to praise our system and to express the hope that it might be adapted to meet their necessities on the other side of the Atlantic.

The mining and metallurgical laboratory, then, as developed in this country, may be considered a necessary adjunct to every school of mining engineering. In it the lecture-instruction is illustrated with practical experiments, carried out by the students themselves. But it has also a larger scope. By the method of experiment, the student learns how to take hold of each problem as it presents itself and carry it through the different stages until it is, or the reason is discovered why it cannot be, satisfactorily solved. He is thus taught to observe closely, to make careful notes, to compare the results obtained and draw his own inferences and conclusions, and, finally, to report what he has done in clear and accurate language.

In fitting up a laboratory, we have to consider only the departments of mechanical concentration and metallurgy. Practical mining can be taught only in the mine. Some schools (for instance, the one at Ballarat, Victoria, Australia) are provided with a model of full natural size, showing a shaft with the lode, cross-cuts, etc. While this, apart from the question of expense, is an improvement on the small models formerly so extensively found at schools, it cannot but give a false impression of what a mine really is. The practical study of mining, in this country at least, is carried on to-day in "summer schools." The students spend some time in mines, going systematically through the different kinds of work, and thus becoming sufficiently familiar with mine-operations to listen understandingly to lectures on the subject. It is the merit of Prof. H. S. Munroe, of Columbia College, to have given to the summer school of mining such an impetus that to-day there is hardly an American mining school without this auxiliary course.

Before discussing in detail the equipment of a laboratory, it is desirable to consider the relation which the laboratory plant should bear, as regards general arrangement and the kind and size of apparatus, to the large scale working plant of actual practice. A commercial concentrating works, for example, must treat daily a considerable quantity of ore, and must work cheaply, which can only be done if the machines are so connected with one another that the ore shall receive a minimum amount of handling after the work is once under way. In the laboratory, on the other hand, the work, being purely experimental, must be carried on, step by step, in a deliberate and tentative way; and it is therefore essential that the operator shall be able to inspect the material under treatment before and after every operation. Consequently, the machines must be separate, that they may be easily accessible for starting, stopping, accelerating and retarding, and may be connected at will; in short, that the work may be modified indefinitely under the immediate eye of the experimenter. A laboratory in which this principle is neglected carries in it the germ of failure. The writer was once connected with such an establishment, in which a full-sized ore dressing plant had been erected according to the plan followed in commercial work, viz., the crushed ore was raised by a bucket elevator to a set of screens placed in a line step-wise, one discharging into the other, and the sized products falling directly upon the jigs and the table below. Of course, a few tons of ore were quickly disposed of; but when the products obtained were examined after the experiment, the observer did not know very much more than he had known before. Such a working plant may be of some value for obtaining more accurate quantitative results after all the necessary details have been determined by the use of detached machines; but it will do little more than substantiate what has already been sufficiently proven.

There are two opposite views concerning the kind and size of machinery proper for laboratory use. One holds that it should follow as closely as possible that of a working plant. The other maintains the superiority of somewhat different and smaller apparatus as better suited to experimental purposes and also more economical. Having tried both kinds, the writer decidedly prefers the latter, especially for educational purposes, and is of the opinion that there are few mechanical questions to which a machine smaller than the commercial size cannot give a satisfactory answer. In addition to economy, convenience and other considerations, the saving of physical strain upon the student secured by the smaller apparatus is of importance. Fatiguing operations, especially for those unaccustomed to the work, exhaust the powers and unfit the student for mental effort.

The best size for the single machine can only be arrived at by repeated trials, which have now been made for almost all given cases, as will be shown later on.

In the discussion of the details of a laboratory, it will be more profitable to start from the basis of an actual working laboratory, whatever may be its defects, than from an imaginary perfect one. The laboratories of the Massachusetts Institute of Technology, shown in plan in Fig. 1, may well serve this purpose.

The following are the different rooms, pieces of apparatus, etc., referred to by numbers in Fig. 1. In the present paper numbers enclosed in brackets are to be understood as referring to this figure.

1. Milling-room.
2. Blake Challenge rock-breaker.
3. Cornish rolls.
4. Gates rock-breaker.
5. Hendrie-Bolthoff sample-grinder.
6. Iron sampling-floor.
7. Cornish feeder.
8. Automatic feed-trough.
9. Richards' *Spitzlutte.*
10. Coarse Collom jig.
11. Fine Collom jig.
12. Convex continuous round table.
13. Hendy Improved Challenge ore-feeder.
14. Stamp-battery.
15. Amalgamated plates.
16. Frue vanner.
17. Richards' movable sieve jig.
18. Water-tanks.
19. Steam-drying tables.
20. Bucking plates and Taylor hand-crusher.
21. Sampling-table.
22. Ore-bins.
23. Pounding-block.
24. Upright engine.
24.1. Morrel agate mortars.
25. Dynamo, 50 V by 50 A.
26. Dynamo, 2 V by 50 A.
26.1. Revolving barrel.
27. Depositing-table.
28. Leaching-tubs.
29. Larger amalgamating-pans.
30. Small amalgamating-pans.
31. Settler.
32. Tank.
33. Space to grow in.
34. Store-room.
35. Blacksmith's drilling machine.
36. Carpenter's bench.
36.1. Ball-mill.
37. Assay-room.
38. Students' desks.
39. Pulp-balances.
40. Muffle-furnaces.
41. Crucible-furnaces.
42. Stack.
43. Iron table.
44. Balance-room.
45. Button-balances.
46. Store-room.
47. Store-room.
48. Furnace-room.
49. Blacksmith's forge.
50. Anvil.
51. Blacksmith's table.
52. Water-jacket blast-furnace.
53. Furnace ore-bins.
54. Brückner roasting-cylinder.
55. Copper-refining furnace.
56. Large hand-roasting reverberatory.
57. Roasting-stall.
58. Cast-iron kettle
59. Large cupelling-furnace.
60. Small hand-roasting reverberatory.
61. Small cupelling-furnace
62. Pot-furnaces.
63. Space to grow in.
64. Professors' laboratory.
65. Table for electrolytic work.
66. Experimental *Spitzlutte.*
67. Chemical desks.
68. Hood.
69. Blow-pipe room.
70. Tables.
71. Cases for apparatus, etc.
72. Sink.
73. Library.
74. Book-cases.
75. Space to grow in.
76. Table.
77. Professors' desks.
78. Lithographic notes, etc.
79. Toilet-room.
80. Lockers.
81. Basins.
82. Closets.
83. Professors' room.
84. Stack.

These laboratories are located in the basement of the Rogers building, in the main building of the Institute, and comprise the entire department of mining, engineering and metallurgy, with the exception of the lecture-rooms and collections. While at first * all the metallurgical work, including dry-assaying, was done in the room marked [48] and the milling-work in the space now covered by machines [13] and [16], there are to-day a separate furnace-room [48], an assay- and balance-room [37, 44], a milling-room [1] and a blow-pipe room [69]. To these may be added two storage-rooms [46, 47], a toilet-room [79], a library [73] and the private laboratory [64] and office [77]. Upon closer inspection, it will be seen that the apparatus is pretty closely crowded. Although there is some "space to grow" [33, 63, 75], and there are places near [1] and [33] still open, there is little room for additional permanent machinery, the available space being necessary for erecting temporary apparatus and giving room to move about in. A laboratory built to-day with a liberal allowance of space and of funds would probably be planned somewhat differently as regards general arrangement, and would also possess a larger amount and variety of apparatus. The work in it would be easier and could be more conveniently and quickly, but not better, done.

In discussing the machines and furnaces, sufficient data will be given to enable the reader to form a clear idea of the relation which the laboratory-apparatus bears to that used in large-scale work.

The apparatus of the laboratory is best classed under three heads, corresponding with its purposes:

A.—Concentrating.
B.—Sampling and assay.
C.—Metallurgical.

A.—Concentrating Apparatus.

1. *Coarse Crushing.*—Coarse-crushing is represented by the Blake Challenge rock-breaker [2], with a receiving-capacity of 4½ by 5 inches, and the Gates rock-breaker [4] with a receiving-hopper 12 inches in diameter. The machines are at a sufficient height above the platform to allow a wheelbarrow or bucket to be placed below the discharge. A pipe, connected with a small suction-fan, serves to carrry off the dust, if desirable. The Blake is used for crushing lump-ore, the jaws being set 1¼ inches apart; the Gates for smaller sizes, the liners being set at ½ inch. The Dodge and Lowry crushers may be added to the plant if it is desired to crush ore more uniformly than can be done with the Blake or the Gates type; but this will hardly be necessary for the testing of ores, although it might be useful for illustrating class-work. The small Taylor hand-crusher [20] is very convenient for breaking up specimens.

2. *Fine Crushing.*—For fine crushing there are: a pair of Cornish rolls, a stamp-battery, a non-discharging ball mill, sets of pans, a sample grinder, and bucking plates.

The Cornish rolls [3], 9 inches in diameter and 9 inches in face, are of chilled iron, without the outside shell so common for large scale work; are driven by direct and cross belt, and make 70 revolutions per minute. The pressure on the sliding box is maintained by springs. The rolls have a large feed hopper, with adjustable discharge slot, holding about 100 pounds of quartzose ore. The crushed ore is directed by three converging pieces of sheet iron (a short, steep one at the back, and a long, flatter one on either side), towards an oblong opening, 5½ by 27 inches, through which it drops into an oblong sheet-iron box, 14 by 36 inches, of No. 22 iron, with sides 6 inches and ends 4 inches deep. The upper edges of all sheet iron boxes or vessels used in the laboratory are bent around a ¼-inch iron rod to give them strength, and are painted with asphalt varnish. If the ore is to be screened, an oblong wooden screen frame, 54 by 11 inches inside dimensions, made of 2½ by ⅞-inch wood, and closed at the upper end, is suspended in a slightly inclined position from four iron ($\frac{5}{16}$-inch) hooks from the wooden frame of the rolls, and oscillated by an excentric of 1-inch throw and 200 shakes per minute, driven from the main shaft below. The ore drops upon a piece of sheet iron, 11 by 12 inches, in the upper end of the frame, passing over which it comes to the screen (54 by 12¾ inches). Through this the finer parts fall into a sheet iron box, while the coarser ones are carried over into another which adjoins the first. The screens are fastened to the lower sides of their frames by means of angle hoop-iron and screws.

The crushing capacity of the rolls per hour is 600 pounds of quartzose ore to ¼-inch size, or 300 pounds to ⅛-inch, or 150 pounds to $\frac{1}{16}$-inch. While they serve their purpose for fine crushing, as a preliminary operation in ore dressing, yet, if ore is to be rolled previous to chloridizing and leaching, Krom rolls are very desirable for finishing, the Cornish rolls serving in that case as roughing rolls.

Roller mills, such as the Huntington, Griffin, and Tustin, or discharging ball mills, such as the Brückner, while doing satisfactory work in dry and wet rolling, are better suited for the mill than the laboratory, on account of the difficulty of cleaning up.

The stamp battery [14 and Fig. 2] is of the California pattern. It has the usual single discharge mortar for wet crushing, but only three stamps; the weight of the stamps is 228 pounds; the mortar bottom is 19¾ by 6 inches; the depth 5 inches; the discharge surface 20 by 10½ inches; the screen-frame 21½ by 13 inches; and the screen surface 18⅞ by 9¼ inches. The cams permit the lifting of the stamps to a height of 8 inches. The rate of crushing Nova Scotia gold quartz with a 7-inch height of discharge, a length of drop of 5¼ inches and 98 drops per minute is 3,353 pounds in twenty-four hours, or 1 pound for every 4,198 foot-pounds developed. With a 7½-inch drop and 60 drops per minute, it is 2,117 pounds, or 1 pound for every 5,816 foot-pounds. The coarsely crushed ore is fed to the battery by a Hendy Improved Challenge Ore Feeder [13]. A double discharge mortar, of which one side can be closed by an iron plate, will soon replace the old mortar, so that in the laboratory it will be possible to do both dry and wet stamping. In planning a new mill a battery with three stamps would not be chosen. The choice would lie between a 5-stamp battery of light stamps, say 300 pounds each, a 1 or 2-stamp battery, the stamp weighing 750 pounds, and a steam stamp. The 5-stamp battery has the advantage that the same number of stamps is used as in common practice. It would not be feasible to have a full size 5-stamp battery, as it entails too much work and requires more ore than is convenient and suitable for experimental work in the laboratory. The 1 or 2-stamp battery with 750 pound stamps dropping in a narrow double discharge mortar, one side of which could be closed at will, the discharge to be on a level with the base of the die and to be raised by chuck blocks to 16 inches, and the stamps to have a length of drop of from 4 to 10 inches, would be very acceptable. The results obtained with it would resemble very closely those of large scale work. As to the desirability of a steam stamp for laboratory use, the writer feels himself at present unable to express an opinion.

* R. W. Raymond, Statistics of Mines and Mining, 1874, pp. 499 and 500.