed, one forgot, in talking with him, that he was an old man, as there was nothing in the manner or the matter of his conversation to remind one of it. Like most good talkers, he was a delightful letter-writer; a good letter being, indeed, only good talk flowing from the pen instead of the tongue. His interest in all the events of the day, in literature, and in the law, remained warm to the last. And his love for his *Alma Mater*, whose eldest son by several years he lived to be, did not wax cold with age. When the great Boston fire had seriously impaired the property of the University, at the first appeal of President Eliot, he instantly sent a thousand dollars for the relief of the nursing mother of his mind.

The life of Mr. Binney was certainly one of a felicity rarely equalled. Though his many days were not unclouded by great sorrows, his strength was made equal to the darkest of them by occupation, by reason, and by religion. It was a life singularly rounded and complete. Twenty-five years given to preparation for his life's work; fifty years of active devotion to it; a crowning quarter of a century of honorable and honored repose, — make up a sum of happiness such as has fallen to the lot of few mortals to enjoy. He passed his active years in doing well what he liked best to do. His declining years had every blessing that filial affection, devoted friendship, and general reverence could bring to smooth and adorn them. Without having aspired to or won high office, he enjoyed a great reputation coextensive with the country. And he died in the fulness of near a century of years, universally honored and revered as the patriarch of the American bar, and the foremost citizen, not of his State only, but of the nation.

SIR WILLIAM EDMOND LOGAN.

Sir William Edmond Logan, Knight, was born in Montreal, Canada, in 1798, and died at Castle Malgwyn, Llechryd, in South Wales, June 22, 1875. Like so many others who have attained distinction in British North America, Logan was descended from a loyalist stock, one of those families who, adhering to the British crown, left the revolted colonies a hundred years since. His grandfather then removed from the neighborhood of Schenectady, N.Y., to Montreal, carrying with him two sons, one of whom was the father of our late associate. They were of Scottish origin; and when the father and uncle of Mr. Logan had gained wealth in commercial pursuits, and transferred their business as merchants and bankers to Great Britain, the former purchased a small estate near Stirling in Scotland, a circumstance which has led one of his English biographers into the error of speaking of Mr. Logan as a Scotchman. His education, begun in Montreal, was continued at the High School and the University of Edinburgh; but we find him already at the age of twenty in the counting-house of his uncle in London, where he remained for ten years, devoting much of his leisure to the study of natural history, as well as to music and painting, in both of which he was a successful amateur. In 1829, his uncle having acquired an interest in a copper-smelting establishment, with some coal lands at Swansea, in South Wales, Logan removed there to assume their direction, where he remained for nine years, becoming a successful copper-smelter and coal-miner. The study of the coal-field of the neighborhood here engaged his attention, and he made of it a very careful and minute map, which was presented by him to the British Association in 1837. When, later, the geological survey of Great Britain under De la Beche was extended to this region, the work of Logan was placed at the disposal of the government, and, its exactness having been verified, was adopted and published by the survey. In the course of these labors, he made careful studies as to the relations of the stigmariæ constantly found in the clays which immediately underlie the coal-beds, and in 1840 brought this matter before the Geological Society of London, announcing the conclusion that the stigmariæ belonged to the plants which had furnished at least a large part of the coal. It was afterwards shown that other observers had already indicated a similar relation, and that Mammatt, from his studies of the coal-field of Ashby-de-la-Zouche, had in 1836 maintained that the coal was the product of a vegetation *in situ*, rooted in the under-clay. To Logan is, however, due the credit of careful and original observations on the subject, which he subsequently extended to the coal-fields of Nova Scotia and Pennsylvania, which were visited by him in 1841. In 1842, he was offered the direction of a geological survey of Canada, which he accepted, beginning his work in the spring of 1843, with the aid of Mr. Alexander Murray, now director of the geological survey of Newfoundland. It was not till four years later that he was joined by Dr. T. Sterry Hunt. The labors of Logan for 1843 and 1844 were directed to the coal basin of Nova Scotia and New Brunswick and to the paleozoic formations of the adjacent peninsula of Gaspé, and included his study of the now famous section of the Joggins at the head of the Bay of Fundy, where over 14,000 feet of coal measures, including seventy-six coal seams, are displayed in unbroken sequence. In 1845, his attention was turned to the more ancient rocks which appear on the Ottawa River and its tributaries; and in 1846 he made with Mr. Murray a preliminary survey of the geology of the north shore of Lake Superior.

It is with the ancient crystalline rocks that his name will be chiefly associated, and especially with the formations since called Laurentian and Huronian; and it may be well in this connection to state briefly the results of their examination by the Canadian survey, which now belong to the history of geological science. The gneissic character of the crystalline rocks which were known to underlie the paleozoic formations in northern New York and Canada had long been recognized; but the prevalent view with regard to such gneissic rocks, both there and elsewhere, was that expressed by Emmons, who had carefully studied them in the first-named region, that they were igneous or fire-formed rocks, the laminated structure of which is not due to the intervention of water. He maintained that they were in no sense of sedimentary origin, and included no sedimentary layers, a view to which some recent writers still incline. In the first year of the Canadian survey, however, Mr. Murray (in his report published in 1844), having studied these rocks to the north of Lake Ontario, declared that these granites and gneisses (the extension of those of the Adirondacks) "present evidences of stratification," and were therefore to be regarded not as primary, but rather as "metamorphic" rocks; a term which had been proposed by Lyell to designate crystalline sedimentary strata. In the subsequent report of Logan, who examined the same rocks on the Ottawa in 1845, and published his report in 1847, they were again described as "metamorphic rocks, ... apparently of sedimentary origin, chiefly syenitic gneiss with crystalline limestones," which were said to be distinctly interbedded. Resting upon these on Lake Temiscaming, Logan described in the same report a newer series, chiefly of chloritic slates holding pebbles of the underlying gneiss; and in his report of his examination of Lake Superior in 1845 (also published in 1847), these two series were distinctly indicated as a lower formation of granitic gneiss, often syenitic, and an upper one of micaceous, chloritic, and talcose slates, frequently with epidote, associated with hornblendic rocks and greenstones, quartzites, and conglomerates including pebbles of the older rocks; this upper series being probably several thousand feet in thickness.

In their report for 1851 on the geology of Lake Superior, Messrs. Foster and Whitney also described these crystalline rocks, including the two divisions, as the Azoic system, which they recognized as of sedimentary origin. The farther studies of the Canadian survey established the importance of the two divisions, and the necessity of separate designations for them; and in Logan's report for 1853 (published in 1854) the name of the Laurentian series was given to the lower formation, which forms the chief part of the elevated region to the north-west of the St. Lawrence to which the title of the Laurentide Mountains had been previously assigned. The name of Laurentian has since been adopted for the similar rocks of Continental Europe and of the British Isles. In 1855, the designation of Huronian was given by the Canadian survey to the upper division, including the series characterized by greenstones and talcose and chloritic schists which is largely developed on the shores of Lakes Huron and Superior (where it had been carefully studied and mapped by Mr. Alexander Murray), and constitutes the Huron Mountains to the south of the latter lake.

The subsequent labors of Logan on the Ottawa established clearly the regularly stratified character of the Laurentian series, of which he measured about 20,000 feet, consisting of four gneiss formations separated by three limestones, each of the latter having a thickness of from 1,000 to 1,500 feet, and associated with quartzites; the whole constituting a series comparable in value to the entire lower Paleozoic. These strata, greatly affected by undulations and penetrated by eruptive rocks, were by Logan traced with infinite labor over an area of 2,000 square miles; and a geological map of this region, published by him in the Atlas to the Geology of Canada in 1863, is the first attempt to unravel the stratigraphy of this most ancient and disturbed series of rocks.

At the summit of this series was found a mass of about 10,000 feet of stratified crystalline rocks, which, unlike those below, consisted chiefly of labradorite and hypersthene rocks, with some little included gneiss and quartzite and a band of crystalline limestone. This series Logan subsequently showed to be unconformable to the older gneisses, and gave it the name of Upper Laurentian, subsequently exchanged for that of Labradorian or Norian.

Indirect evidence that these lowest rocks were not really Azoic was soon pointed out, and in 1858 obscure forms resembling those of Stromatopora were detected in the Laurentian limestones, and were exhibited by Logan to the American Association for the Advancement of Science, in 1859, as probably organic; but it was not till 1864 that Dawson announced that these and other similar forms were the remains of a gigantic rhizopod, to which he gave the name of Eozoön Canadense. The history of this curious form is well known, and its organic nature, though at one time much contested, is now disputed by few.

To Logan we owe a large part in the investigations of the Canadian Survey which have established the following great facts in the geology of the Azoic or, as they may henceforth be called, the Eozoic rocks: —

I. The relations of the Laurentian as a great stratified series of crystalline rocks of aqueous origin, occupying a position at the base of the known geological column and containing evidences of organic life.

II. The fact of the unconformable superposition to the Laurentian of the Upper Laurentian or Norian series.

III. The first recognition that unconformably overlying the Laurentian was still another series of crystalline stratified rocks, the Huronian. (The relative ages of the Norian and Huronian still remain undetermined, for the reason that they have never yet certainly been found in juxtaposition.)

IV. The fact that the Laurentian, Norian, and Huronian, are all of them unconformably overlaid by the lower members of the New York Paleozoic series.

His labors on the Laurentian rocks were continued at intervals up to 1867, and were performed with an amount of fatigue and sacrifice of personal comfort which can only be understood by those who have had to traverse these rugged forest regions. He often wandered for days through a wilderness, with a prismatic compass in hand, counting his paces, and gathering rock-specimens as he went. His notes, made in pencil, were always written out each night in ink, and the journeyings of the day protracted, often by the light of the camp-fire.

In the intervals of these investigations, Logan was devoting his attention to another region of crystalline rocks, the extension of the Green Mountains of Vermont through eastern Canada to a point a little south-east of Quebec, the study of which he began in 1847.

The previous attempts to establish a parallelism between the geological succession in eastern New York and western New England had led most American geologists to suppose that the crystalline schists of the latter region were the stratigraphical equivalents of the lower members of the New York Paleozoic series in an altered condition; though there were not wanting those who, with Emmons, regarded these crystalline strata as a part of the primary or so-called Azoic series. Logan, who began, as was his custom, to work out the stratigraphy of these rocks in minute detail, accepted the views of the majority on this disputed question, and endeavored to establish a parallelism between the subdivisions of these crystalline strata of the Green Mountains and their prolongation into Canada, and the uncrystalline fossiliferous strata which are found everywhere along their north-western base from the valley of Lake Champlain. These, the so-called Upper Taconic of Emmons, he at first looked upon as newer than the Trenton limestone, but, yielding to the evidence of organic remains, assigned them at length to their true position immediately below the horizon of this limestone, and named them the Quebec group. That these uncrystalline strata were really newer rocks than the adjacent crystallines (of which they include fragments), Logan was unwilling to admit, and spent many years in an unsuccessful attempt to establish a correspondence between the two series. That these latter rocks, called by him the "altered Quebec group," belong to the same Huronian series which he was the first to distinguish farther to the westward as of pre-paleozoic age, will now be questioned by none who have compared the two regions.

The record of Logan's later life is little else than that of his patient and unwearying devotion to the work of the geological survey of Canada, of which he remained the director for twenty-five years. In 1863, he prepared and published, with the aid of Professor James Hall, a geological map of northeastern America, including the region north to James's Bay, south to Virginia, and west to Nebraska. This map, on a scale of twenty-five miles to the inch, remains the most complete attempt to delineate the geology of the region. His other published works are confined to the reports of the geological survey, and a few papers to scientific societies on kindred subjects. He had little aptitude for literary labor, and found the work of composition difficult. He rendered good service to science and to his native country at the international exhibitions of 1851 and 1855, being a juror at the first, and a commissioner at the second. On the latter occasion he was knighted by the Queen, and by the Emperor Napoleon made a chevalier of the

Legion of Honor, in which order he was subsequently raised to the rank of officer. He was a Fellow of the Royal Society of London, of the Imperial Leopoldo-Carolinian Academy of Germany, and of many other scientific societies. In the year 1857, he was president of the American Association for the Advancement of Science.

In 1869, his advancing years and failing health, together with the necessity of devoting more time to his large estate, led him to resign his position as director of the geological survey, though he still continued to spend a portion of his summer in geological exploration, much of which was in the western parts of Vermont and Massachusetts. The incompleted results of these last few years, however, remain unpublished. He left his home in Montreal in August, 1874, to spend the autumn and winter in Great Britain, intending to return to his geological labors in the spring; but, his bodily ailments increasing, he died and was buried at the home of his sister in Wales.

Sir William Logan was unmarried, and, though genial and kindly in his social relations, led a solitary and very retired life. His work in science was neither that of a paleontologist, a lithologist, or a mineralogist; in all of which departments he was, throughout his career, ably seconded by the labors of James Hall, Sterry Hunt, Dawson, and Billings. His great merit was the possession of a rare skill in stratigraphy, and an amount of patience, industry, and devotion to his work, which has rarely been equalled, and has enabled him to connect his name imperishably with the geology of the older rocks.

WILLIAM SWEETSER.

William Sweetser, son of William and Elizabeth (Bennison) Sweetser, was born in Boston, September 8, 1797. He was fitted for college under the tuition of Rev. Mr. Frothingham, then of Saugus, afterward of Belfast, Me. He entered Harvard College in 1811, was graduated in 1815, and received his medical degree in 1818. He then settled at Sherburne, Mass., where he came at once into an extensive country practice, and won the entire confidence and high regard of the community.

He received the Boylston prize in 1820, for a dissertation on "Cynanche Trachealis, or Croup;" and again, in 1823, for one on "The Functions of the Extreme Capillary Vessels in Health and Disease." He subsequently, in 1829, received a premium offered by the Massachusetts Medical Society, for the best dissertation on "Intemperance."

In 1824, he returned to his native city, and remained there till his removal to New York, about thirty years ago.

His services as a teacher were so early and so fully required, that, on leaving Sherburne, he virtually relinquished the regular practice of his profession. On the strength of his reputation in the Medical School, as a student of rare merit and promise, he was, in 1819, chosen Professor of the Theory and Practice of Medicine, in the University of Vermont. In 1845, he was elected to a similar Professorship in Bowdoin College. He subsequently held professorships in Geneva College, and in the Medical School at Castleton, Vt., and for two years was a lecturer at Jefferson Medical College in Philadelphia. During the prime of life, he arranged his courses of lectures at these different institutions, so as to hold several professorships at the same time; but with increasing years he resigned them successively, and closed his public career by a last course of lectures at Bowdoin College in 1861.

The remainder of his life was passed in retirement with a devotion to his private studies and to general literature, which yielded only and late to growing bodily infirmity. He died on the 14th of October, 1875.

Dr. Sweetser's professional and scientific reputation was high, and it was thoroughly genuine. He had no extraneous attractions of person, address, or elocution; and his modesty never suffered him to push his own claims, or to seek recognition for his own merits. Whatever fame he had was won by native ability, deep thought, hard study, and faithful service. In private life, he was a man of amiable disposition, pure and high principle, and blameless character, most respected and loved by those who knew him best.

His published works, besides the dissertations already referred to, and numerous addresses, and other occasional pamphlets, are as follows: —

Treatise on Consumption, 1833; Treatise on Digestion and its Disorders, 1837; Mental Hygiene, 1843; Human Life, 1867.

GABRIEL ANDRAL.

Gabriel Andral, the son of a prominent physician, was born in Paris, November 6, 1797, and died in that city, February 13, 1876, in the seventy-ninth year of his age.

Andral studied medicine at the college of Louis le Grand, and took his medical degree in 1821. He gained a sub-professorship, by competition, in 1823. He was chosen Professor of Hygiene in 1828, and the same year was appointed one of the physicians of the Hospital La Pitié. He was promoted to the chair of Internal Pathology in 1836, and to that of General Pathology and Therapeutics, the highest in rank, in 1839. He was elected to the Academy of Medicine in 1823, and to the Academy of Sciences in 1843.

Thus, early taking prominent positions, he rose progressively to the highest eminence as practitioner, author, and teacher, and became a ruling influence in the exciting movements and bustling progress of medical science in his day.

As a practitioner he was abundantly successful, numbering among his clients the highest and noblest in the land. He was courteous in manner, and considerate in manipulation. His prudence in experimentation, and his little reliance upon drugs as remedies, less superstitious certainly than that of some of his associates, led occasionally to the ungracious remark that he was more interested in pathological verifications than in therapeutic success. Nevertheless, he was noted for great accuracy in diagnosis, and for eminently judicious treatment of the sick.

The most considerable of his publications, the first volume of which was published in 1823, only two years after his graduation, was his *Clinique Médicale*, which reached its third edition in five volumes in 1834. This work of years, still much consulted, is distinguished for good faith in researches, ardent regard for truth, opposition to hypothesis, and a philosophic spirit. In 1829, he began his *Precis d'Anatomie Pathologique*, which, in its three parts, ultimately formed two volumes. This was an attempt to trace out more thoroughly the laws connecting morbid appearances found after death with the symptoms manifested by disease during life. With more comprehensive views than his contemporaries, then leaning too much to solidism, he showed this to be one, but only one, of the important methods for establishing in full the science of the sick man. In the same spirit, in connection with Gavarret and Delaford, he instituted observations on the blood, in health and disease, and published the results in 1843, in a treatise entitled *Essai d'Hématologie Pathologique*.

As a teacher he was unrivalled. By his originality, good judgment, sound learning, and brilliant speech, he compelled the interested attention of the most indifferent student, as that of the ablest scientists who crowded his amphitheatre. Honest and earnest, he gained the confidence of all by the remarkably clear statements of what he himself implicitly believed. Some idea, however inadequate, of the substance and spirit of these lectures, may be obtained from a very faithful and appreciative report of a portion of them published by Latour in three volumes in 1836, under the title of *Cours de Pathologie Interne.*

At the height of his fame, Andral was without question the grandest professor in the Faculty at Paris, then the most renowned in the world.

Andral married the daughter of the celebrated Royer-Collard, by whom he had one son, Charles Guillaume Paul Andral, born June 13, 1828, now Vice-President of the Council of State, and an eminent member of the French bar. In 1866, his wife becoming ill of a painful and incurable disease, Andral gave up his extensive practice, his professorship, and high scientific positions, and retired while in the full possession of his physical and mental powers to Châteauvieux, her family country-seat, there to devote himself entirely to her necessities and comfort, — a self-sacrifice worthy and characteristic of his affectionate nature, and well-known goodness of heart.

A few months after the death of his wife, Andral came up to Paris, temporarily, to revisit the scenes of his former labors and triumphs. In the chilly court of the Institute, he was seized with bronchitis, which in a few days terminated his life. Thus he died, as he had always wished, in his native city.

His obsequies were attended by distinguished statesmen, deputations from the Institute, the Medical Faculty, and the Academies, a military body-guard from the Legion of Honor (in which he was a Commander), and a host of eminent associates and friends, who, to the number of more than a thousand, in spite of a furious storm, overcrowded the church of St. Pierre-de-Chaillot, in their earnest desire to pay him the last tributes of affection and respect.

THE MARCHESE GINO CAPPONI.

On the 5th of February, of the present year, Florence put on mourning for her illustrious son, Gino Capponi. Clothed in the simple dress of a " Brother of Mercy," his body lay for several hours of that day exposed to public view in a hall on the ground floor of the palace of his family, and was thence followed to its last resting-place by ministers, magistrates, senators, deputies, and persons specially deputed to represent the most eminent literary and artistic bodies of the States. The telegraph brought messages of condolence to the Syndic of Florence from his brother syndics of other Italian cities, and the King at Rome wrote to the Marchese Farinola: —

"I feel the most lively grief at the very bitter loss which Italy has suffered this day in the death of Gino Capponi. I share fully in the mourning of his family and of the country.

"VICTOR EMMANUEL."

The honors then paid by men of all ranks and parties to "l'ottimo nostro Gino Capponi," as the Florentines loved to call him, were his due. Last scion of an illustrious house, he was himself illustrious for his virtues and his unselfish patriotism. Like his ancestors, many of whom had taken part in public affairs, he always stood on the side of liberty and progress, feeling that nobility of race is only respectable and respected in its possessor, when he recognizes that it obliges him to make use of the prerogatives which belong to it for the common advancement of all good and noble objects. Eminent as a wise and far-sighted patriot, who knew how to act and speak at the right moment, as well as to stand firm and be silent when deeds and words would have retarded rather than advanced the cause which he had at heart, being in short a wide-minded conservative and a genuine Republican, but in no sense a radical or an agitator, Gino Capponi passed hopefully through the dark days which were Italy's portion from 1815 to 1848, kept a firm hand on the helm during the crisis which followed, and lived to see the increasing brightness of the new day which has now fully dawned upon his beloved country. But not only was he a true patriot, and as such beloved by all who had the good of Italy at heart, he was also the friend and protector of such eminently patriotic writers as Nicolini, Giusti, Gioberti, Balbo, and Leopardi, whose pens were as sharp swords ever directed against the breasts of those who sought to make the world believe that Italy was a land of the dead; a land having a glorious Past, whose echoes they would fain have silenced, but which now contained nought but "spectres and mummies." In "La Terra dei Morti," a poem which Giuseppe Giusti, the Tuscan satirist, dedicated to his friend Gino Capponi, he thus bitterly designates his fellow-countrymen, crushed under Austrian rule, and with words which sting cries out to them: "What do a dead people care for history? to you skeletons, what importeth to talk of liberty and glory?" That the heart of Gino Capponi fully sympathized in the poet's emotion is proved by the dedication of this burning page to him; and that the poet counted on his affection is shown in a poem, written years afterwards, when the dark cloud had passed away and better days had come to Italy. "Since the days of Petrarch," he writes in the letter prefixed to it, "the poetic law has been recognized that the public is the proper confidant of the rhymer's affections. No one who knows that you are the only one to whom I have recourse in all which passes between myself and me ('*tra me e me*'), will wonder at this public confession which I send you; and to those who do not know it, I have wished to say in verse what bonds unite us." These bonds, be it said, were never severed until the 31st of March, 1850, when Giusti, who had for months been the guest of his illustrious friend, expired at the Palazzo Capponi, and was thence carried to his grave in the church of San Miniato. Himself an author of no mean repute, the sympathies of men of letters centred round Gino Capponi. They had none of that jealousy of him, which too often divides the craft, but for half a century were in the habit of looking up to him as "a permanent minister of literature." In him they found a wise adviser and an influential friend, sympathetic, kind, hospitable, and generous. A short abstract of the chief events of his life founded on Count Passerini's biographical notice in Litta's Famiglie Celebri, as published in "La Nazione," will suffice to show how nobly he filled the triple *rôle* of patriot, patron, and friend.

Son of the Marchese Pier Roberto and the Marchesa Maria Maddalena Frescobaldi, Gino Alessandro Giuseppe Gasparo Capponi was born at Florence, on the 14th of September, 1792. At the age of seven, when the Grand Duke Ferdinand III. was driven out of Tuscany by the invading French, he left his native city with his parents; and during four years of exile, as also after his return home, pursued his studies under the best masters until 1813, when he was sent to France as one of a deputation charged to offer aid and assistance from the City of Florence to the Emperor Napoleon, whose power and prestige had received a rude shock in the Russian campaign and by the disastrous battle of Leipsic. In recognition of his services on this important mission, he was appointed Chamberlain to the Grand Duke, an office which did not prevent him from visiting France, Germany, and England, for the purpose of completing his education, and of gaining that valuable experience of men and things, which he was to turn to good account in after life. On his return to Italy, he immediately assumed the position to which his birth, his talents, and his virtues entitled him. Every good enterprise found in him a ready helper; and through the interest which he took in the opening of schools, savings banks, and infant asylums, he did much to advance the cause of morality and civilization among his countrymen. Regarding the press as a most valuable agency to this end, his pen was never idle. He was one of the founders of the "Antologia," a paper which he enriched with many valuable articles; as also of the "Archivio Storico Italiano," a periodical filled with Italian chronicles and documents of the greatest historical interest. History had great attractions for him, and his private library contained many valuable manuscripts and rare books, of which he himself compiled and published a catalogue. The volume of historical documents, which he published in 1838, and "Le Istorie di Giovanni Cavalcanti," which followed it two years later, together with many numerous and important newspaper articles, gave him a literary reputation which was acknowledged, not only by the four learned societies of Florence, the Crusca, the Georgofili, the Ateneo, and the Colombaria, but also by the most celebrated Transalpine Academies, all of which desired to enroll him among their members. To one not cognizant of the condition of Italy, during the years which began at Campo Formio and ended at Novara, it is difficult to realize the tact, prudence, and discretion required of a man who, like the Marchese Gino Capponi, had the best interests of Italy at heart, and desired to serve them. To be a liberal, and the friend of liberals, was to be an object of suspicion; and although the position of Tuscany was then far better than that of Lombardy, the Roman States, or the Kingdom of Naples, it was a task of no small difficulty to aid in steering the ship of reform through the numberless shoals and quicksands which beset her path, without running her aground and aggravating the dangers of her position. The great object in view was to form a national resolve that liberty should be achieved, and to strengthen the national character, so that, when that result was brought about, it should not degenerate into license. Like Napoleon III., who was always on the eve of "crowning the edifice," to use his favorite expression, the Grand Duke was wont to dangle projects of reform before the eyes of his subjects. His government professed to be liberal, and proposed to institute advanced reforms in the State; but it wished to take its own time, and did not care to have the task taken out of its hand by spirits impatient of a long delayed result. Thus it happened that, when Gino Capponi and his friends asked to be allowed to print a journal which was intended to direct public opinion in the right direction, permission was refused by the Minister, on the ground that the government desired to be itself the initiator of even greater reforms than those which they projected. The pressure of outside events at last became so great, that, late in the year 1847, Capponi was invited by the Grand Duke to form one of a committee charged to propose a form of representative government suited to the needs of Tuscany. This Commission instituted a Council of State, in which Capponi, who was elected Senator, was called upon to take a seat; and when, after the events of 1848, a new ministry was to be constituted, he was charged to form it, and to become its President. During the short time that he retained this office, he gave proof of his great ability and judgment. The acts of his government were directed towards the founding of liberal institutions, the furthering of the war of independence, and the confederation of the Italian princes, that they might represent Italian nationality as a principle and an accomplished fact. Events impossible to control, jealousies not to be appeased, and the increased strength of those who would not be content with such a measure of law-abiding liberty as the Capponi ministry favored, brought about its downfall after a few months; but, if it did not reap the laurels of success, it carried with it in defeat the respect of honest men, who recognized that it had striven to conciliate liberty and order, and to keep down those disorderly elements which now got the upper hand and threatened to shipwreck both. In the provisional government, which was constituted in February, 1848, after the flight of the Grand Duke, Capponi took no part, feeling that the wisest course was to bide his time. This came in 1849, when constitutional government was restored by the people and the Priors of the Commune, who, on assuming the reins of government, called Capponi, with other distinguished citizens, to assist them in their difficult task. One month later the Commission resigned its powers into the hands of the Count Luigi Serristori, who had been nominated by the Grand Duke as his commissioner with full powers, and Capponi then retired into private life. He continued however, to use his influence with the government to satisfy the legitimate demands of the people; and, had his advice been listened to, the resolution of April, 1859, which put an end to the rule of the Austro-Lorraine dynasty in Tuscany for ever, might have been averted or delayed. Although Capponi was one of those who had nourished the vain belief that the government of the Grand Duke could be brought into harmony with the aspirations of the country, and therefore may be classed with those who are popularly known as "Codini," he frankly accepted the situation; and, being above all things anxious to bring about that state of affairs most favorable to the unity of Italy, he took his seat in the Tuscan Assembly, and with his colleagues voted the perpetual exclusion of the Austro-Lorraine family from power, and that union of Tuscany to the Subalpine kingdom, which was soon after consummated by the never-to-be-forgotten entrance of King Victor Emmanuel into Florence. He could not see, as others did, those streets strewn with flowers, those houses draped with banners and tapestries, that King of a United Italy, who, riding on a white charger, came with an endless crowd of willing subjects, to add one more jewel to his crown; for since 1844 he had been blind. But his ears were open to the sounds of rejoicing, and no heart of all those which swelled with emotion on that day to think that Italy was no longer "a geographical expression," but a country one and indivisible, beat more loyally than his, or responded more warmly to the calls of that memorable occasion. With it his connection with political events ceased. During the remainder of his life, he occupied himself with literary labors, and by the publication of his "History of the Florentine Republic," a year before his death, brought them to a noble termination. For many years, as he says in his preface to this work, it had from time to time engaged his attention, but owing to frequent interruptions it was not completed until its author had attained the age of eighty. With what conscientiousness he labored to make it a faithful record of events, and why he did so, he himself tells us in this same preface, in these simple words: "Once that I had undertaken it, it seemed to me to be the duty of an honest man to labor at it with the utmost diligence, and to give it my best thoughts, because a history carelessly written is often a false history, or, in other words, a lie. Wherefore, for all the shortcomings of this book, I have no other excuse to offer to the reader but this very plausible one, that I was unable to make it better than it is."

CHARLES-FRANÇOIS-MARIE, COMTE DE RÉMUSAT.

Charles-François-Marie, Comte de Rémusat, died on the 6th of June, 1875. He was born on the 14th of March, 1797, and had thus nearly reached his seventy-eighth year. He was the son of Count de Rémusat, a chamberlain of the first Napoleon, who married a niece of the Count de Vergennes, an intimate friend of the Empress Josephine. Some of his early years were thus passed at St. Cloud, where his father was Préfet of the Palace. He was educated at the Lycée Napoléon, and was there distinguished for his scholarship. He began early to write in the journals and periodicals, and always on the liberal side. In 1830, he took bold ground, with M. Thiers, against the ordinances of M. Polignac, which cost Charles X. his throne.

He had just before married, for his second wife (the first having survived her marriage only two years), Mlle. de Lasteyrie, the granddaughter of the celebrated Marquis de Lafayette. He was an aide-de-camp of Lafayette at this period, when the marquis was commander-in-chief of the National Guard. He soon entered the Chamber of Deputies, was in the confidential cabinet service of M. Casimir Periér, and afterwards Minister of the Interior. As writer, deputy, and minister, he uniformly espoused and advocated liberal opinions and measures. He protested against the *coup d'état* of Napoleon III. in 1851, and was imprisoned and afterwards exiled.

He had been made a member of the Academy of Moral and Political Sciences in 1842, and one of the forty members of the French Academy in 1846. His exemption from political service during the Second Empire gave him the desired opportunity to pursue his philosophical and literary studies. He had published two volumes of Philosophical Essays, in 1842; two volumes on Abélard, in 1845; and, in the same year, an elaborate Report to the Academy on German Philosophy. In 1854, he published a work on the spiritual power of the eleventh century, under the title of "Saint Anselm of Canterbury;" in 1856, he published "Studies and Portraits of England in the Eighteenth Century," a work which he enlarged to two volumes in 1865; in 1858, he published his "Life, Time, and Philosophy of Bacon;" and, in 1864, a volume on Religious Philosophy.

A volume entitled "Channing, sa Vie et ses Œuvres," of which a second edition was printed in 1861, has been sometimes included in the works of Rémusat; but he wrote only the prefaces to the successive editions, while the volume itself was written by an accomplished English lady, Mrs. Robert Hollond.

In 1871, after the downfall of the empire and the conclusion of the war with Germany, M. de Rémusat was made Minister of Foreign Affairs, and was prominently associated with M. Thiers in achieving the territorial liberation of France from German occupation. When M. Thiers resigned the Presidency of the French Republic in 1873, M. de Rémusat also retired from ministerial service. He remained, however, a member of the Chamber of Deputies to the end of his life.

A few months only before his death, he laid before the French Academy his "History of Philosophy in England from Bacon to Locke," in two volumes.

He was buried in the old Cimitière de Picpus in Paris, where the tomb of Lafayette is well known to American travellers. Eulogies were pronounced at his grave by representatives of the French Academy and of the Chamber of Deputies; and an elaborate Memoir of his life and writings was communicated to the Revue des Deux Mondes (November, 1875) by his life-long friend, M. Duvergier de Hauranne, in which ample justice was done to him as an eminent writer, a religious philosopher, and a constant and able supporter of liberal principles.

The United States Minister to France (Mr. Washburne), in a published despatch to the State Department at Washington (18 June, 1875), after alluding to the friendship which M. de Rémusat had always manifested for our country and its institutions, speaks of him as follows: "To quick intelligence and rare culture he united the simplest manners and most unaffected modesty. His genial disposition, the graces of his spirit, and the charm of his conversation, left upon all the impression of his purity and worth as a citizen, his accomplishments as a statesman, and his fidelity, honesty, and patriotism as a public servant. The love of France was the hope and inspiration of his life. . . . Though always holding liberal opinions, his inclinations were monarchical; but, yielding to the logic of events and the demands of circumstances, it was his judgment that the Republic was the only form of Government that could give peace and safety to France."

He was elected a member of this Academy on the 12th of November, 1873.

SIR CHARLES WHEATSTONE.

Charles Wheatstone was born at Gloucester, in the year 1802. His early education appears to have been very limited; but he displayed, as a boy, a strong taste for mechanics, and especially for the construction or modification of musical instruments. He began his scientific career with the study of acoustics, and made numerous original experiments and researches, his first paper appearing in the "Annals of Philosophy," in 1823. For some years he was a dealer in musical instruments; but he soon began to direct his attention to other subjects, and in 1834 published the results of a series of experiments on the velocity of electricity, made with apparatus constructed for him by the late Mr. Joseph Saxton, of Washington. The progress of science has shown that Wheatstone's experiments led him to conclusions which were in some respects untenable; but his paper was received with acclamation, and certainly gave a decided impulse to the science of electricity. The application of the revolving mirror to the measurement of very small intervals of time was the germ of the later determination of the velocity of light by Fizeau and Foucault. In 1837, Wheatstone associated himself with Cooke in a new attempt to solve the often mooted problem of an electric telegraph. The history of Wheatstone's share in the invention has often been written. He was not the first inventor of an electric telegraph. He was not even the first who attempted to carry into execution a clearly defined scientific conception. But he brought to the practical solution of the problem great mechanical resources, with extraordinary energy and perseverance, and in the end he triumphed in England exactly as Morse triumphed in this country, — triumphed by the tenacity of his intellectual grasp of the subject, by unflagging perseverance and unwavering faith. In estimating Wheatstone's merit in connection with the development of the electric telegraph, the eminent services rendered by his partner, Cooke, must not be forgotten. The two together did for England what Morse alone did for this country; but the special methods of Cooke and Wheatstone are already nearly forgotten, while those of Morse are in almost universal use. The list of Wheatstone's papers in the catalogue of the Royal Society includes only thirty titles. In 1838, he published his first paper on binocular vision, and during the same year he gave to the world the earliest form of the stereoscope. He seems to have considered the subject from a purely scientific point of view, and the form which he gave to the instrument was not adapted to popular use. The invention of the lenticular stereoscope by Sir David Brewster was the next step; but the full beauty and usefulness of the invention did not appear until after the discovery of the art of photography. With the somewhat bitter controversy which followed Brewster's improvement, we have nothing to do. To Wheatstone belongs the creation, not merely of a scientific instrument which almost takes rank with the microscope and telescope, not merely of a toy which has found its way to the households of all civilized races of men, and which is an unfailing source of cultivated and refined pleasure, but of a whole branch of physiological optics, the science of binocular vision, applicable to color as well as to form, and full of fruits of usefulness and beauty. In 1843, Wheatstone rendered another great service to science by the publication of a memoir on new instruments and processes for the determination of the constants of a voltaic circuit. In this paper he made known to England, and we believe we may also say to America, the theory of the galvanic circuit first proposed by Ohm. He gave to the applications of the theory a simple and clear mathematical form, devised a new and advantageous terminology, and introduced most ingenious special forms of apparatus, in particular that now universally known as Wheatstone's bridge. His prismatic analysis of the light of the electric spark taken between electrodes of mercury belongs with the early history of the spectroscope, and deserves to be cited in connection with that instrument. Wheatstone's eminent services to science received the fullest recognition during his lifetime, in both wealth and honor. It is, perhaps, too soon to measure his intellectual stature with perfect fairness, and materials for the story of his life are still wanting; but his name will always be associated with two of the most beautiful and useful of human inventions. On the 19th of October last, he closed a life which may well be called memorable.

Since the last Annual Meeting, the Academy has received an accession of nineteen new members: eight Fellows, — Henry Adams, Thomas Dwight, R. T. Edes, E. L. Godkin, Charles E. Hamlin, Hiram F. Mills, Ira Remsen, John L. Sibley; eight Associate Fellows, — A. N. Arnold, Joseph Le Conte, F. A. Genth, D. C. Gilman, O. C. Marsh, Alfred M. Mayer, H. A. Rowland, W. Sellers; and three Foreign Honorary Members, — Balfour Stewart, A. C. Ramsay, Count Sclopis di Salerano. On the other hand, by removal from the State, or by resignation, the following ten Fellows have abandoned their membership: S. P. Andrews, A. N. Arnold, J. B. Greenough, R. S. Greenough, Thomas Hill, Nathaniel Holmes, Edward Pearce, W. H. Pettee, G. M. Searle, W. H. Swift.

The list of the Academy corrected to May 10, 1876, is hereto added. It includes 191 Fellows, 94 Associate Fellows, and 66 Foreign Honorary Members.

LIST

OF THE FELLOWS AND FOREIGN HONORARY MEMBERS.

MAY 10, 1876.

FELLOWS. — 191.

(Number limited to two hundred.)

CLASS I. — *Mathematical and Physical Sciences.* — 61.

SECTION I. — 8.

Mathematics.

Ezekiel B. Elliott,	Washington.
William Ferrel,	Washington.
Benjamin A. Gould,	Cordoba.
Gustavus Hay,	Boston.
Benjamin Peirce,	Cambridge.
James M. Peirce,	Cambridge.
John D. Runkle,	Boston.
Edwin P. Seaver,	Cambridge.

SECTION II. — 7.

Practical Astronomy and Geodesy.

J. Ingersoll Bowditch,	Boston.
Alvan Clark,	Cambridgeport.
Henry Mitchell,	Roxbury.
Robert Treat Paine,	Boston.
William A. Rogers,	Cambridge.
George M. Searle,	New York.
Henry L. Whiting,	Boston.

SECTION III. — 27.

Physics and Chemistry.

John Bacon,	Boston.
John H. Blake,	Boston.
Thos. Edwards Clark,	Williamstown.
W. J. Clark,	Amherst.
Josiah P. Cooke, Jr.,	Cambridge.
James M. Crafts,	Boston.
William P. Dexter,	Roxbury.
Charles W. Eliot,	Cambridge.
Moses G. Farmer,	Newport.
Wolcott Gibbs,	Boston.
Augustus A. Hayes,	Brookline.
Henry B. Hill,	Cambridge.
Eben N. Horsford,	Cambridge.
T. Sterry Hunt,	Boston.
Charles L. Jackson,	Cambridge.
Joseph Lovering,	Cambridge.
John M. Merrick,	Boston.
William R. Nichols,	Boston.
John M. Ordway,	Boston.
Edward C. Pickering,	Boston.
Ira Remsen,	Williamstown.
Edward S. Ritchie,	Boston.
S. P. Sharples,	Cambridge.
Frank H. Storer,	Jamaica Plain.
John Trowbridge,	Cambridge.
Cyrus M. Warren,	Brookline.
Charles H. Wing,	Boston.

SECTION IV. — 19.

Technology and Engineering.

H. L. Abbot,	New York.
G. R. Baldwin,	Quebec.
John M. Batchelder,	Cambridge.
C. O. Boutelle,	Washington.
Edward C. Cabot,	Boston.
Henry L. Eustis,	Cambridge.
James B. Francis,	Lowell.
John B. Henck,	Boston.
John C. Lee,	Salem.
William R. Lee,	Roxbury.
Hiram F. Mills,	Lawrence.
Alfred P. Rockwell,	Boston.
John Rodgers,	Washington.
Stephen P. Ruggles,	Boston.
Charles S. Storrow,	Boston.
John H. Temple,	W. Roxbury.
William R. Ware,	Boston.
William Watson,	Boston.
Morrill Wyman,	Cambridge.

Class II. — *Natural and Physiological Sciences.* — 66.

Section I. — 11.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé, Boston.
William T. Brigham, Boston.
Algernon Coolidge, Boston.
John L. Hayes, Cambridge.
Charles T. Jackson, Boston.
Jules Marcou, Cambridge.
Raphael Pumpelly, Boston.
William B. Rogers, Boston.
Nathaniel S. Shaler, Cambridge.
Charles U. Shepard, Amherst.
Josiah D. Whitney, Cambridge.

Section II. — 10.

Botany.

Jacob Bigelow, Boston.
George B. Emerson, Boston.
William G. Farlow, Boston.
George L. Goodale, Cambridge.
Asa Gray, Cambridge.
H. H. Hunnewell, Wellesley.
John A. Lowell, Boston.
Chas. J. Sprague, Boston.
Edward Tuckerman, Amherst.
Sereno Watson, Cambridge.

Section III. — 26.

Zoölogy and Physiology.

Alex. E. R. Agassiz, Cambridge.
J. A. Allen, Cambridge.
Robert Amory, Brookline.
Nath. E. Atwood, Provincetown.
James M. Barnard, Boston.
Henry P. Bowditch, Boston.
Thomas M. Brewer, Boston.
Samuel Cabot, Boston.
John Dean, Waltham.
Silas Durkee, Boston.
Herrmann A. Hagen, Cambridge.
C. E. Hamlin, Cambridge.
Alpheus Hyatt, Cambridge.
Wm. James, Cambridge.
Samuel Kneeland, Boston.
Theodore Lyman, Boston.
John McCrady, Cambridge.
Edward S. Morse, Salem.
Alpheus S. Packard, Jr., Salem.
Charles Pickering, Boston.
L. Francis Pourtales, Cambridge.
Frederic W. Putnam, Salem.
Samuel H. Scudder, Cambridge.
D. Humphreys Storer, Boston.
Henry Wheatland, Salem.
James C. White, Boston.

Section IV. — 19.

Medicine and Surgery.

Samuel L. Abbot, Boston.
Henry J. Bigelow, Boston.
Henry I. Bowditch, Boston.
Edward H. Clarke, Boston.
Benjamin E. Cotting, Roxbury.
Thomas Dwight, Boston.
Robert T. Edes, Roxbury.
Calvin Ellis, Boston.
Richard M. Hodges, Boston.
Oliver W. Holmes, Boston.
R. W. Hooper, Boston.
John B. S. Jackson, Boston.
Edward Jarvis, Dorchester.
Edward Reynolds, Boston.
Horatio R. Storer, Boston.
John E. Tyler, Boston.
J. Baxter Upham, Boston.
Charles E. Ware, Boston.
Henry W. Williams, Boston.

Class III. — *Moral and Political Sciences.* — 64.

Section I. — 19.

Philosophy and Jurisprudence.

George Bemis,	Boston.
George T. Bigelow,	Boston.
Francis Bowen,	Cambridge.
Richard H. Dana, Jr.,	Boston.
C. C. Everett,	Cambridge.
Horace Gray,	Boston.
Nich. St. John Green,	Cambridge.
Frederic H. Hedge,	Cambridge.
L. P. Hickok,	Northampton.
Ebenezer R. Hoar,	Concord.
Mark Hopkins,	Williamstown.
C. C. Langdell,	Cambridge.
Henry W. Paine,	Cambridge.
Theophilus Parsons,	Cambridge.
Charles S. Peirce,	Washington.
William A. Stearns,	Amherst.
Benjamin F. Thomas,	Boston.
Emory Washburn,	Cambridge.
Francis Wharton,	Cambridge.

Section II. — 11.

Philology and Archæology.

Ezra Abbot,	Cambridge.
William P. Atkinson,	Boston.
H. G. Denny,	Boston.
Epes S. Dixwell,	Cambridge.
William Everett,	Cambridge.
William W. Goodwin,	Cambridge.
Ephraim W. Gurney,	Cambridge.
Chandler Robbins,	Boston.
John L. Sibley,	Cambridge.
E. A. Sophocles,	Cambridge.
Edward J. Young,	Cambridge.

Section III. — 18.

Political Economy and History.

Chas. F. Adams, Jr.,	Quincy.
Henry Adams,	Boston.
Erastus B. Bigelow,	Boston.
Caleb Cushing,	Newburyport.
Charles Deane,	Cambridge.
Charles F. Dunbar,	Cambridge.
Samuel Eliot,	Boston.
George E. Ellis,	Boston.
E. L. Godkin,	Cambridge.
William Gray,	Boston.
Edward Everett Hale,	Boston.
J. L. Motley,	Boston.
Francis Parkman,	Brookline.
A. P. Peabody,	Cambridge.
Edmund Quincy,	Dedham.
Nathaniel Thayer,	Boston.
Henry W. Torrey,	Cambridge.
Robert C. Winthrop,	Boston.

Section IV. — 16.

Literature and the Fine Arts.

Charles F. Adams,	Boston.
William T. Andrews,	Boston.
George S. Boutwell,	Groton.
J. Elliot Cabot,	Brookline.
Francis J. Child,	Cambridge.
Ralph Waldo Emerson,	Concord.
John C. Gray,	Cambridge.
George S. Hillard,	Boston.
Henry W. Longfellow,	Cambridge.
James Russell Lowell,	Cambridge.
Charles Eliot Norton,	Cambridge.
John K. Paine,	Cambridge.
Thomas W. Parsons,	Boston.
Charles C. Perkins,	Boston.
John G. Whittier,	Amesbury.
Edward Wigglesworth,	Boston.

ASSOCIATE FELLOWS. — 94.

(Number limited to one hundred.)

Class I. — *Mathematical and Physical Sciences.* — 36.

Section I. — 7.

Mathematics.

Charles Avery, Clinton, N.Y.
Alexis Caswell, Providence, R.I.
Charles Davies, New York.
Simon Newcomb, Washington, D.C.
H. A. Newton, New Haven, Conn.
James E. Oliver, Ithaca, N.Y.
Truman H. Safford, Chicago, Ill.

Section II. — 12.

Practical Astronomy and Geodesy.

S. Alexander, Princeton, N.J.
W. H. C. Bartlett, West Point, N.Y.
J. H. C. Coffin, Washington, D.C.
Chas. H. Davis, Washington, D.C.
Wm. H. Emory, Washington, D.C.
J. E. Hilgard, Washington, D.C.
George W. Hill, Nyack, N.Y.
Elias Loomis, New Haven, Conn.
Maria Mitchell, Poughkeepsie, N.Y.
C. H. F. Peters, Clinton, N.Y.
Charles Wilkes, Washington, D.C.
Chas. A. Young, Hanover, N.H.

Section III. — 12.

Physics and Chemistry.

F. A. P. Barnard, New York.
John W. Draper, New York.
Joseph Henry, Washington, D.C.
S. W. Johnson, New Haven, Conn.
John Le Conte, San Francisco, Cal.
A. M. Mayer, Hoboken, N. J.
W. A. Norton, New Haven, Conn.
Ogden N. Rood, New York.
H. A. Rowland, Baltimore.
L. M. Rutherfurd, New York.
Benj. Silliman, New Haven, Conn.
J. L. Smith, Louisville, Ky.

Section IV. — 5.

Technology and Engineering.

R. Delafield, Washington, D.C.
A. A. Humphreys, Washington, D.C.
Wm. Sellers, Philadelphia.
George Talcott, Albany, N.Y.
W. P. Trowbridge, New Haven, Conn.

Class II. — *Natural and Physiological Sciences.* — 30.

Section I. — 14.

Geology, Mineralogy, and Physics of the Globe.

George J. Brush, New Haven, Conn.
James D. Dana, New Haven, Conn.
J. W. Dawson, Montreal, Canada.
Edward Desor, Neufchâtel, Switz.
J. C. Fremont, New York.
F. A. Genth, Philadelphia.
Arnold Guyot, Princeton, N.J.
James Hall, Albany, N.Y.
F. S. Holmes, Charleston, S.C.
Joseph LeConte, San Francisco.
J. Peter Lesley, Philadelphia.
Fred. B. Meek, Washington, D.C.
Wm. T. Roepper, Bethlehem, Pa.
Geo. C. Swallow, Columbia, Mo.

Section II. — 4.

Botany.

A. W. Chapman, Apalachicola, Fla.
G. Engelmann, St. Louis, Mo.
Leo Lesquereux, Columbus, Ohio.
S. T. Olney, Providence, R.I.

Section III. — 9.

Zoölogy and Physiology.

S. F. Baird, Washington, D.C.
C. E. Brown-Séquard, New York.
J. C. Dalton, New York.
J. P. Kirtland, Cleveland, Ohio.
J. L. LeConte, Philadelphia.
Joseph Leidy, Philadelphia.
O. C. Marsh, New Haven, Conn.
S. Weir Mitchell, Philadelphia.
St. John Ravenel, Charleston, S.C.

Section IV. — 3.

Medicine and Surgery.

W. A. Hammond, New York.
Isaac Hays, Philadelphia.
George B. Wood, Philadelphia.

Class III. — *Moral and Political Sciences.* — 28.

Section I. — 6.

Philosophy and Jurisprudence.

D. R. Goodwin, Philadelphia.
R. G. Hazard, Peacedale, R.I.
James McCosh, Princeton.
Noah Porter, New Haven, Conn.
Isaac Ray, Philadelphia.
Jeremiah Smith, Dover, N.H.

Section II. — 11.

Philology and Archæology.

A. N. Arnold, Hamilton, N.Y.
D. C. Gilman, Baltimore.
S. S. Haldeman, Columbia, Pa.
A. C. Kendrick, Rochester, N.Y.
Geo. P. Marsh, Rome.
L. H. Morgan, Rochester, N.Y.
A. S. Packard, Brunswick, Me.
E. E. Salisbury, New Haven, Conn.
A. D. White, Ithaca, N.Y.
W. D. Whitney, New Haven, Conn.
T. D. Woolsey, New Haven, Conn.

Section III. — 7.

Political Economy and History.

S. G. Arnold, Newport, R.I.
Geo. Bancroft, Washington.
S. G. Brown, Clinton, N.Y.
Henry C. Carey, Philadelphia.
Henry C. Lea, Philadelphia.
Barnas Sears, Scranton, Va.
J. H. Trumbull, Hartford.

Section IV. — 4.

Literature and the Fine Arts.

James B. Angell, Ann Arbor, Mich.
Wm. C. Bryant, New York.
F. E. Church, New York.
Wm. W. Story, Rome.

FOREIGN HONORARY MEMBERS.—66.

(Appointed as vacancies occur.)

Class I.—*Mathematical and Physical Sciences.*—25.

Section I.—8.

Mathematics.

John C. Adams,	Cambridge.
Sir George B. Airy,	Greenwich.
Brioschi,	Milan.
Arthur Cayley,	London.
Chasles,	Paris.
Le Verrier,	Paris.
Liouville,	Paris.
J. J. Sylvester,	Woolwich.

Section II.—4.

Practical Astronomy and Geodesy.

Döllen,	Pulkowa.
H. A. E. A. Faye,	Paris.
Peters,	Altona.
Otto Struve,	Pulkowa.

Section III.—11.

Physics and Chemistry.

Bunsen,	Heidelberg.
Chevreul,	Paris.
Dumas,	Paris.
Helmholtz,	Berlin.
Kirchhoff,	Berlin.
J. C. Maxwell,	Cambridge.
J. C. Poggendorff,	Berlin.
Regnault,	Paris.
Balfour Stewart,	Manchester.
G. G. Stokes,	Cambridge.
Wöhler,	Göttingen.

Section IV.—2.

Technology and Engineering.

Clausius,	Bonn.
Sir Wm. Thomson,	Glasgow.

Class II.—*Natural and Physiological Sciences.*—25.

Section I.—8.

Geology, Mineralogy, and Physics of the Globe.

Barrande,	Prague.
Charles Darwin,	London.
Dove,	Berlin.
James Prescott Joule,	Manchester.
W. H. Miller,	Cambridge.
Rammelsberg,	Berlin.
A. C. Ramsay,	London.
Sir Edward Sabine,	London.

Section II.—7.

Botany.

George Bentham,	London.
Alexander Braun,	Berlin.
Decaisne,	Paris.
Alphonse de Candolle,	Geneva.
Elias Fries,	Upsal.
Hofmeister,	Tübingen.
Joseph Dalton Hooker,	London.

SECTION III. — 8.

Zoölogy and Physiology.

Von Baer, St. Petersburg.
T. L. W. Bischoff, Munich.
Milne-Edwards, Paris.
Ehrenberg, Berlin.
Albrecht Kölliker, Würzburg.
Richard Owen, London.
C. Th. Von Siebold, Munich.
Valentin, Berne.

SECTION IV. — 2.

Medicine and Surgery.

Rokitansky, Vienna.
Virchow, Berlin.

CLASS III. — *Moral and Political Sciences.* — 16.

SECTION I. — 4.

Philosophy and Jurisprudence.

T. C. Bluntschli, Heidelberg.
Sumner Maine, London.
James Martineau, London.
Sclopis di Salerano, Turin.

SECTION II. — 6.

Philology and Archæology.

Pascual de Gayangos, Madrid.
Benjamin Jowett, Oxford.
Christian Lassen, Bonn.
Lepsius, Berlin.
Max Müller, Oxford.
F. Ritschl, Bonn.

SECTION III. — 5.

Political Economy and History.

W. Ewart Gladstone, London.
Charles Merivale, Oxford.
Mommsen, Berlin.
Von Ranke, Berlin.
Thiers, Paris.

SECTION IV. — 1.

Literature and the Fine Arts.

Gérôme, Paris.

STATUTES

AND

STANDING VOTES

OF THE

AMERICAN ACADEMY OF ARTS AND SCIENCES.

(*Adopted May* 30, 1854: *amended September* 8, 1857, *November* 12, 1862, *May* 24, 1864, *November* 9, 1870, *February* 11, 1873, *and January* 26, 1876.)

CHAPTER I.

OF FELLOWS AND FOREIGN HONORARY MEMBERS

1. The Academy consists of *Fellows* and *Foreign Honorary Members*. They are arranged in three classes, according to the Arts and Sciences in which they are severally proficient, viz.: Class I. The Mathematical and Physical Sciences; Class II. The Natural and Physiological Sciences; Class III. The Moral and Political Sciences. Each Class is divided into four Sections, viz.: Class I. Section 1. Mathematics; Section 2. Practical Astronomy and Geodesy; Section 3. Physics and Chemistry; Section 4. Technology and Engineering. Class II. Section 1. Geology, Mineralogy, and Physics of the Globe; Section 2. Botany; Section 3. Zoölogy and Physiology; Section 4. Medicine and Surgery. Class III. Section 1. Philosophy and Jurisprudence; Section 2. Philology and Archæology; Section 3. Political Economy and History; Section 4. Literature and the Fine Arts.

2. Fellows resident in the State of Massachusetts can alone vote at the meetings of the Academy.* They shall each pay to the Treasurer the sum of ten dollars on admission, and an annual assessment of ten dollars, with such additional sum, not exceeding five dollars, as the Academy shall, by a standing vote, from time to time determine.

3. Fellows residing out of the State of Massachusetts shall be known and distinguished as Associate Fellows. They shall not be liable to the payment of any fees or annual dues, but, on removing within the State, shall be admitted to the privileges,† and be subject to the obligations, of Resident Fellows. The number of Associate Fellows shall not exceed *one hundred*, of whom there shall not be more than *forty* in either of the three classes of the Academy.

4. The number of Foreign Honorary Members shall not exceed *seventy-five;* and they shall be chosen from among persons most eminent in foreign countries for their discoveries and attainments in either of the three departments of knowledge above enumerated. And there shall not be more than thirty Foreign Members in either of these departments.

CHAPTER II.

OF OFFICERS.

1. There shall be a President, a Vice-President, a Corresponding Secretary, a Recording Secretary, a Treasurer, and a Librarian, which officers shall be annually elected, by written votes, at the Annual Meeting, on the day next preceding the last Wednesday in May.

2. At the same time and in the same manner, nine Councillors shall be elected, three from each Class of the Academy, but the same Fellows shall not be eligible for more than three

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* The number of Resident Fellows is limited by the Charter to 200.

† Associate Fellows may attend but cannot vote at meetings of the Academy. See Chapter I. 2.

successive years. These nine Councillors, with the President, Vice-President, the Treasurer, and the two Secretaries, shall constitute the Council. It shall be the duty of this Council to exercise a discreet supervision over all nominations and elections. With the consent of the Fellow interested, they shall have power to make transfers between the several sections of the same Class, reporting their action to the Academy.

3. If any office shall become vacant during the year, the vacancy shall be filled by a new election, and at the next stated meeting.

CHAPTER III.

OF THE PRESIDENT.

1. It shall be the duty of the President, and, in his absence, of the Vice-President or next officer in order, as above enumerated, to preside at the meetings of the Academy; to summon extraordinary meetings, upon any urgent occasion; and to execute or see to the execution of the Statutes of the Academy.

2. The President, or, in his absence, the next officer as above enumerated, is empowered to draw upon the Treasurer for such sums of money as the Academy shall direct. Bills presented on account of the Library, or the publications of the Academy, must be previously approved by the respective committees on these departments.

3. The President, or, in his absence, the next officer as above enumerated, shall nominate members to serve on the different committees of the Academy which are not chosen by ballot.

4. Any deed or writing, to which the common seal is to be affixed, shall be signed and sealed by the President, when thereto authorized by the Academy.

CHAPTER IV.

OF STANDING COMMITTEES.

1. At the Annual Meeting there shall be chosen the following Standing Committees, to serve for the year ensuing, viz.: —

2. The Committee of Finance, to consist of the President, Treasurer, and one Fellow chosen by ballot, who shall have charge of the investment and management of the funds and trusts of the Academy. The general appropriations for the expenditures of the Academy shall be moved by this Committee at the Annual Meeting, and all special appropriations from the general and publication funds shall be referred to or proposed by this Committee.

3. The Rumford Committee, of seven Fellows, to be chosen by ballot, who shall consider and report on all applications and claims for the Rumford Premium, also on all appropriations from the income of the Rumford Fund, and generally see to the due and proper execution of this trust.

4. The Committee of Publication, of three Fellows, to whom all Memoirs submitted to the Academy shall be referred, and to whom the printing of Memoirs accepted for publication shall be intrusted.

5. The Committee on the Library, of three Fellows, who shall examine the Library, and make an annual report on its condition and management.

6. An Auditing Committee, of two Fellows, for auditing the accounts of the Treasurer.

CHAPTER V.

OF THE SECRETARIES.

1. The Corresponding Secretary shall conduct the correspondence of the Academy, recording or making an entry of

all letters written in its name, and preserving on file all letters which are received; and at each meeting he shall present the letters which have been addressed to the Academy since the last meeting. With the advice and consent of the President, he may effect exchanges with other scientific associations, and also distribute copies of the publications of the Academy among the Associate Fellows and Foreign Honorary Members, as shall be deemed expedient; making a report of his proceedings at the Annual Meeting. Under the direction of the Council for Nomination, he shall keep a list of the Fellows, Associate Fellows, and Foreign Honorary Members, arranged in their Classes and in Sections in respect to the special sciences in which they are severally proficient; and he shall act as secretary to the Council.

2. The Recording Secretary shall have charge of the Charter and Statute-book, journals, and all literary papers belonging to the Academy. He shall record the proceedings of the Academy at its meetings; and, after each meeting is duly opened, he shall read the record of the preceding meeting. He shall notify the meetings of the Academy, and apprise committees of their appointment. He shall post up in the Hall a list of the persons nominated for election into the Academy; and, when any individual is chosen, he shall insert in the record the names of the Fellows by whom he was nominated.

3. The two Secretaries, with the Chairman of the Committee of Publication, shall have authority to publish such of the proceedings of the Academy as may seem to them calculated to promote the interests of science.

CHAPTER VI.

OF THE TREASURER.

1. The Treasurer shall give such security for the trust reposed in him as the Academy shall require.

2. He shall receive officially all moneys due or payable,

and all bequests or donations made to the Academy, and by order of the President or presiding officer shall pay such sums as the Academy may direct. He shall keep an account of all receipts and expenditures; shall submit his accounts to the Auditing Committee; and shall report the same at the expiration of his term of office.

3. The Treasurer shall keep a separate account of the income and appropriation of the Rumford Fund, and report the same annually.

4. All moneys which there shall not be present occasion to expend shall be invested by the Treasurer, under the direction of the Finance Committee, on such securities as the Academy shall direct.

CHAPTER VII.

OF THE LIBRARIAN AND LIBRARY.

1. It shall be the duty of the Librarian to take charge of the books, to keep a correct catalogue of the same, and to provide for the delivery of books from the Library. He shall also have the custody of the publications of the Academy.

2. The Librarian, in conjunction with the Committee on the Library, shall have authority to expend, as they may deem expedient, such sums as may be appropriated, either from the Rumford or the General Fund of the Academy, for the purchase of books and for defraying other necessary expenses connected with the Library. They shall have authority to propose rules and regulations concerning the circulation, return, and safe-keeping of books; and to appoint such agents for these purposes as they may think necessary.

3. To all books in the Library procured from the income of the Rumford Fund, the Librarian shall cause a stamp or label to be affixed, expressing the fact that they were so procured.

4. Every person who takes a book from the Library shall give a receipt for the same to the Librarian or his assistant.

5. Every book shall be returned in good order, regard

being had to the necessary wear of the book with good usage. And if any book shall be lost or injured, the person to whom it stands charged shall replace it by a new volume or set, if it belong to a set, or pay the current price of the volume or set to the Librarian; and thereupon the remainder of the set, if the volume belonged to a set, shall be delivered to the person so paying for the same.

6. All books shall be returned to the Library for examination, at least one week before the Annual Meeting.

CHAPTER VIII.

OF MEETINGS.

1. There shall be annually four stated meetings of the Academy; namely, on the day next preceding the last Wednesday in May (the Annual Meeting), on the second Wednesday in October, on the second Wednesday in January, and on the second Wednesday in March; to be held in the Hall of the Academy, in Boston. At these meetings only, or at meetings adjourned from these and regularly notified, shall appropriations of money be made, or alterations of the statutes or standing votes of the Academy be effected.

2. Fifteen Fellows shall constitute a quorum for the transaction of business at a stated meeting. Seven Fellows shall be sufficient to constitute a meeting for scientific communications and discussions.

3. The Recording Secretary shall notify the meetings of the Academy to each Fellow residing in Boston and the vicinity; and he may cause the meetings to be advertised, whenever he deems such further notice to be needful.

CHAPTER IX.

OF THE ELECTION OF FELLOWS AND HONORARY MEMBERS.

1. Elections shall be made by ballot, and only at stated meetings.

2. Candidates for election as Resident Fellows must be proposed by two or more Resident Fellows in a recommendation signed by them specifying the section to which the nomination is made, which recommendation shall be transmitted to the Corresponding Secretary, and by him referred to the Council for nomination. No person recommended shall be reported by the Council as a candidate for election, unless he shall have received a written approval, signed at a meeting of the Council by at least eight of its members. All nominations thus approved shall be read to the Academy at a stated meeting, and shall then stand on the nomination list during the interval between two stated meetings, and until the balloting. No person shall be elected a Resident Fellow, unless he shall have been resident in this Commonwealth one year next preceding his election; and any Resident Fellow, who shall remove his domicile from the Commonwealth, shall be deemed to have abandoned his Fellowship. If any person elected a Resident Fellow shall neglect for one year to pay his admission fee, his election shall be void; and, if any Resident Fellow shall neglect to pay his annual assessments for two years, provided that his attention shall have been called to this article, he shall be deemed to have abandoned his Fellowship; but it shall be in the power of the Treasurer, with the consent of the Council, to dispense (*sub silentio*) with the payment both of the admission fee and of the assessments, whenever in any special instance he shall think it advisable so to do.

3. The nomination of Associate Fellows shall take place in the manner prescribed in reference to Resident Fellows; and after such nomination shall have been publicly read at a stated meeting previous to that when the balloting takes

place, it shall be referred to a Council for Nomination; and a written approval, authorized and signed at a meeting of said Council by at least seven of its members, shall be requisite to entitle the candidate to be balloted for. The Council may in like manner originate nominations of Associate Fellows; which must be read at a stated meeting previous to the election, and be exposed on the nomination list during the interval.

4. Foreign Honorary Members shall be chosen only after a nomination made at a meeting of the Council, signed at the time by at least seven of its members, and read at a stated meeting previous to that on which the balloting takes place.

5. Three-fourths of the ballots cast must be affirmative, and the number of affirmative ballots must amount to eleven, to effect an election of Fellows or Foreign Honorary Members.

6. Each section of the Academy is empowered to present lists of persons deemed best qualified to fill vacancies occurring in the number of Foreign Honorary Members or Associate Fellows allotted to it; and such lists, after being read at a stated meeting, shall be referred to the Council for Nomination.

7. If, in the opinion of a majority of the entire Council, any Fellow — Resident or Associate — shall have rendered himself unworthy of a place in the Academy, the Council shall recommend to the Academy the termination of his Fellowship; and, provided that a majority of two-thirds of the Fellows at a stated meeting, consisting of not less than fifty Fellows, voting by ballot yea or nay, shall adopt this recommendation, his name shall be stricken off the roll of Fellows.

CHAPTER X.

OF AMENDMENTS OF THE STATUTES.

1. All proposed alterations of the Statutes, or additions to them, shall be referred to a committee, and, on their report at a subsequent meeting, shall require for enactment a majority

of two-thirds of the members present, and at least eighteen affirmative votes.

2. Standing Votes may be passed, amended, or rescinded, at any stated meeting, by a majority of two-thirds of the members present. They may be suspended by a unanimous vote.

CHAPTER XI.

OF LITERARY PERFORMANCES.

1. The Academy will not express its judgment on literary or scientific memoirs or performances submitted to it, or included in its publications.

RUMFORD PREMIUM.

In conformity with the terms of the gift of Benjamin Count Rumford, granting a certain fund to the American Academy of Arts and Sciences, and with a decree of the Supreme Judicial Court for carrying into effect the general charitable intent and purpose of Count Rumford, as expressed in his letter of gift, the Academy is empowered to make from the income of said fund, as it now exists, at any annual meeting, an award of a gold and silver medal, being together of the intrinsic value of three hundred dollars, as a premium, to the author of any important discovery or useful improvement in light or in heat, which shall have been made and published by printing, or in any way made known to the public, in any part of the continent of America, or any of the American islands; preference being always given to such discoveries as shall, in the opinion of the Academy, tend most to promote the good of mankind; and to add to such medals, as a further premium for such discovery and improvement, if the Academy see fit so to do, a sum of money not exceeding three hundred dollars.

STANDING VOTES.

1. Communications of which notice has been given to the Secretary shall take precedence of those not so notified.

2. Resident Fellows who have paid all fees and dues chargeable to them are entitled to receive one copy of each volume or article printed by the Academy, on application to the Librarian personally or by written order, within two years from the date of publication. And the current issues of the Proceedings shall be supplied, when ready for publication, free of charge to all the Fellows and Members of the Academy who desire to receive them.

3. The Committee of Publication shall fix from time to time the price at which the publications of the Academy may be sold. But members may be supplied at half this price with volumes which they are not entitled to receive free, and which are needed to complete their sets.

4. One hundred extra copies of each paper accepted for the Memoirs of the Academy shall be separately printed, of which fifty shall be placed at the disposal of the author, free of charge.

5. Resident Fellows may borrow and have out from the Library six volumes at any one time, and may retain the same for three months, and no longer.

6. Upon special application, and for adequate reasons assigned, the Librarian may permit a larger number of volumes, not exceeding twelve, to be drawn from the Library, for a limited period.

7. Works published in numbers, when unbound, shall not be taken from the Hall of the Academy, except by special leave of the Librarian.

8. Books, publications, or apparatus shall be procured from the income of the Rumford Fund only on the certificate of the Rumford Committee, that they, in their opinion, will best facilitate and encourage the making of discoveries and improvements which may merit the Rumford Premium.

9. The annual meeting shall be holden at half-past three o'clock, P.M. The other stated meetings, at half-past seven o'clock, P.M.

10. A meeting for receiving and discussing scientific communications shall be held on the second Wednesday of each month, not appointed for stated meetings, excepting July, August, and September.

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V.

W.

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