

BREATHING AND RESPIRATORY VOLUMES AND CAPACITIES

MATERIALS NEEDED

Textbook
 Spirometer, handheld (dry portable)
 70% alcohol
 Cotton
 Disposable mouthpieces
 Meterstick

For Demonstration:

Lung function model

1. Describe the mechanisms responsible for inspiration and expiration.
2. Define the respiratory air volumes and respiratory capacities.
3. Measure or calculate the respiratory air volumes and capacities.

PROCEDURE A—BREATHING MECHANISMS

1. Review the sections entitled "Inspiration" and "Expiration" in chapter 19 of the textbook.
2. Complete Part A of Laboratory Report 54.

SAFETY

- Clean the spirometer with cotton moistened with 70% alcohol before each use.
- Place a new disposable mouthpiece on the stem of the spirometer before each use.
- Dispose of the cotton and mouthpieces according to your laboratory instructor's directions.

DEMONSTRATION

Observe the mechanical lung function model. Note that it consists of a heavy plastic bell jar with a rubber sheeting tied over its wide open end. Its narrow upper opening is plugged with a rubber stopper through which a glass Y tube is passed. Small rubber balloons are fastened to the arms of the Y (fig. 54.1). What happens to the balloons when the rubber sheeting is pulled downward?

What happens when the sheeting is pushed upward?

How do you explain these changes?

What part of the respiratory system is represented by the rubber sheeting?
 the bell jar?
 the Y tube?
 the balloons?

WARNING

If the subject begins to feel dizzy or light-headed while performing Procedure B, stop the exercise and breathe normally.

Breathing involves the movement of air from outside the body through the bronchial tree and into the alveoli and the reversal of this air movement. These movements are caused by changes in the size of the thoracic cavity that result from skeletal muscle contractions and from the elastic recoil of stretched tissues.

The volumes of air that move in and out of the lungs during various phases of breathing are called *respiratory air volumes* and *capacities*. These volumes can be measured by using an instrument called a *spirometer*. However, the values obtained vary with a person's age, sex, height, and weight. Various respiratory capacities can be calculated by combining two or more of the respiratory volumes.

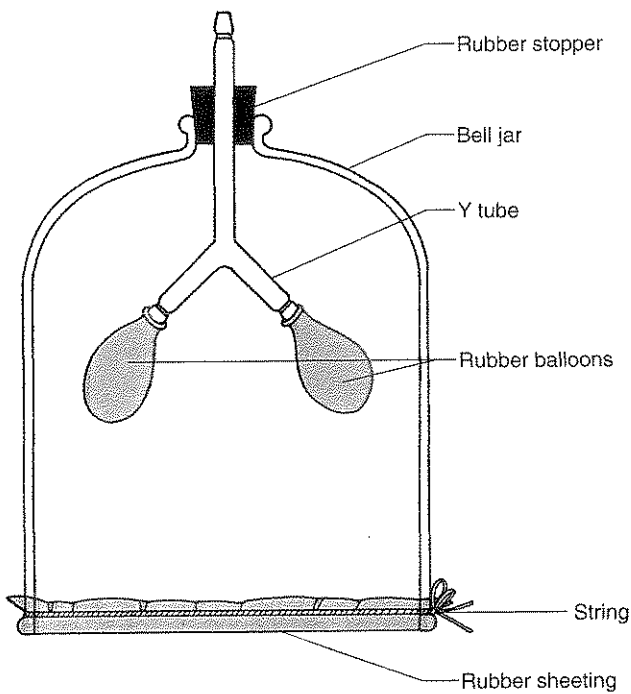
PURPOSE OF THE EXERCISE

To review the mechanisms of breathing and to measure or calculate certain respiratory air volumes and respiratory capacities.

LEARNING OBJECTIVES

After completing this exercise, you should be able to

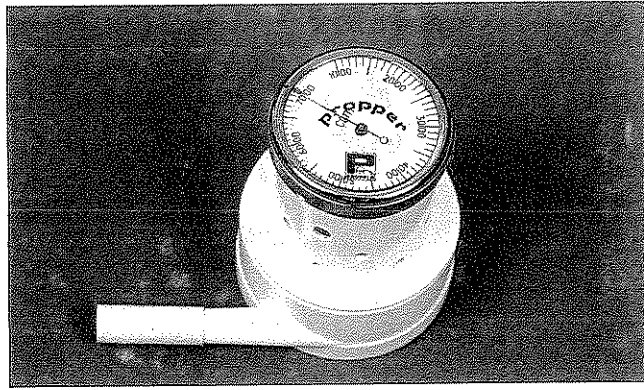
Figure 54.1 A lung function model.



PROCEDURE B—RESPIRATORY AIR VOLUMES AND CAPACITIES

1. Review the section entitled "Respiratory Volumes and Capacities" in chapter 19 of the textbook.
2. Complete Part B of the laboratory report.
3. Obtain a handheld spirometer. Note that the needle can be set at zero by rotating the adjustable dial. Before using the instrument, clean it with cotton moistened with 70% alcohol and place a new disposable mouthpiece over its stem. The instrument should be held with the dial upward, and air should be blown into the disposable mouthpiece. Movement of the needle indicates the air volume that leaves the lungs (fig. 54.2).
4. *Tidal volume* is the volume of air that enters (or leaves) the lungs during a *respiratory cycle* (one inspiration plus the following expiration). *Resting tidal volume* is the volume of air that enters (or leaves) the lungs during normal, quiet breathing (fig. 54.3). To measure this volume, follow these steps:
 - a. Sit quietly for a few moments.
 - b. Position the spirometer dial so that the needle points to zero.
 - c. Place the mouthpiece between your lips and exhale three ordinary expirations into it after inhaling through the nose each time. *Do not force air out of your lungs; exhale normally.*

Figure 54.2 A handheld spirometer can be used to measure respiratory air volumes.



- d. Divide the total value indicated by the needle by 3, and record this amount as your resting tidal volume on the table in Part C of the laboratory report.
5. *Expiratory reserve volume* is the volume of air in addition to the tidal volume that leaves the lungs during forced expiration. To measure this volume, follow these steps:
 - a. Breathe normally for a few moments. Set the needle to zero.
 - b. At the end of an ordinary expiration, place the mouthpiece between your lips and exhale all of the air you can force from your lungs through the spirometer.
 - c. Record the results as your expiratory reserve volume in Part C.
 6. *Vital capacity* is the maximum volume of air that can be exhaled after taking the deepest breath possible. To measure this volume, follow these steps:
 - a. Breathe normally for a few moments. Set the needle at zero.
 - b. Breathe in and out deeply a couple of times, then take the deepest breath possible.
 - c. Place the mouthpiece between your lips and exhale all the air out of your lungs, slowly and forcefully.
 - d. Record the value as your vital capacity in Part C. Compare your result with that expected for a person of your sex, age, and height listed in tables 54.1 and 54.2. Use the meterstick to determine your height in centimeters if necessary or multiply your height in inches times 2.54 to calculate your height in centimeters. Considerable individual variations from the expected will be noted due to parameters other than sex, age, and height, which could include physical shape, health, medications, and others.

Table 54.1 Predicted Vital Capacities (in Milliliters) for Females

Age	Height in Centimeters																								
	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184	186	188	190	192	194
16	2950	2990	3030	3070	3110	3150	3190	3230	3270	3310	3350	3390	3430	3470	3510	3550	3590	3630	3670	3715	3755	3800	3840	3880	3920
17	2935	2975	3015	3055	3095	3135	3175	3215	3255	3295	3335	3375	3415	3455	3495	3535	3575	3615	3655	3695	3740	3780	3820	3860	3900
18	2920	2960	3000	3040	3080	3120	3160	3200	3240	3280	3320	3360	3400	3440	3480	3520	3560	3600	3640	3680	3720	3760	3800	3840	3880
20	2890	2930	2970	3010	3050	3090	3130	3170	3210	3250	3290	3330	3370	3410	3450	3490	3525	3565	3605	3645	3685	3725	3765	3800	3840
22	2860	2900	2940	2980	3020	3060	3095	3135	3175	3215	3255	3290	3330	3370	3410	3450	3490	3530	3570	3610	3650	3685	3725	3765	3800
24	2830	2870	2910	2950	2985	3025	3065	3100	3140	3180	3220	3260	3300	3335	3375	3415	3455	3495	3530	3570	3610	3650	3685	3725	3765
26	2800	2840	2880	2920	2960	3000	3035	3070	3110	3150	3190	3230	3265	3300	3340	3380	3420	3455	3495	3530	3570	3610	3650	3685	3725
28	2775	2810	2850	2890	2930	2965	3000	3040	3070	3115	3155	3190	3230	3270	3305	3345	3380	3420	3460	3495	3535	3570	3610	3650	3685
30	2745	2780	2820	2860	2895	2935	2970	3010	3045	3085	3120	3160	3195	3235	3270	3310	3345	3385	3420	3460	3495	3535	3570	3610	3645
32	2715	2750	2790	2825	2865	2900	2940	2975	3015	3050	3090	3125	3160	3200	3235	3275	3310	3350	3385	3420	3460	3495	3535	3570	3610
34	2685	2725	2760	2795	2835	2870	2910	2945	2980	3020	3055	3090	3130	3165	3200	3240	3275	3310	3350	3385	3420	3460	3495	3535	3570
36	2655	2695	2730	2765	2805	2840	2875	2910	2950	2985	3020	3060	3095	3130	3165	3200	3240	3275	3310	3350	3385	3420	3460	3495	3535
38	2630	2665	2700	2735	2770	2810	2845	2880	2915	2950	2990	3025	3060	3095	3130	3170	3205	3240	3275	3310	3345	3385	3420	3455	3490
40	2600	2635	2670	2705	2740	2775	2810	2850	2885	2920	2955	2990	3025	3060	3095	3135	3170	3205	3240	3275	3310	3345	3380	3415	3450
42	2570	2605	2640	2675	2710	2745	2780	2815	2850	2885	2920	2955	2990	3025	3060	3100	3135	3170	3205	3240	3275	3310	3345	3380	3415
44	2540	2575	2610	2645	2680	2715	2750	2785	2820	2855	2890	2925	2960	2995	3030	3060	3095	3130	3165	3200	3235	3270	3305	3340	3375
46	2510	2545	2580	2615	2650	2685	2715	2750	2785	2820	2855	2890	2925	2960	2995	3030	3060	3095	3130	3165	3200	3235	3270	3305	3340
48	2480	2515	2550	2585	2620	2650	2685	2715	2750	2785	2820	2855	2890	2925	2960	2995	3030	3060	3095	3130	3165	3200	3235	3270	3305
50	2455	2485	2520	2555	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2930	2965	2995	3025	3060	3095	3130	3165	3200	3235	3270
52	2425	2455	2490	2525	2555	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990	3025	3060	3095	3130	3165	3200	3235
54	2395	2425	2460	2495	2530	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990	3025	3060	3095	3130	3165	3200
56	2365	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990	3025	3060	3095	3130	3165
58	2335	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990	3025	3060	3095	3130
60	2305	2340	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990	3025	3060	3095
62	2280	2310	2340	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990	3025	3060
64	2250	2280	2310	2340	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990	3025
66	2220	2250	2280	2310	2340	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955	2990
68	2190	2220	2250	2280	2310	2340	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925	2955
70	2160	2190	2220	2250	2280	2310	2340	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895	2925
72	2130	2160	2190	2220	2250	2280	2310	2340	2370	2400	2430	2460	2495	2525	2560	2590	2625	2655	2690	2720	2755	2790	2825	2860	2895
74	2100	2130	2160	2190	2220	2245	2275	2305	2335	2360	2390	2420	2450	2475	2505	2535	2565	2590	2620	2650	2680	2710	2740	2765	2795

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Table 54.2 Predicted Vital Capacities (in Milliliters) for Males

Age	Height in Centimeters																								
	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184	186	188	190	192	194
16	3765	3820	3870	3920	3975	4025	4075	4130	4180	4230	4285	4335	4385	4440	4490	4540	4590	4645	4695	4745	4800	4850	4900	4955	5005
18	3740	3790	3840	3890	3940	3995	4045	4095	4145	4200	4250	4300	4350	4405	4455	4505	4555	4610	4660	4710	4760	4815	4865	4915	4965
20	3710	3760	3810	3860	3910	3960	4015	4065	4115	4165	4215	4265	4320	4370	4420	4470	4520	4570	4625	4675	4725	4775	4825	4875	4930
22	3680	3730	3780	3830	3880	3930	3980	4030	4080	4135	4185	4235	4285	4335	4385	4435	4485	4535	4585	4635	4685	4735	4790	4840	4890
24	3635	3685	3735	3785	3835	3885	3935	3985	4035	4085	4135	4185	4235	4285	4330	4380	4430	4480	4530	4580	4630	4680	4730	4780	4830
26	3605	3655	3705	3755	3805	3855	3905	3955	4005	4050	4100	4150	4200	4250	4300	4350	4395	4445	4495	4545	4595	4645	4695	4740	4790
28	3575	3625	3675	3725	3775	3820	3870	3920	3970	4020	4070	4115	4165	4215	4265	4310	4360	4410	4460	4510	4555	4605	4655	4705	4755
30	3550	3595	3645	3695	3740	3790	3840	3890	3935	3985	4035	4080	4130	4180	4230	4275	4325	4375	4425	4470	4520	4570	4615	4665	4715
32	3520	3565	3615	3665	3710	3760	3810	3855	3905	3950	4000	4050	4095	4145	4195	4240	4290	4340	4385	4435	4485	4530	4580	4625	4675
34	3475	3525	3570	3620	3665	3715	3760	3810	3855	3905	3950	4000	4045	4095	4140	4190	4225	4285	4330	4380	4425	4475	4520	4570	4615
36	3445	3495	3540	3585	3635	3680	3730	3775	3825	3870	3920	3965	4010	4060	4105	4155	4200	4250	4295	4340	4390	4435	4485	4530	4580
38	3415	3465	3510	3555	3605	3650	3695	3745	3790	3840	3885	3930	3980	4025	4070	4120	4165	4210	4260	4305	4350	4400	4445	4495	4540
40	3385	3435	3480	3525	3575	3620	3665	3710	3760	3805	3850	3900	3945	3990	4035	4085	4130	4175	4220	4270	4315	4360	4410	4455	4500
42	3360	3405	3450	3495	3540	3590	3635	3680	3725	3770	3820	3865	3910	3955	4000	4050	4095	4140	4185	4230	4280	4325	4370	4415	4460
44	3315	3360	3405	3450	3495	3540	3585	3630	3675	3720	3770	3815	3860	3905	3950	3995	4040	4085	4130	4175	4220	4270	4315	4360	4405
46	3285	3330	3375	3420	3465	3510	3555	3600	3645	3690	3735	3780	3825	3870	3915	3960	4005	4050	4095	4140	4185	4230	4275	4320	4365
48	3255	3300	3345	3390	3435	3480	3525	3570	3615	3655	3700	3745	3790	3835	3880	3925	3970	4015	4060	4105	4150	4190	4235	4280	4325
50	3210	3255	3300	3345	3390	3430	3475	3520	3565	3610	3650	3695	3740	3785	3830	3870	3915	3960	4005	4050	4090	4135	4180	4225	4270
52	3185	3225	3270	3315	3355	3400	3445	3490	3530	3575	3620	3660	3705	3750	3795	3835	3880	3925	3970	4010	4055	4100	4140	4185	4230
54	3155	3195	3240	3285	3325	3370	3415	3455	3500	3540	3585	3630	3670	3715	3760	3800	3845	3890	3930	3975	4020	4060	4105	4145	4190
56	3125	3165	3210	3255	3295	3340	3380	3425	3465	3510	3550	3595	3640	3680	3725	3765	3810	3850	3895	3940	3980	4025	4065	4110	4150
58	3080	3125	3165	3210	3250	3290	3335	3375	3420	3460	3500	3545	3585	3630	3670	3715	3755	3800	3840	3880	3925	3965	4010	4050	4095
60	3050	3095	3135	3175	3220	3260	3300	3345	3385	3430	3470	3500	3555	3595	3635	3680	3720	3760	3805	3845	3885	3930	3970	4015	4055
62	3020	3060	3110	3150	3190	3230	3270	3310	3350	3390	3440	3480	3520	3560	3600	3640	3680	3730	3770	3810	3850	3890	3930	3970	4020
64	2990	3030	3080	3120	3160	3200	3240	3280	3320	3360	3400	3440	3490	3530	3570	3610	3650	3690	3730	3770	3810	3850	3900	3940	3980
66	2950	2990	3030	3070	3110	3150	3190	3230	3270	3310	3350	3390	3430	3470	3510	3550	3600	3640	3680	3720	3760	3800	3840	3880	3920
68	2920	2960	3000	3040	3080	3120	3160	3200	3240	3280	3320	3360	3400	3440	3480	3520	3560	3600	3640	3680	3720	3760	3800	3840	3880
70	2890	2930	2970	3010	3050	3090	3130	3170	3210	3250	3290	3330	3370	3410	3450	3480	3520	3560	3600	3640	3680	3720	3760	3800	3840
72	2860	2900	2940	2980	3020	3060	3100	3140	3180	3210	3250	3290	3330	3370	3410	3450	3490	3530	3570	3610	3650	3690	3730	3760	3800
74	2820	2860	2900	2930	2970	3010	3050	3090	3130	3170	3200	3240	3280	3320	3360	3400	3440	3470	3510	3550	3590	3630	3670	3710	3740

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Critical Thinking Application

It can be noted from the data in tables 54.1 and 54.2 that vital capacities gradually decrease with age. Propose an explanation for this normal correlation.

7. *Inspiratory reserve volume (IRV)* is the volume of air in addition to the tidal volume that enters the lungs during forced inspiration. Calculate your inspiratory reserve volume by subtracting your tidal volume (TV) and your expiratory reserve volume (ERV) from your vital capacity (VC):

$$IRV = VC - (TV + ERV)$$

8. *Inspiratory capacity (IC)* is the maximum volume of air a person can inhale following exhalation of the tidal volume. Calculate your inspiratory capacity by adding your tidal volume (TV) and your inspiratory reserve volume (IRV):

$$IC = TV + IRV$$

9. *Functional residual capacity (FRC)* is the volume of air that remains in the lungs following exhalation of the tidal volume. Calculate your functional residual capacity (FRC) by adding your expiratory reserve volume (ERV) and your residual volume (RV), which you can assume is 1,200 mL:

$$FRC = ERV + 1,200$$

10. Complete Part C of the laboratory report.

OPTIONAL ACTIVITY

Determine your *minute respiratory volume*. To do this, follow these steps:

1. Sit quietly for a while, and then to establish your breathing rate, count the number of times you breathe in 1 minute. This might be inaccurate because conscious awareness of breathing rate can alter the results. You might ask a laboratory partner to record your breathing rate at some time when you are not expecting it to be recorded.
2. Calculate your minute respiratory volume by multiplying your breathing rate by your tidal volume:

$$\frac{\text{(breathing rate)}}{\text{(breathing rate)}} \times \frac{\text{(tidal volume)}}{\text{(tidal volume)}} = \frac{\text{(minute respiratory volume)}}{\text{(minute respiratory volume)}}$$

3. This value indicates the total volume of air that moves into your respiratory passages during each minute of ordinary breathing.

Figure 54.3 Graphic representation of respiratory volumes and capacities.

