TISSUE RESPIRATION IN INVERTEBRATES

DOROTHY E. BLISS
AND
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THE AMERICAN MUSEUM OF NATURAL HISTORY
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PREFACE

May we introduce this work with an explanation of its general organization and its contents? In Section 1, Introduction, we have traced the historical development of the study of invertebrate tissue respiration from its beginnings late in the nineteenth century up to the present time. In doing so, we have placed particular emphasis on the influence exerted by new apparatus and techniques. We have presented graphically the distribution of studies among various phyla and classes of invertebrate animals. From this initial survey it should be apparent to the reader how rapidly the field of invertebrate tissue respiration is developing and how broad and active it remains today.

While scanning the literature, we found a wealth of usable data. Section 2, the principal portion of this volume, contains these data, arranged to indicate the variation in respiratory rate with animal and type of tissue, with amount of tissue, with concentration and type of substrate, with sex of the animal, with season of the year in which the assay was made, and with many other factors.

Owing to such an abundance of material, we found it necessary to limit our coverage as regards specific enzymes and enzyme systems. Thus, while Section 2 includes many examples of endogenous respiration, for the most part it omits reference to enzymes other than those of the citric acid cycle and the electron transport system. Furthermore, whereas data from an original paper containing few entries usually appear in their entirety, those from a more extensive study have been selected (1) to afford representative sampling and (2) to illustrate principles and hypotheses. Footnote superscript "t" appears after any bibliographical reference in Section 2 if there are more data in an original paper than appear in Section 2.

Although the data contained in Section 2 refer to tissues derived from invertebrates of many species, the section includes no information regarding the respiration of protozoans, nor does it deal with respiratory rates of sperms and of fertilized or unfertilized eggs.

Many types of tissue preparations are mentioned in Section 2. These include whole organs, slices, teased tissues, minces, cell suspensions, homogenates, and fractions (nuclear fraction, mitochondria, microsomes, or soluble fraction).

The arrangement of data in Section 2 is phylogenetic, according to the classification advocated by Hyman (1940-1959, vol. 1). Since phylum and class are the categories most frequently selected for mention by biochemists and experimental biologists, we have not included references to other higher categories. The valid scientific name of each animal and at least one of its common names appear in this section. In a Systematic Index (see Section 9) a scientific name, if no longer valid, can be traced to the presently correct one.

In order to tabulate the data on invertebrate tissue respiration, we found it necessary to convert figures on oxygen uptake from the units employed by a given investigator into one of several selected expressions of metabolic rate. Thus in Section 2, data appear as the mean number of microliters of oxygen per hour per milligram of nitrogen, protein, wet weight, or dry weight, or alternatively as "enzymatic activity," with footnotes indicating the units in which enzymatic activity is given. The complete list of footnotes, which are arranged in an arbitrary, not sequential, order, is repeated on each page of Section 2, although a reference to every footnote may not appear on every page within the body of the table.

Wherever we have converted our units, we have indicated this fact by the footnote superscript "a" after the data. When possible, we have changed all expressions for concentration of reactants into molarity and have noted this

also by the superscript "a." We have omitted all reference to standard deviation and standard error.

Within the table comprising Section 2 is a column bearing the title "Remarks." It contains miscellaneous information about the salt solutions and inhibitors used, the methods employed for determining nitrogen content, the composition of various gas phases, and so on. In this column we have noted, for example, that during an assay cytochrome *c* was present in the complete system, that P/O ratios appear in an original paper, or that specimens used in a particular study were collected during winter and spring. In other words, items that we consider vital for proper evaluation of the data appear in this column.

There are many unfilled spaces in Section 2. The reader should clearly understand their significance. The scientific name and common name of an animal appear only once for each work. Such usage is also true for temperature, providing there is no change in this factor during a given study, and also for apparatus, when only one type is used throughout the study. The author or authors and the date of publication are given once for each work. Thus, an unfilled space in the first, second, third, and last columns signifies that the same animal was used by the same author at the same temperature and with the same apparatus as previously noted.

Quite a different meaning should be read into an unfilled space in columns 4 through 15. In these columns such a blank space usually indicates that no information regarding the point in question appears in the original paper. In a few instances, however, an unfilled space in columns 4 through 15 relates to data or descriptive material which, in our opinion, is either unsuitable for inclusion or of questionable interpretation.

In Section 3 we have analyzed the data on invertebrate tissue respiration, giving emphasis to principles and relationships that the data illustrate. We have noted particularly the effects of metabolic inhibitors and the influence of sex, age, composition of the suspending medium, surgery, injury, and stage in the molt cycle or life cycle on tissue respiration in various invertebrates. In some instances we have based our analysis in part upon information contained within an original paper but not included in Section 2.

A discussion (Section 4) follows the analysis of data. It is concerned not only with the material presented in tabular form in Section 2 and analyzed in the subsequent section but also with broad principles and hypotheses suggested in the various original papers. This discussion seeks to examine selected data in terms of the light that they may shed upon these principles and hypotheses.

A list of abbreviations and symbols used in Section 2 appears in Section 5. Wherever possible, abbreviations are identical with those given in Webster's New International Dictionary, second edition, unabridged, 1958.

Section 6 consists of the Glossary, which is intended to give in a cursory way some understanding of the many technical terms used in this work. For the most part, this glossary does not include terms that appear in Webster's New International Dictionary, second edition, unabridged, 1958.

In Section 7 (Guide to Literature), we have made suggestions for supplementary reading on tissue metabolism and other pertinent fields. Here we have listed books and articles that deal with such topics as cell structure, electron microscopy, intermediary metabolism, and manometric methods, to name a few. Popular, semi-popular, and semi-technical references bear an asterisk. The complete citation for each book and article appears in the Bibliography (Section 8).

Section 9 consists of three indexes. In the first, designated the Systematic Index, there is a page reference for every mention of a given animal in this volume. Insofar as we are aware, the generic and specific names appearing in this work are valid. Occasionally an author has used an invalid name in an original paper. By use of the Systematic Index, the reader can trace the invalid name to the presently correct one. Also indexed here are common names of animals cited in the present work.

In the Author Index, there is a reference for every citation in this volume (exclusive of the Bibliography).

The third and last index deals with the various subjects of which there is mention in this work.

No paper on invertebrate tissue respiration

that has come to our attention since February 1, 1960, have we analyzed for inclusion in this work. On the other hand, we have cited without analysis some papers that have appeared since that time. The closing date does not apply to entries in Sections 7 and 8, which we have continually revised to include pertinent recent publications.

May we request that any reader who finds errors or omissions in this volume bring them to our attention? Should usage justify such action, we may eventually assemble and publish any data appearing in new studies or in those inadvertently omitted from the present work.

Persons to whom we owe a debt of gratitude are many. In the first place, we thank Dr. William R. Harvey, Dr. Melvin V. Simpson, and Dr. Heinrich Waelsch, all of whom offered valuable advice regarding the content and format of certain entries.

For verifying scientific names and making suggestions regarding generally accepted common names, we thank Dr. Elisabeth Deichmann, Dr. William K. Emerson, Dr. G. E. Gates, Dr. Willard D. Hartman, Dr. Libbie H. Hyman, Mr. Morris K. Jacobson, and Mr. John C. Pallister. Valid names of Crustacea came from the systematic index included in Waterman (1960). According to the preface, Dr. Fenner A. Chace, Jr., acted as referee on all taxonomic citations pertaining to the Crustacea. Hence, for their indirect assistance, we are grateful to Dr. Chace and Dr. Waterman.

For suggesting or verifying definitions of terms included within the glossary we thank Dr. H. E. Coomans, Dr. Emerson, Dr. Henry Harbury, Dr. Hyman, Dr. Mary Ellen Jones, Dr. Sam Katz, Dr. Sasha Malamed, Dr. Berta Scharrer, and Dr. Simpson.

For permitting inclusion of unpublished material, we thank Dr. Rose Robyns Coelho and Dr. Harvey. The unpublished data submitted by Dr. Harvey appear in his thesis for the Ph.D. degree, Harvard University.

For permission to quote a passage from *Cancer Research*, we thank the University of Chicago.

For her patient, experienced editorial advice and guidance, we express appreciation to Miss Ruth Tyler, Editor of Scientific Publications of the American Museum of Natural History. Without her, this volume would never have reached its final stages.

For giving freely of their time and still retaining their patience despite the trying nature of their tasks, we thank Miss Ana Uscocovich, Mrs. Phyllis Fish, and Miss Joan Ruff, typists. For considerable assistance in the initial stages of the work, when references had to be tracked down and unwanted ones eliminated, we acknowleged particularly the help of Mrs. Patricia Cannon Sprague. For other assistance of various sorts during the course of compilation, we are grateful to Mrs. Jane Rouillion Boyer, Mr. William F. Mussig, Mr. Frederick V. Weir, and Mrs. Mary Weitzman. For their competent help in the tedious task of preparing the indexes, we thank Mr. Arnold Ross and Miss Susan E. Bliss.

We have a special word of thanks for members of the staff of the Library of the American Museum of Natural History, who furthered in no small way the progress of our work.

We also express our gratitude to Dr. Charles M. Breder, Jr., and to members of the Publications Committee of the Council of the Scientific Staff of the American Museum of Natural History for making possible the preparation and printing of this volume.

Lastly, we gratefully acknowledge the support of the National Science Foundation through grants (NSF G-4006 and NSF G-11254) to one of us (D.E.B.), and also the support of both the National Institute of Neurological Diseases and Blindness and the National Cancer Institute of the United States Public Health Service through predoctoral and postdoctoral fellowships to the other (D.M.S.) while she was at Radcliffe College, Brandeis University, and Yale University.

We have tried to produce an accurate reference on tissue respiration in invertebrates. For all errors that remain, we accept full responsibility.

DOROTHY E. BLISS
DOROTHY M. SKINNER

December 15, 1961

CONTENTS

Section 1: INTRODUCTION

This introductory chapter traces the historical development of the study of invertebrate tissue respiration as a branch of experimental biology. Interest in its study has appeared relatively recently. It is only slightly more than 30 years since the first work to come to the attention of the authors appeared in print. Today tissue respiration of the invertebrates is an established domain of the experimental biologist.

During the period 1929 through 1959, there occurred at least 114 studies on the respiration of invertebrate tissues as reported in 98 different papers. Other published accounts, not known to us, may exist. Figure 1 shows the phylogenetic distribution of the animals used in these studies. Note that, with the exception of the Platyhelminthes, all the major invertebrate phyla are represented. Investigators have used insects and pelecypod mollusks most often, cephalopod mollusks and crustaceans quite frequently. The preponderance of insects as experimental animals seems particularly significant when one examines figure 2. Here (fig. 2M) the distribution of all studies on invertebrate tissue respiration appears according to year. Clearly apparent is a marked increase in the total number of studies during the last decade. It is also clear that one may attribute much of this increase to work with insect tissues (fig. 2K).

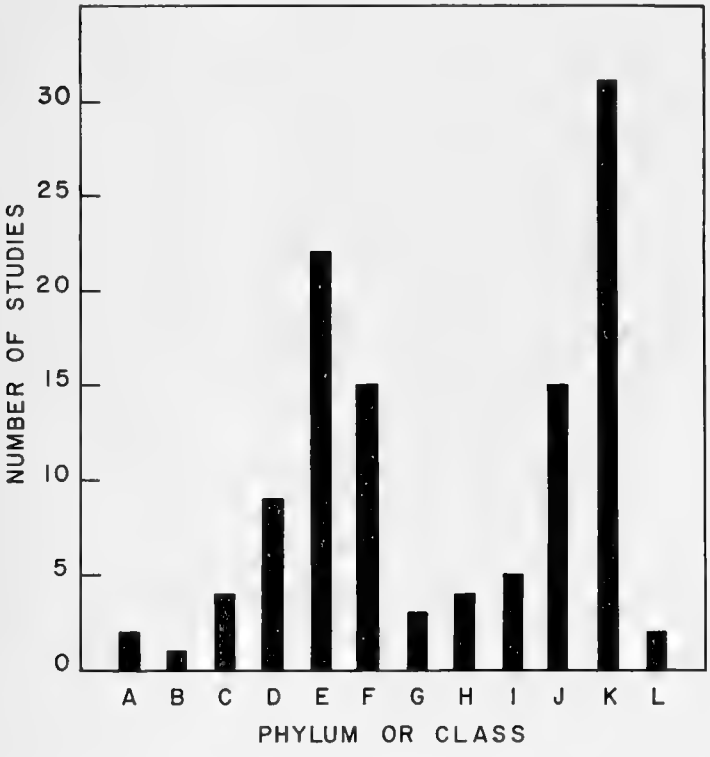

Fig. 1. Frequency distribution of studies on invertebrate tissue respiration from 1929 through 1959 arranged according to phyla and classes studied. A. Porifera: Demospongiae. B. Coelenterata: Hydrozoa, Scyphozoa, Anthozoa. C. Aschelminthes: Nematoda. D. Mollusca: Gastropoda. E. Mollusca: Pelecypoda. F. Mollusca: Cephalopoda. G. Annelida: Polychaeta. H. Annelida: Clitellata. I. Arthropoda: Merostomata. J. Arthropoda: Crustacea. K. Arthropoda: Insecta. L. Echinodermata: Holothuroidea.

There are several other points worthy of note. In the first place, the respiratory activity of crustacean tissues (fig. 2J) has been a regular subject of investigation throughout the period of 1929 through 1959, with no single year or period of years notable for any particularly large number of studies. Secondly, studies on Merostomata (entirely confined to the American species or horseshoe crab, *Limulus polyphemus*) appeared for the most part during the 1930's (fig. 2I). On the other hand, work with tissues of cephalopod mollusks has taken place largely during the late 1940's and 1950's (fig. 2F). Some of this work concerns the metabolism of squid giant axons, now so important as a research tool to the neurophysiologist (see Keynes, 1958).

The historical development of the types of tissue preparations used in the study of tissue respiration is the historical development of tissue respiration itself. Earliest studies generally concerned the respiration of whole organs or pieces of organs. Warburg (1931) was the first investigator to slice tissues into thin sections in order to provide an adequate supply of oxygen for cells of the interior. Because freehand slicing produced non-uniform results, Deutsch (1936) and later Stadie and Riggs (1944) devised mechan-

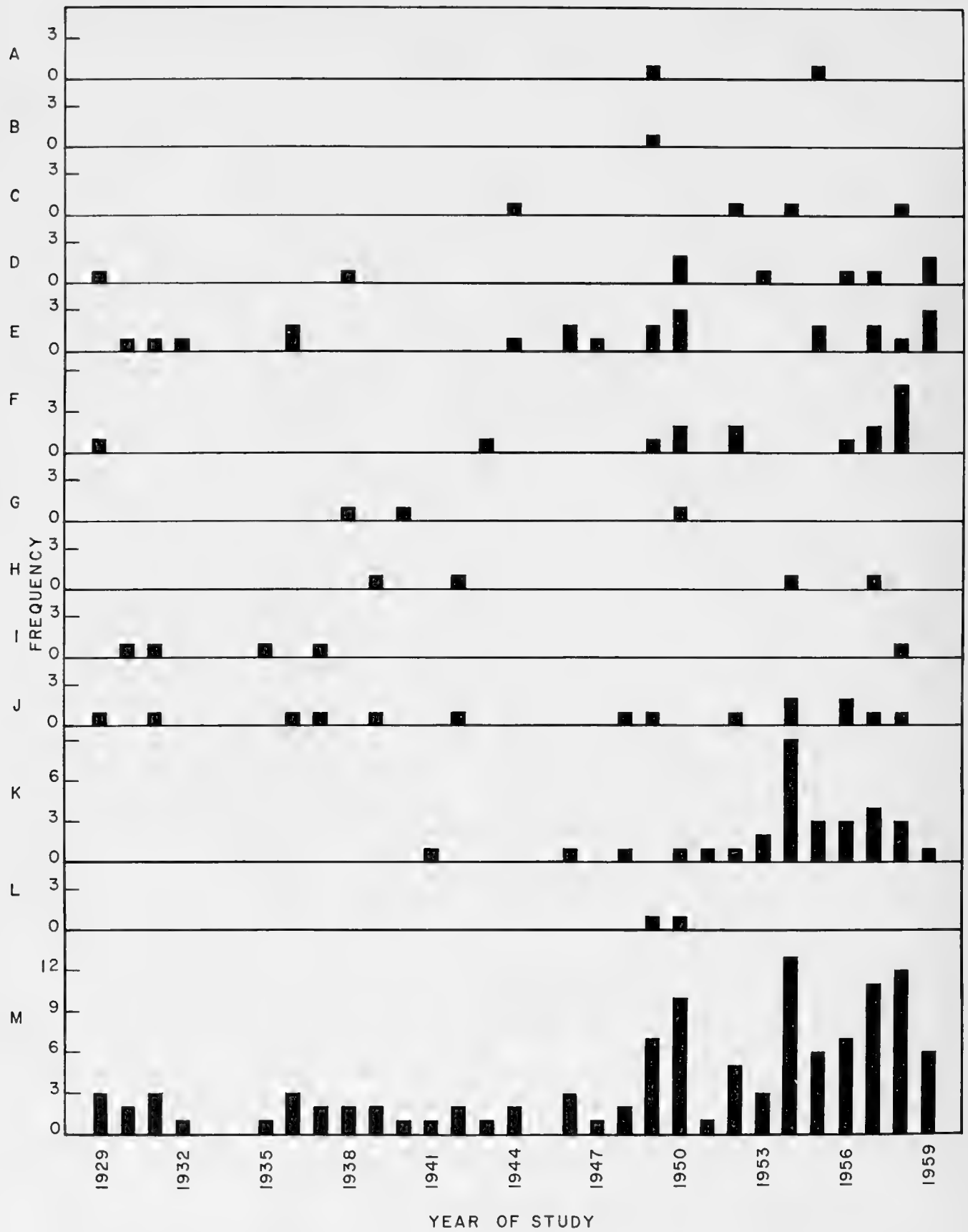

Fig. 2. Frequency distribution of studies on invertebrate tissue respiration from 1929 through 1959 arranged according to year in which the studies were published. A. Porifera: Demospongiae. B. Coelenterata: Hydrozoa, Scyphozoa, Anthozoa. C. Aschelminthes: Nematoda. D. Mollusca: Gastropoda. E. Mollusca: Pelecypoda. F. Mollusca: Cephalopoda. G. Annelida: Polychaeta. H. Annelida: Clitellata. I. Arthropoda: Merostomata. J. Arthropoda: Crustacea. K. Arthropoda: Insecta. L. Echinodermata: Holothuroidea. M. Frequency distribution of all studies.

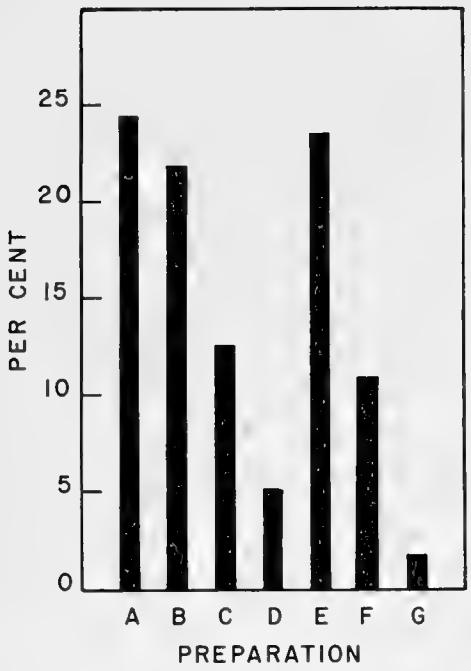

Fig. 3. Percentage distribution of various types of tissue preparations employed in studies on invertebrate tissue respiration from 1929 through 1959. Types of preparations indicated as follows: A. Whole organ. B. Pieces (including) fragments, strips, teased tissue, zones, parts). C. Slices (including sheets, thin sections). D. Suspension (including cell suspension, ground tissue, mince). E. Homogenate. F. Particulate fraction (including mitochondria and microsomes). G. Other fractions (nuclear, supernatant).

ical aids. For a more complete treatment of work with tissue slices, see Field (1948) and Robbie (1948).

Soon a method was devised for fractionating finely ground or homogenized tissues into their cellular components by centrifugation at different speeds for different lengths of time (see Claude, 1946a, 1946b: Schneider, 1946). Thenceforth, workers directed much of their attention to characterizing these cell fractions. They studied the effects of various metabolites, ions, suspending media, and poisons on the respiratory rates of the various fractions and also on the ability of these fractions to form the high-energy phosphate compounds found to be coupled to their respiration.

In figure 3 there appears the per cent of the total number of studies on invertebrate respiration for which each type of procedure was used. Selection of the whole organ (A), pieces of organ (B), and homogenate (E) took place with approximately equal frequency. A more revealing graph is that of figure 4. The diagonal line from the lower left to the upper right corner of the graph emphasizes the trend through the years towards the use of more and more finely divided tissue preparations. The vertical arrow indicates the approximate time when methods for the preparation of suspensions and homogenates first appeared. The use of homogenates and particulate fractions derived from homogenates in studies on invertebrate tissue respiration followed quickly upon this development.

At no time during the 30-year period have whole organs or tissue slices fallen into disfavor as subjects for respiratory studies. Indeed, in 1950 Krebs questioned the trend towards the disruption of cell structure in attempts to explore certain aspects of cell physiology. He pointed out that one can attribute much of the conflicting data on the respiratory rates of homologous tissues from different animals to the type of tissue preparation and the type of medium used. From his studies he concluded that tissue slices suspended in particular synthetic media comprise the type of preparation most likely to yield meaningful results.

For the future, therefore, a reverse trend has something to recommend it. According to Greenstein (1956, p. 651): "It is possible that studies of cellular metabolism, which began with observation on the whole animal and then progressed successively through studies of isolated organs, tissue slices, homogenates, cell fractions, and finally highly purified individual metabolic factors can with profit turn back to the whole animal. Studies of the effect of constitutional factors on metabolic reactions . . . . *in vitro* provide a certain interest but, like all *in vitro* approaches, are at the mercy of the experimental conditions which the investigator chooses to select."

Just as methods of preparing tissues for study of their respiratory rates have undergone marked changes over a period of years, so also have the ways in which respiratory measurements are made. First, let us examine the percentage distribution of the various methods. More than one-half of the investigations cited in Section 2 have involved the use of the Warburg manometric method (see fig. 5A), while 16 per cent have involved various forms of differential manometer, including Fenn, Barcroft, and Thunberg (fig. 5B). Another 11 per cent of these studies were concerned with the spectrophotometer (fig. 5E), 5 per cent with chemical methods (Winkler and micro-Winkler, fig. 5D), 4 per cent with microvolumetric techniques (fig. 5C),

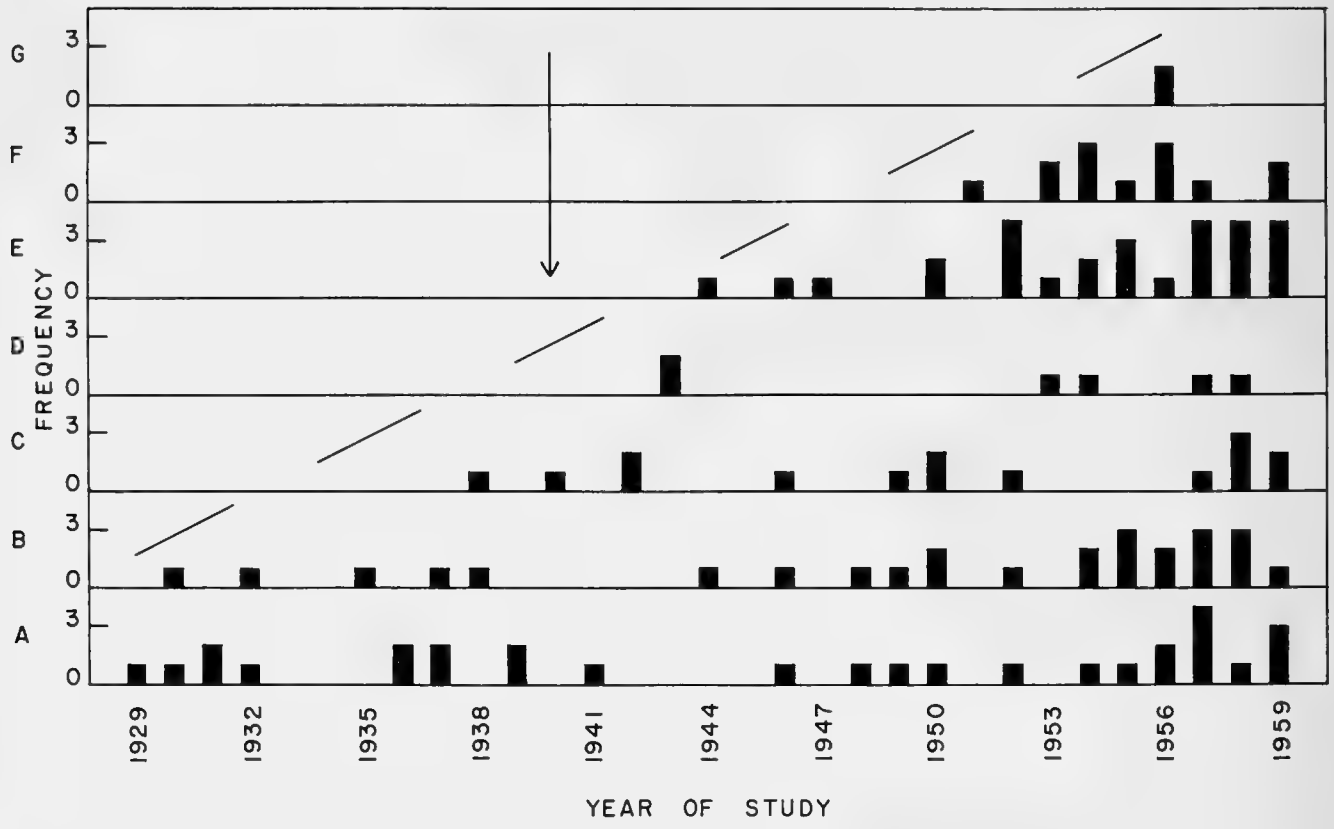

Fig. 4. Frequency distribution of types of tissue preparations used in studies on invertebrate tissue respiration from 1929 through 1959 arranged according to year in which studies were published. Vertical arrow: approximate date when methods for preparation of suspensions and homogenates were first developed. A. Whole organ. B. Pieces (including fragments, strips, teased tissue, zones, parts). C. Slices (including sheets, thin sections). D. Suspension (including cell suspension, ground tissue, mince). E. Homogenate. F. Particulate fraction (including mitochondria and microsomes). G. Other fractions (nuclear, supernatant).

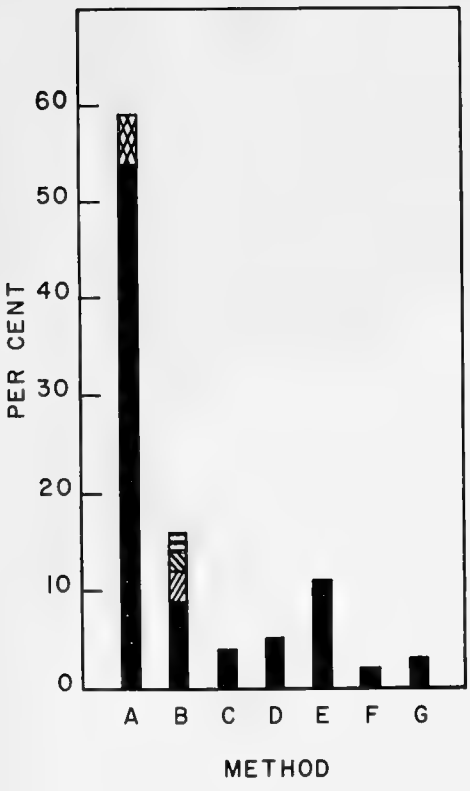

Fig. 5. Percentage distribution of methods employed in studies of invertebrate tissue respiration from 1929 through 1959. Methods indicated are: A. Manometric (Warburg, ; unspecified,). B. Differential (Barcroft, ; Fenn, ; Thunberg, ; unspecified,). C. Microvolumetric. D. Chemical (Winkler and micro-Winkler). E. Spectrophotometric. F. Polarographic. G. Miscellaneous.

2 per cent with the polarograph (fig. 5F), and 3 per cent with a variety of miscellaneous procedures (fig. 5G).

The selection of method as a function of year is illustrated in figure 6. That the Warburg method has been a perennial favorite is clear from figure 6A. In only eight out of the 30 years has there been no use of the Warburg method for studies of invertebrate tissue respiration; furthermore, in every year since 1945 this method has been used at least once. During the 1950's the Warburg method was selected for use on the average of four times a year.

With the advent of spectrophotometric methods for the investigation of tissue metabolism, various investigators applied these procedures to invertebrate tissues, most frequently those of insects. Particular mention may be made of a study by Shappirio and Williams (1957a, 1957b). Through spectroscopy at low temperatures (see Keilin and Hartree, 1949), Shappirio and Williams (1957a) were able to detect enzymes of the terminal electron transport system in diapausing pupae of the Cecropia moth, even though these enzymes are present during this stage of the life cycle in extremely low concentrations. Subsequently (1958b), by the spectrophotometric method, they traced changes in the activity of these enzymes during diapause and adult development (see Discussion, p. 82).

Studies involving the use of differential respirometers, including the Barcroft, Fenn, and Thunberg, have appeared quite regularly throughout the 30-year period (fig. 6B), without, apparently, marked fluctuations in the frequency of their use. A scarcity of studies employing microvolumetric techniques (fig. 6C) seems somewhat surprising in view of the convenience of this type of procedure.

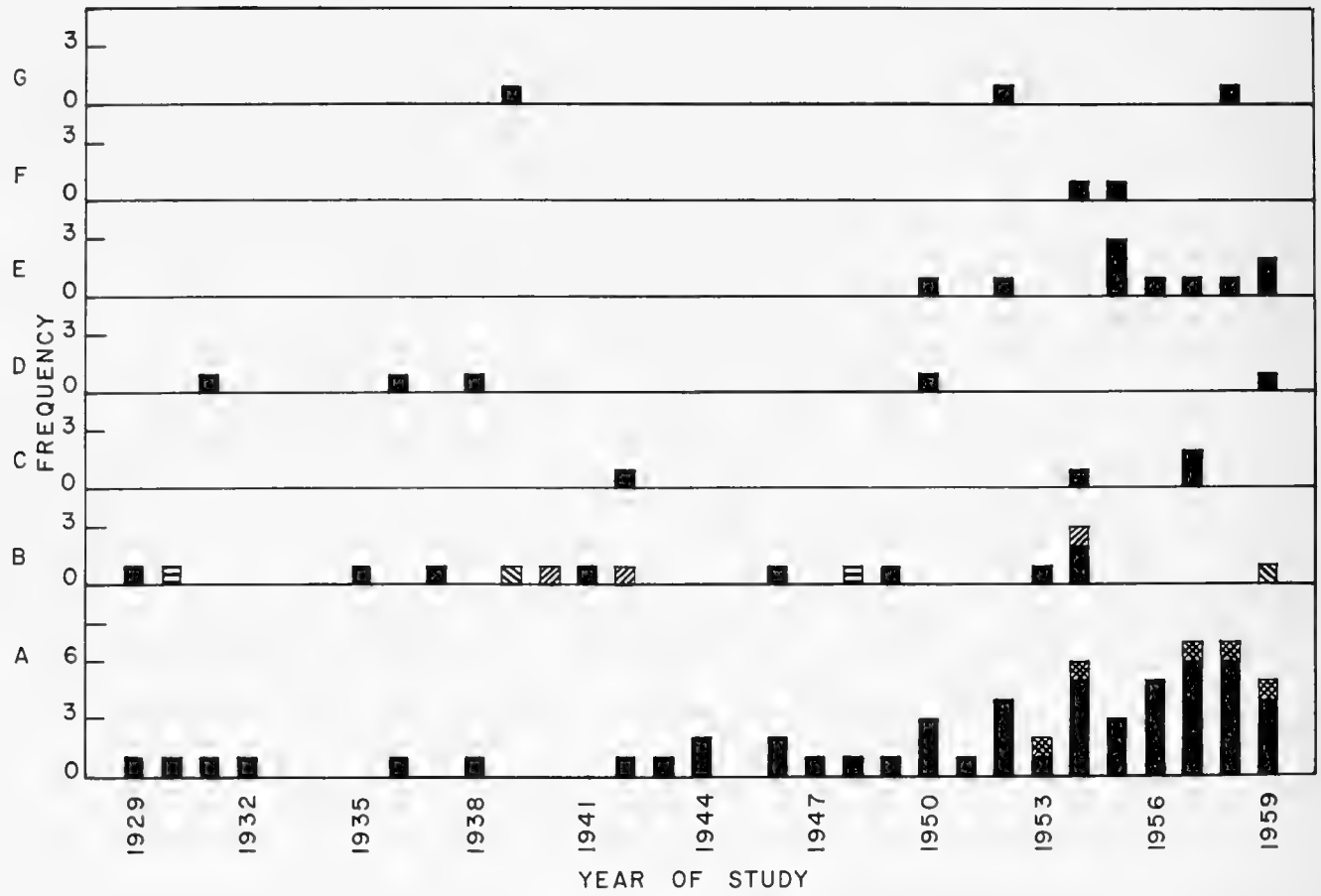

Fig. 6. Frequency distribution of methods used in studies on invertebrate tissue respiration from 1929 through 1959 arranged according to year in which the studies were published. Methods indicated are: A. Manometric (Warburg, ; unspecified,). B. Differential (Barcroft, ; Fenn, ; Thunberg, ; unspecified,). C. Microvolumetric. D. Chemical (Winkler and micro-Winkler). E. Spectrophotometric. F. Polarographic. G. Miscellaneous.

Section 2: PRESENTATION OF DATA:
A TABLE OF RESPIRATORY RATES OF INVERTEBRATE TISSUES

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
PORIFERA															
Demospongiae															
Cinachyra cavernosa Sponge	25	Warburg	Slices	Endogenous		3						0.6		Dry weight given for tissue minus skeletal material	Robbie (1949)[t]
Dysidea crawshayi Sponge	25	Warburg	Slices	Endogenous		2						0.6		(Same as above)	Robbie (1949)[t]
Geodia gibberosa Sponge	25	Warburg	Slices	Endogenous		1						0.6		(Same as above)	Robbie (1949)[t]
Ircinia fasciculata Stinker sponge	25	Warburg	Slices	Endogenous		5						1.6		(Same as above)	Robbie (1949)[t]
Lissodendoryx isodictyalis Sponge	25	Warburg	Slices	Endogenous		4						1.4		(Same as above)	Robbie (1949)[t]
Microciona prolifera Red oyster sponge	37	Warburg	Finger-like projections (apical portions): Slices	Endogenous	*ca.* 200 mg.	1					0.115			Without phenol	Gordon, Spiegel, and Villee (1955)
			(Same as above)	Endogenous	*ca.* 200 mg.	1					0.157			With phenol (0.2%)	
			(Same as above)	Endogenous	*ca.* 200 mg.	2					0.169[a]			With insulin (4 units) containing phenol (0.2%)	
			Finger-like projections (apical portions): Slices	Pyruvate (1×10^{-3} M[a])		1					0.126			Without phenol	
			(Same as above)	Pyruvate (1×10^{-3} M[a])		3					0.146[a]			With phenol (0.2%)	
			(Same as above)	Pyruvate (1×10^{-3} M[a])		4					0.164[a]			With insulin (4 units) containing phenol (0.2%)	
			Finger-like projections (apical portions): Slices	Glucose (5.6×10^{-3} M[a])		4					0.110[a]			Without phenol	
			(Same as above)	Glucose (5.6×10^{-3} M[a])		6					0.123[a]			With phenol (0.2%)	
			(Same as above)	Glucose (5.6×10^{-3} M[a])		7					0.146[a]			With insulin (4 units) containing phenol (0.2%)	
Pseudaxinella rosacea (formerly *Axinella rosacea*) Sponge	25	Warburg	Slices	Endogenous		2						0.7		Dry weight given for tissue minus skeletal material	Robbie (1949)[t]
Spheciospongia sp. Sponge	25	Warburg	Slices	Endogenous		1						0.4		(Same as above)	Robbie (1949)[t]
Tedania ignis Fire sponge	25	Warburg	Slices	Endogenous		6						2.9		(Same as above)	Robbie (1949)[t]

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] Δ log [cytochrome c]/mg. wet wt./min.
[g] $-\Delta$ log [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] Δ log [ferricytochrome c]/mg. protein/min.
[j] Δ log $[CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Terpios fugax Sponge	25	Warburg	Slices	Endogenous		1						0.6		(Same as above)	Robbie (1949)[t]
Tethya aurantia Sea orange (sponge)	25	Warburg	Slices	Endogenous		1						0.5		(Same as above)	Robbie (1949)[t]
COELENTERATA															
Hydrozoa															
Physalia physalis (formerly *Physalia pelagica*) Portuguese man-of-war	25	Warburg	Tentacles	Endogenous		3						1.7			Robbie (1949)[t]
Scyphozoa															
Cassiopea frondosa Jellyfish	25	Warburg	Tentacles Umbrella	Endogenous Endogenous		10 18						0.6 0.7			Robbie (1949)[t]
Pelagia noctiluca (formerly *Pelagia cyanella*) Jellyfish	25	Warburg	Umbrella	Endogenous		2						0.8			Robbie (1949)[t]
Anthozoa															
Condylactis gigantea Sea anemone	25	Warburg	Tentacles	Endogenous		3						0.8			Robbie (1949)[t]
Gorgonia flabellum Purple sea fan	25	Warburg	Branches: Cell suspension	Endogenous		2						2.2		Dry weight given for tissue minus skeletal material	Robbie (1949)[t]
Plexaura flexuosa Purple gorgonian	25	Warburg	Slices	Endogenous		13						3.0		(Same as above)	Robbie (1949)[t]
ASCHELMINTHES															
Nematoda															
Ascaris lumbricoides Pig ascarid	39	Warburg	Muscle: Homogenate "Muscle pulp" "Muscle pulp" "Muscle pulp" "Muscle pulp"	 Endogenous Succinate (0.02 M) Succinate (0.02 M) Succinate (0.02 M)								 1.3 1.3 11.0[a] 27.5[a]		 Methylene blue added Methylene blue added; also catalase and ethanol added to remove H_2O_2 formed as a product of the reaction	Laser (1944)[t]

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] Δ log [cytochrome c]/mg. wet wt./min.
[g] $-\Delta$ log [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] Δ log [ferricytochrome c]/mg. protein/min.
[j] Δ log $[CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
			"Coenzyme-free muscle pulp"	Succinate (0.02 M)								19.5[a]		Methylene blue added	
			"Coenzyme-free muscle pulp"	Succinate (0.02 M)								57[a]		Methylene blue added; also catalase and ethanol added to remove H_2O_2 formed as a product of the reaction	
Ascaris lumbricoides Pig ascarid	38	Warburg	Muscle: Homogenate ("coenzyme-free muscle pulp")	Succinate (0.025 M)							0.85[a]			In 100% O_2; catalase and ethanol added to remove H_2O_2 formed as a product of the reaction	Bueding and Charms (1952)[t]
Ascaris lumbricoides Pig ascarid	25	Warburg												All assays: P/O ratios in original paper	Chin and Bueding (1954)[t]
			Muscle: Particulate fraction								0.0718[a]			Gas phase: O_2; undialysed supernatant of perienteric fluid added	
			(Same as above)	Pyruvate (0.02 M)							0.0406[a]			Gas phase: O_2; dialysed supernatant of perienteric fluid added	
			(Same as above)	Pyruvate (0.02 M)							0.0304[a]			Gas phase: air; dialysed supernatant of perienteric fluid added	
			(Same as above)	Pyruvate (0.02 M) + succinate (0.02 M)							0.0607[a]			(Same as above)	
			(Same as above)	Pyruvate (0.02 M)							0.0443[a]			(Same as above)	
			(Same as above)	Pyruvate (0.02 M)							0.0749[a]			Gas phase: air; dialysed supernatant of perienteric fluid added; with DNP (3×10^{-5} M)	
			(Same as above)	Pyruvate (0.02 M)							0.0457[a]			Gas phase: air; dialysed supernatant of perienteric fluid added; with DNP (8×10^{-5} M)	
Parascaris equorum (formerly *Ascaris megalocephala*) Horse ascarid	39	Warburg	Muscle of body wall: Cell suspension	Endogenous							6.0			In physiological saline; gas phase: air	Durrani (1958)
			(Same as above)	Endogenous							2.3			In distilled water; gas phase: air	
			(Same as above)	Glucose (0.22 M[a])							3.1				
			(Same as above)	Succinate (0.05 M[b])							7.2				

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
MOLLUSCA															
Gastropoda															
Aplysia sp. Sea hare	16	Warburg; also differential manometer	Nerve	Endogenous	22.9 mg. dry wt.							0.52		Nerve unstimulated; in artificial sea water with urea and bicarbonate	Meyerhof and Schulz (1929)
Aplysia sp. Sea hare	25	Warburg	Gizzard: Slices (from frozen tissue)	Endogenous								0.33			Ghiretti, Ghiretti-Magaldi, and Tosi (1959)
			Gizzard: Slices (from frozen tissue)	Endogenous								0.06		With KCN (1×10^{-3} M)	
			Gizzard: Slices (from frozen tissue)	Succinate (0.01 M[c])								1.80			
			Gizzard: Slices (from frozen tissue)	Succinate (0.01 M[c]) + malonate (0.01 M[c])								0.96			
			Gizzard: Slices (from frozen tissue)	Succinate (0.01 M[c]) + malonate (0.01 M[c]) + fumarate (0.003 M[c])								0.90			
			Gizzard: Slices (from frozen tissue)	Fumarate (0.003 M[c])								0.30			
			Gizzard: Slices (from frozen tissue)	Citrate (0.01 M[c])								0.64			
			Gizzard: Slices (from frozen tissue)	Malate (0.01 M[c])								0.56			
	Not specified	Spectrophotometer	Buccal mass muscle: Particle preparation (from frozen tissue)	Succinate (1.7×10^{-3} M) + cytochrome *c* (1.8×10^{-3} M)									0.077	With KCN (1×10^{-3} M)	
			(Same as above)	Reduced cytochrome *c* (2.5×10^{-5} M)									0.019	With KCN (1×10^{-3} M)	
			Gizzard muscle: Particle preparation (from frozen tissue)	Succinate (1.7×10^{-3} M) + cytochrome *c* (1.8×10^{-3} M)									0.457		
			(Same as above)	Reduced cytochrome *c* (2.5×10^{-5} M)									0.044	With KCN (1×10^{-3} M)	
													0.447	All assays: For units of enzymatic activity, see footnote r	
			Buccal mass muscle: Particle preparation (from frozen tissue):											All assays: Protein determination by methods of Lowry *et al.* (1951) and Kalckar (1947)	
			30,000 x *g.*	DPNH (2×10^{-4} M) + cytochrome *c* (1.8×10^{-5} M)									0.301	With KCN (1×10^{-3} M)	
			107,000 x *g.*	DPNH (2×10^{-4} M) + cytochrome *c* (1.8×10^{-5} M)									0.113	With KCN (1×10^{-3} M)	
			Gizzard muscle: Particle preparation (from frozen tissue):												
			30,000 x *g.*	DPNH (2×10^{-4} M) + cytochrome *c* (1.8×10^{-5} M)									0.262	With KCN (1×10^{-3} M)	
			107,000 x *g.*	DPNH (2×10^{-4} M) + cytochrome *c* (1.8×10^{-5} M)									0.076	With KCN (1×10^{-3} M)	

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[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
			Midgut gland: Crude homogenate (from frozen tissue)	DPNH (2×10^{-4} M) + cytochrome *c* (1.8×10^{-5} M)									0.106	With KCN (1×10^{-3} M)	
			Midgut gland: Particle preparation (from frozen tissue) 30,000 x *g*.	DPNH (2×10^{-4} M) + cytochrome *c* (1.8×10^{-5} M)									0.106	With KCN (1×10^{-3} M)	
			107,000 x *g*.	DPNH (2×10^{-4} M) + cytochrome *c* (1.8×10^{-5} M)									0.039	With KCN (1×10^{-3} M)	
Aplysia limacina Sea hare	25	Manometer	Buccal mass muscle: Particle suspension (from frozen tissue)	Endogenous	4.5 mg. dry wt.							0			Ghiretti, Ghiretti-Magaldi, and Tosi (1959)
			(Same as above)	Succinate (0.01 M[a,c])	4.5 mg. dry wt.							4.7[a]			
			(Same as above)	Succinate (0.01 M[a,c]) + cytochrome *c* (6×10^{-7} M[c])	4.5 mg. dry wt.							8.9[a]			
			(Same as above)	Ascorbate (0.01 M[a,c])	4.5 mg. dry wt.							0			
			(Same as above)	Ascorbate (0.01 M[a,c]) + cytochrome *c* (6×10^{-7} M[c])	4.5 mg. dry wt.							46.1[a]			
			(Same as above)	Hydroquinone (0.01 M[a,c])	4.5 mg. dry wt.							3.6[a]			
			(Same as above)	Hydroquinone (0.01 M[a,c]) + cytochrome *c* (6×10^{-7} M[c])	4.5 mg. dry wt.							35.8[a]			
			(Same as above)	*p*-phenylenediamine (0.01 M[a,c])	4.5 mg. dry wt.							10.2[a]			
			(Same as above)	*p*-phenylenediamine (0.01 M[a,c]) + cytochrome *c* (6×10^{-7} M[c])	4.5 mg. dry wt.							30.4[a]			
Busycon sp. Conch	25	Warburg	Muscle, white: Thin sheets or slices	Glucose (0.011 M[a])		10					0.052[a]				Villee, Lichtenstein, Nathanson, and Rolander (1950)
Helix aspersa Dented garden snail or petit-gris	23	Warburg	Heart	Endogenous	1.50 mg. dry wt.							1.00		In isotonic chloride solution	Cardot, Faure, and Arvanitaki (1950)[t]
			Heart	Endogenous	1.50 mg. dry wt.							2.27		In salt solution: $Na^+/K^+=5$	
			Heart	Endogenous	1.50 mg. dry wt.							1.65		$Na^+/K^+=20$	
Helix pisana Little edible land snail	23	Warburg	Heart	Endogenous	0.50 mg. dry wt.							1.75		In isotonic chloride solution	Cardot, Faure, and Arvanitaki (1950)[t]
Helix pomatia Vineyard snail or Burgundy snail	28	Warburg	Midgut gland: Slices	Endogenous		92						2.93		In Baldwin's (1938) phosphate solution	Baldwin (1938)[t]
Helix pomatia Vineyard snail or Burgundy snail	23	Warburg	Heart	Endogenous	3.50 mg. dry wt.							0.85		In isotonic chloride solution	Cardot, Faure, and Arvanitaki (1950)[t]

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[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Helix pomatia Vineyard snail or Burgundy snail	38	Manometer	Midgut gland: Suspension	Endogenous		5		Active	11					All assays: Cytrochrome *c* (1×10^{-5} M[c]) present All assays: Method of nitrogen determination not specified	Rees (1953)[t]
			(Same as above)	Endogenous		7		Hibernating	12						
			(Same as above)	Succinate (0.033 M[a,c])		8		Active	36						
			(Same as above)	Succinate (0.033 M[a,c])		6		Hibernating	39						
			(Same as above)	α-Ketoglutarate (0.01 M[a,c])		5		Active	16						
			(Same as above)	α-Ketoglutarate (0.01 M[a,c])		5		Hibernating	17						
			Midgut gland: Mitochondria	Endogenous					0						
			(Same as above)	Succinate (0.033 M[a,c])					110						
			(Same as above)	Malate (0.01 M[a,c])					18[a]						
			(Same as above)	Malate (0.01 M[a,c] + DPN (3.3×10^{-4} M[a,c])					31[a]						
			(Same as above)	α-Ketoglutarate (0.01 M[a,c])					19[a]						
			(Same as above)	α-Ketoglutarate (0.01 M[a,c]) + DPN (3.3×10^{-4} M[a,c])					25[a]						
Helix pomatia Vineyard snail or Burgundy snail	28	Warburg	Slices of: Cerebral ganglion	Endogenous		20						4.00		In Baldwin's (1938) phosphate solution	Kerkut and Laverack (1957)[t]
			Pedal ganglion	Endogenous		18						2.89		(Same as above)	
			Midgut gland	Endogenous		23						2.78		(Same as above)	
			Gut buccal mass	Endogenous		24						1.37		(Same as above)	
			Esophagus	Endogenous		24						2.68		(Same as above)	
			Midgut	Endogenous		24						2.56		(Same as above)	
			Mantle	Endogenous		24						1.76		(Same as above)	
			Kidney	Endogenous		27						2.24		(Same as above)	
			Columella muscle	Endogenous		24						1.80		(Same as above)	
			Female duct	Endogenous		24						1.03		(Same as above)	
			Albuminous gland	Endogenous		22						1.20		(Same as above)	
			Body wall	Endogenous		24						0.78		(Same as above)	
			Dart sac	Endogenous		22						0.66		(Same as above)	
			Foot: fore	Endogenous		17						0.81		(Same as above)	
			Foot: middle	Endogenous		12						0.67		(Same as above)	
			Foot: rear	Endogenous		13						0.79		(Same as above)	
Helix vermiculata White-lipped edible land snail	23	Warburg	Heart	Endogenous	0.92 mg. dry wt.							1.36		In isotonic chloride solution	Cardot, Faure, and Arvanitaki (1950)[t]
Levantina hierosolyma (formerly *Helix hierosolyma*) Jerusalem land snail	37	Spectrophotometer; also tetrazolium method (see Kun and Abood, 1949)	Midgut gland: Homogenate (20%)	Endogenous		8		During estivation					0.025	For units of enzymatic activity, see footnote q	Eckstein and Abraham (1959)
								After estivation:							
			(Same as above)	Endogenous		5		10-15 hr.					0.075		
			(Same as above)	Endogenous		3		24 hr.					0.187		
			(Same as above)	Endogenous		4		48 hr.					0.115		
			(Same as above)	Endogenous		7		5-6 da.					0.101		
			Midgut gland: Homogenate (20%)	Succinate (0.014 M[a,c])		8		During estivation					0.114		
								After estivation:							
			(Same as above)	Succinate (0.013 M[a,c])		5		10-15 hr.					0.130		
			(Same as above)	Succinate (0.013 M[a,c])		3		24 hr.					0.222		
			(Same as above)	Succinate (0.013 M[a,c])		4		48 hr.					0.321		
			(Same as above)	Succinate (0.013 M[a,c])		7		5-6 da.					0.496		

[a] Estimated or calculated from available data.
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[c] Final concentration.
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[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Lymnaea stagnalis Pond snail	25	Warburg	Albumen gland: Particulate fraction, largely mitochondria	Endogenous					218[a]					P/O ratios in original paper Cytochrome *c* (5×10^{-5} M[c]) present Nitrogen determination by micro-Kjeldahl procedure	Weinbach (1956)[t]
Pelecypoda															
Anodonta cellensis (cited as *Anodonta celensis*) Fresh-water mussel	Not specified	Polarograph	Posterior adductor muscle: Strips												Brecht, Utz, and Lutz (1955)[t]
			Yellow portion	Endogenous							0.070[a]			Winter	
			White portion	Endogenous							0.073[a]			Winter	
			Yellow portion	Endogenous							0.067[a]			Spring	
			White portion	Endogenous							0.080[a]			Spring	
Crassostrea gigas (formerly *Ostrea gigas*) Oyster	25	Warburg	Mantle: Slices	Endogenous	50-100 mg. wet wt.						0.43[a]			Gas phase: 90% N_2 and 10% O_2	Kawai (1958)
			Gill: Pieces	Endogenous	50-100 mg. wet wt.						0.78[a]			(Same as above)	
			Mantle: Slices	Endogenous	50-100 mg. wet wt.						0.19[a]			Gas phase: 90% CO and 10% O_2; in darkness	
			Gill: Pieces	Endogenous	50-100 mg. wet wt.						0.42[a]			(Same as above)	
			Mantle: Slices	Endogenous	50-100 mg. wet wt.						0.39[a]			Gas phase: 90% CO and 10% O_2; in light	
			Gill: Pieces	Endogenous	50-100 mg. wet wt.						0.77[a]			(Same as above)	
Crassostrea gigas (formerly *Ostrea gigas*) Oyster	25	Warburg	Heart	Endogenous	50-100 mg. wet wt.			2 yrs. (11 cm.)			0.39[a]			Gas phase: air	Kawai (1959)
			Heart	Endogenous	50-100 mg. wet wt.			2 yrs. (11 cm.)			0.20[a]			Gas phase: 90% CO and 10% O_2; in darkness	
			Gill	Endogenous	50-100 mg. wet wt.			2 yrs. (11 cm.)			0.53[a]			Gas phase: air	
			Gill	Endogenous	50-100 mg. wet wt.			2 yrs. (11 cm.)			0.26[a]			Gas phase: 90% CO and 10% O_2; in darkness	
			Mantle	Endogenous	50-100 mg. wet wt.			2 yrs. (11 cm.)			0.29[a]			Gas phase: air	
			Mantle	Endogenous	50-100 mg wet wt.			2 yrs. (11 cm.)			0.14[a]			Gas phase: 90% CO and 10% O_2; in darkness	
Crassostrea gigas (formerly *Ostrea gigas*) Oyster	25	Micro-Winkler	Gill	Endogenous	500[a] mg. wet wt.						0.86-1.44			In sea water	Okamura (1959)[t]

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[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] Δ log [cytochrome c]/mg. wet wt./min.
[g] $-\Delta$ log [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] Δ log [ferricytochrome c]/mg. protein/min.
[j] Δ log [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[n] $m\mu$ moles DPNH oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[o] $m\mu$ moles cytochrome c oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} $\text{cm.}^2/\text{mol.}$).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Crassostrea virginica (formerly *Ostrea virginica*) Virginia oyster	28	Thunberg micro-respirometer (see Thunberg, 1905)	Adductor muscle: Pieces Gray portion	Endogenous	269[a] mg. wet wt.	5		6.8-13.5 cm. long			0.0480[a]				Hopkins (1930)[t]
			White portion	Endogenous	228[a] mg. wet wt.	5		6.8-13.5 cm. long			0.0372[a]				
Crassostrea virginica (formerly *Ostrea virginica*) Virginia oyster	18-21	Warburg	Mantle: Marginal zone	Endogenous							0.13			Florida oysters	Jodrey and Wilbur (1955)[t]
			Pallial zone	Endogenous							0.15			Florida oysters	
			Central zone	Endogenous							0.12			Florida oysters	
	25	Warburg	Mantle	Succinate (0.05 M)		9					25			Mantles isolated for 2-7 days	
			Mantle	Succinate (0.05 M)		7					23			Mantles freshly dissected	
	25	Warburg	Mantle: Pieces	Succinate (0.01 M)							15				
			Mantle: Pieces	*iso* Citrate (0.01 M)							26				
			Mantle: Pieces	Citrate (0.01 M)							2				
			Mantle: Pieces	Malate (0.01 M)							20				
	Not specified	Spectrophotometer	Mantle: Homogenate	Succinate (0.1 M)		9 or more		8.0-11.5 cm. long					0.03	For units of enzymatic activity, see footnote d	
			Mantle: Homogenate	Cytochrome *c* (4.5×10^{-5} M[a])		9 or more		8.0-11.5 cm. long					0.61	For units of enzymatic activity, see footnote e	
Crassostrea virginica (formerly *Ostrea virginica*) Virginia oyster	26	Warburg	Mantle: Strips	Endogenous	180-220 mg. wet wt.						0.156[a]				Maroney, Barber, and Wilbur (1957)
			Mantle: Strips	Endogenous	180-220 mg. wet wt.						0.181[a]			With DNP (1×10^{-6} M)	
			Mantle: Strips	Endogenous	180-220 mg. wet wt.						0.287[a]			With DNP (1×10^{-3} M)	
			Mantle: Strips	Endogenous	180-220 mg. wet wt.						0.135[a]			With DNP (1×10^{-2} M)	
Cristaria plicata Fresh-water mussel	25	Warburg	Gill	Endogenous		10		4-6 yrs.				1.8			Higashi and Kawai (1959)[t]
			Mantle:												
			Edge	Endogenous		6		4-6 yrs.				0.7			
			Lobe	Endogenous		6		4-6 yrs.				0.5			
			Heart	Endogenous		5		4-6 yrs.				0.8			
			Adductor muscle:												
			Striated	Endogenous		4		4-6 yrs.				0.14			
			Smooth	Endogenous		4		4-6 yrs.				0.14			
Driessena sp. (cited as *Dreissensia*) Mussel	20	Warburg	Gill: Epithelium	Endogenous					18.7					R.Q. 0.87 Method of nitrogen determination not specified	Wernstedt (1944)

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log$ [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log \text{[cytochrome c]}}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Gryphaea angulata Portuguese oyster	28	Warburg	Mantle: Whole	Endogenous	100 mg. wet wt.	7						0.89[a]			Chapeau (1932)[t]
			Pieces	Endogenous	100 mg. wet wt.	8						0.98[a]			
			Gill: Whole	Endogenous	80 mg. wet wt.	7						1.76[a]			
			Pieces	Endogenous	80 mg. wet wt.	8						1.86[a]			
			Muscle: Whole	Endogenous	120 mg. wet wt.	7						0.15[a]			
			Pieces	Endogenous	120 mg. wet wt.	8						0.26[a]			
			Midgut gland: Pieces	Endogenous	60 mg. wet wt.	8						1.96[a]			
			Mantle	Endogenous	100 mg. wet wt.	2		10-15 mos.				1.24[a]			
			Mantle	Endogenous	100 mg. wet wt.	6		30 mos.				0.96[a]			
			Mantle	Endogenous	100 mg. wet wt.	1		6 yrs.				0.68			
			Gill	Endogenous	80 mg. wet wt.	2		10-15 mos.				2.3[a]			
			Gill	Endogenous	80 mg. wet wt.	6		30 mos.				1.76[a]			
			Gill	Endogenous	80 mg. wet wt.	1		6 yrs.				1.23			
			Muscle	Endogenous	120 mg. wet wt.	2		10-15 mos.				0.46[a]			
			Muscle	Endogenous	120 mg. wet wt.	6		30 mos.				0.26[a]			
			Muscle	Endogenous	120 mg. wet wt.	1		6 yrs.				0.17			
			Midgut gland	Endogenous	60 mg. wet wt.	2		10-15 mos.				2.14[a]			
			Midgut gland	Endogenous	60 mg. wet wt.	6		30 mos.				1.78[a]			
			Midgut gland	Endogenous	60 mg. wet wt.	1		6 yrs.				0.92			
Hyriopsis schlegelii Fresh-water mussel	25	Warburg	Gill	Endogenous		24		4-6 yrs.				1.3			Higashi and Kawai (1959)[t]
			Mantle: Edge	Endogenous		8		4-6 yrs.				0.6			
			Lobe	Endogenous		8		4-6 yrs.				0.5			
			Heart	Endogenous		10		4-6 yrs.				0.8			
			Adductor muscle: Striated	Endogenous		6		4-6 yrs.				0.19			
			Smooth	Endogenous		6		4-6 yrs.				0.19			
Isognomon alata (formerly *Pedalion alata*) Tree oyster	25	Warburg	Gill	Endogenous		6						1.3			Robbie (1949)[t]

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[n] $m\mu$ moles DPNH oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[o] $m\mu$ moles cytochrome c oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.²/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Mactra sp. Clam	25	Warburg	Muscle: Thin sheets or slices	Glucose (0.011 M[a])		5					0.0784[a]				Villee, Lichtenstein, Nathanson, and Rolander (1950)
			Gill: Thin sheets	Glucose (0.011 M[a])		15					0.253[a]				
Mercenaria mercenaria (formerly *Venus mercenaria*) Quahog	28	Thunberg microrespirometer (see Thunberg, 1905)	Posterior adductor muscle: Pieces												Hopkins (1930)[t]
			Red portion	Endogenous	292[a] mg. wet wt.	32		5.3-13.5 cm. long			0.0419[a]				
			White portion	Endogenous	291[a] mg. wet wt.	31		5.3-13.5 cm. long			0.0353[a]				
			Red portion	Endogenous	290[a] mg. wet wt.	16		<6.5 cm. long			0.0485[a]				
			Red portion	Endogenous	294[a] mg. wet wt.	16		>9 cm. long			0.0354[a]				
			White portion	Endogenous	287[a] mg. wet wt.	15		<6.5 cm. long			0.0427[a]				
			White portion	Endogenous	296[a] mg. wet wt.	16		>9 cm. long			0.0285[a]				
Mercenaria mercenaria (formerly *Venus mercenaria*) Quahog	20	Differential volumeter (modified Thunberg; see Hopkins and Handford, 1943)	Adductor muscle (red): Thin sections	Endogenous		21		2-6 yrs.				0.157[a]		Winter and spring	Hopkins (1946)[t]
			(Same as above)	Endogenous		21		7-20+ yrs.				0.108[a]		Winter and spring	
			(Same as above)	Endogenous		12		2-6 yrs.				0.139[a]		Summer and autumn	
			(Same as above)	Endogenous		12		7-20+ yrs.				0.103[a]		Summer and autumn	
			Mantle: Pieces	Endogenous		23		2-6 yrs.				1.325[a]		Winter and spring	
			Mantle: Pieces	Endogenous		23		7-20+ yrs.				1.040[a]		Winter and spring	
			Mantle: Pieces	Endogenous		7		2-6 yrs.				0.912[a]		Summer and autumn	
			Mantle: Pieces	Endogenous		7		7-20+ yrs.				0.815[a]		Summer and autumn	
			Gill: Pieces	Endogenous		46		2-6 yrs.				1.597[a]		Winter and spring	
			Gill: Pieces	Endogenous		46		7-20+ yrs.				1.590[a]		Winter and spring	
			Gill: Pieces	Endogenous		43		2-6 yrs.				1.603[a]		Summer and autumn	
			Gill: Pieces	Endogenous		43		7-20+ yrs.				1.316[a]		Summer and autumn	
	25	(Same as above)	Gill: Pieces	Endogenous		16		2-6 yrs.				1.546[a]		From water 25°-28° C.	
			Gill: Pieces	Endogenous		16		7-20+ yrs.				1.189[a]		From water 25°-28° C.	
			Gill: Pieces	Endogenous		15		4 yrs.				1.770[a]		From water <20° C.	
			Gill: Pieces	Endogenous		15		22-27 yrs.				1.747[a]		From water <20° C.	
Mercenaria mercenaria (formerly *Venus mercenaria*) Quahog	20	Differential volumeter (modified Thunberg; see Hopkins and Handford, 1943)	Gill: Pieces	Endogenous	25 mg. dry wt.	21						1.225[a]		Sea water (s.g. 1.025). R.Q. 0.90[a]	Hopkins (1946)[t]
			Gill: Pieces	Endogenous	25 mg. dry wt.	21						1.144[a]		Sea water (s.g. 1.025). With HCN (1×10^{-3} M)	
			Gill: Pieces	Endogenous	25 mg. dry wt.	5						1.819[a]		Sea water (s.g. 1.015). R.Q. 0.94[a]	
			Gill: Pieces	Endogenous	25 mg. dry wt.	10						1.417[a]		Sea water (s.g. 1.015). With HCN (1×10^{-3} M)	

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] Δ log [cytochrome c]/mg. wet wt./min.
[g] $-\Delta$ log [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] Δ log [ferricytochrome c]/mg. protein/min.
[j] Δ log [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
			Mantle (central portion): Pieces	Endogenous	20 mg. dry wt.	8						0.771[a]		Sea water (s.g. 1.025)	
			(Same as above)	Endogenous	20 mg. dry wt.	8						0.303[a]		Sea water (s.g. 1.025). With HCN (1×10^{-3} M)	
			(Same as above)	Endogenous	20 mg. dry wt.	7						0.851[a]		Sea water (s.g. 1.015)	
			(Same as above)	Endogenous	20 mg. dry wt.	3						0.274[a]		Sea water (s.g. 1.015). With HCN (1×10^{-3} M)	
			Adductor muscle (red): Pieces	Endogenous	100 mg. dry wt.	3						0.0712[a]		Sea water (s.g. 1.025)	
			(Same as above)	Endogenous	100 mg. dry wt.	3						0.0278[a]		Sea water (s.g. 1.025). With HCN (1×10^{-3} M)	
			(Same as above)	Endogenous	100 mg. dry wt.	3						0.0603[a]		Sea water (s.g. 1.015)	
Mya sp. Soft-shelled clam	25	Warburg	Gill: Thin sheets	Glucose (0.011 M[a])		10					0.280[a]				Villee, Lichtenstein, Nathanson, and Rolander (1950)
Mytilus sp. Mussel	17	Winkler	Gill	Endogenous	67[a] mg. dry wt.	5						1.56[a]		In sea water (S=15°/₀₀)	Schlieper (1931)[t]
			Gill	Endogenous	50[a] mg. dry wt.	4						2.49[a]		In isotonic NaCl solution	
			Gill	Endogenous	67[a] mg. dry wt.	5						1.73[a]		In sea water (S=15°/₀₀)	
			Gill	Endogenous	55[a] mg. dry wt.	5						2.37[a]		In isotonic KCl solution	
			Gill	Endogenous	90[a] mg. dry wt.	6						1.26[a]		In sea water (S=15°/₀₀)	
			Gill	Endogenous	74[a] mg. dry wt.	6						2.16[a]		In isotonic $CaCl_2$ solution	
Mytilus crassitesta Mussel	25	Warburg	Gill	Endogenous	50-100 mg. wet wt.			8 cm. long			0.26[a]			Gas phase: air	Kawai (1959)
			Gill	Endogenous	50-100 mg. wet wt.			8 cm. long			0.13[a]			Gas phase: 90% CO and 10% O_2; in darkness	
Mytilus edulis Edible mussel	7.5	Warburg	Retractor muscle of foot	Endogenous		9					0.018[a]	0.11		In buffered artificial sea water	Glaister and Kerly (1936)[t]
	15	Warburg	(Same as above)	Endogenous		13					0.037[a]	0.22		(Same as above)	
	25	Warburg	(Same as above)	Endogenous		13					0.040[a]	0.24		(Same as above)	
Mytilus edulis Edible mussel	19	Winkler	Gill	Endogenous		11		5.7-7.0 cm. long				1.92[a]		In artificial sea water (S=15°/₀₀)	Pieh (1936)[t]
			Gill	Endogenous		11		5.7-7.0 cm. long				3.10[a]		In isotonic NaCl solution	
Mytilus galloprovincialis Mussel	23	Warburg	Heart: Ventricle only	Endogenous								1.18		In sea water	Cardot, Faure, and Arvanitaki (1950)[t]
			(Same as above)	Endogenous								0.90		In isotonic $MgCl_2$	
			(Same as above)	Endogenous								0.70		In isotonic $CaCl_2$	
			(Same as above)	Endogenous								1.42		In salt solution: $\frac{Na^+ + Ca^{++} + Mg^{++}}{K^+} = 10$	
			(Same as above)	Endogenous								1.18		$\frac{Na^+ + Ca^{++} + Mg^{++}}{K^+} = 50$	

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[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
									Microliters of Oxygen per Hour per Milligram						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Noetia ponderosa (formerly *Arca ponderosa*) Ark shell	28	Thunberg micro-respirometer (see Thunberg, 1905)	Posterior adductor muscle: Pieces Red portion	Endogenous	278[a] mg. wet wt.	7		5.0-6.9 cm. long			0.0312[a]				Hopkins (1930)[t]
			White portion	Endogenous	285[a] mg. wet wt.	7		5.0-6.9 cm. long			0.0179[a]				
Ostrea circumpicta Oyster	24	Micro-Winkler	Heart: Ventricle only	Endogenous	92[a] mg. wet wt.			15 cm. long			0.061[a]			Resting heart	Nomura (1950)[t]
			(Same as above)	Endogenous	92[a] mg. wet wt.			15 cm. long			0.088[a]			Weighted heart	
Pecten sp. Scallop	25	Warburg	Gill: Thin sheets	Glucose (0.011 M[a])		10					0.222[a]				Villee, Lichtenstein, Nathanson, and Rolander (1950)
			Muscle of mantle: Thin sheets or slices	Glucose (0.011 M[a])		5					0.130[a]				
Pecten irradians Scallop	28	Thunberg micro-respirometer (see Thunberg, 1905)	Adductor muscle: Pieces Gray portion	Endogenous	282[a] mg. dry wt.	12		5.0-8.2 cm. long			0.0767[a]				Hopkins (1930)[t]
			White portion	Endogenous	269[a] mg. dry wt.	12		5.0-8.2 cm. long			0.0424[a]				
Pinctada martensii Pearl oyster	25	Warburg	Gill	Endogenous		10		2 yrs.				2.1		Latter half of June	Kawai (1957)[t]
			Pallial margin	Endogenous		7		2 yrs.				0.9		(Same as above)	
			Midgut gland	Endogenous		6		2 yrs.				0.8		(Same as above)	
			Gonad	Endogenous		6		2 yrs.				0.6		(Same as above)	
			Foot muscle	Endogenous		4		2 yrs.				0.6		(Same as above)	
			Epithelium of middle part of mantle edge	Endogenous		5		2 yrs.				0.4		(Same as above)	
			Epithelium adhering to inner surface of shell	Endogenous		5		2 yrs.				0.17		(Same as above)	
			Adductor muscle	Endogenous		5		2 yrs.				0.15		(Same as above)	
			Gill	Endogenous		10					0.36			Latter half of June	
			Gill	Endogenous		5					0.43			Middle of July to end of August	
			Gill	Endogenous		6					0.51			Middle of October	
			Gill	Endogenous		8					0.56			End of December to middle of January	
Pinctada martensii Pearl oyster	25	Warburg	Gill	Endogenous	50-100 mg. wet wt.			2 yrs. (6 cm.)			0.48[a]			Gas phase: air	Kawai (1959)
			Gill	Endogenous	50-100 mg. wet wt.			(Same as above)			0.25[a]			Gas phase: 90% CO and 10% O_2; in darkness	
			Mantle	Endogenous	50-100 mg. wet wt.			2 yrs. (6 cm.)			0.15[a]			Gas phase: air	
			Mantle	Endogenous	50-100 mg. wet wt.			(Same as above)			0.07[a]			Gas phase: 90% CO and 10% O_2; in darkness	
			Midgut gland	Endogenous	50-100 mg. wet wt.			2 yrs. (6 cm.)			0.27[a]			Gas phase: air	
			Midgut gland	Endogenous	50-100 mg. wet wt.			(Same as above)			0.15[a]			Gas phase: 90% CO and 10% O_2; in darkness	

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log$ [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log \text{[cytochrome c]}}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Pinna muricata (probably refers to *Atrina serrata*) Pen shell	28	Thunberg microrespirometer (see Thunberg, 1905)	Posterior adductor muscle: Pieces Gray portion	Endogenous	273[a] mg. wet wt.	6		14.2-28.8 cm. long			0.0507[a]				Hopkins (1930)[t]
			White portion	Endogenous	276[a] mg. wet wt.	6		14.2-28.8 cm. long			0.0413[a]				
			Pedal retractor muscle: Pieces	Endogenous	258[a] mg. wet wt.	4		16.5-28.2 cm. long			0.0371[a]				
Saxostrea commercialis Australian rock oyster	37	Warburg	Adductor muscle: Homogenate	Endogenous	600 mg. (200 mg./ml.)			2-3 yrs.			0.00525[a]			Duration of homogenization: 1.5 min. } Temp. of homogenization: 37° C.	Humphrey (1946)[t]
			(Same as above)	Endogenous	300 mg. (100 mg./ml.)			2-3 yrs.			0.0148[a]			1.5 min. }	
			(Same as above)	Endogenous	150 mg. (50 mg./ml.)			2-3 yrs.			0.0260[a]			1.5 min. }	
			Adductor muscle: Homogenate	Endogenous	600 mg.			2-3 yrs.			0.0283[a]			1 min. } Temp. of homogenization: 20°C.	
			(Same as above)	Endogenous	600 mg.			2-3 yrs.			0.0242[a]			3 min. }	
			(Same as above)	Endogenous	600 mg.			2-3 yrs.			0.0267[a]			5 min. }	
			(Same as above)	Endogenous	600 mg.			2-3 yrs.			0.0265[a]			1 min. } 37° C.	
			(Same as above)	Endogenous	600 mg.			2-3 yrs.			0.0213[a]			3 min. }	
			(Same as above)	Endogenous	600 mg.			2-3 yrs.			0.0205[a]			5 min. }	
			(Same as above)	Endogenous	600 mg.			2-3 yrs.				0.21 (max.)		1.5 min. 37° C.	
Saxostrea commercialis Australian rock oyster	"Room temp."	Warburg	Muscle: Homogenate	Succinate (0.02 M[c])	600 mg.			2-3 yrs.			0.055[a]				Humphrey (1947)[t]
			Muscle: Homogenate	Succinate (0.02 M[c]) + cytochrome *c* (1×10^{-5} M)	600 mg.			2-3 yrs.			0.138[a]				
			Muscle: Homogenate	Cytochrome *c* (1×10^{-5} M[c]) + ascorbic acid (0.01 M[c])	400 mg.			2-3 yrs.			0.120[a]				
Cephalopoda															
Eledone sp. Octopus	16	Warburg; also differential manometer	Mantle nerve and stellate ganglion	Endogenous	9.8 mg. dry wt.	3						0.63[a]		Nerve and ganglion unstimulated; in artificial sea water with urea and bicarbonate	Meyerhof and Schulz (1929)
			(Same as above)	Endogenous	16.0 mg. dry wt.	1						0.30		Nerve and ganglion unstimulated; in *Maja* serum (presumably *Maja* blood)	
Loligo pealeii Squid	25	Warburg	Gill	Endogenous		5						1.8			Robbie (1949)[t]
			Eye:												
			Retina	Endogenous		3						1.1			
			"Cornea"	Endogenous		4						0.4			
			Lens	Endogenous		2						0.002			

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] Δ log [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta$ log [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] Δ log [ferricytochrome *c*]/mg. protein/min.
[j] Δ log [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Loligo pealeii Squid	Not specified	Spectrophotometer	Giant nerve fiber: Homogenate	Succinate (0.017 M[c]) + cytochrome *c* (1.7×10^{-5} M[c])									0.120	All assays: For units of enzymatic activity, see footnote f	Cooperstein and Lazarow (1950)
			Axoplasm	(Same as above)									0.108		
			Homogenate	Cytochrome *c*									0.375		
			Axoplasm	Cytochrome *c*									0.395		
			Fibrous sheath and small nerves surrounding giant axon: Homogenate	Succinate (0.017 M[c]) + cytochrome *c* (1.7×10^{-5} M[c])									0.112		
			(Same as above)	Cytochrome *c*									0.410		
			Fin nerve: Homogenate	Succinate (0.017 M[c]) + cytochrome *c* (1.7×10^{-5} M[c])									0.113		
			Fin nerve: Homogenate	Cytochrome *c*									0.360		
			Stellate ganglion: Homogenate	Succinate (0.017 M[c]) + cytochrome *c* (1.7×10^{-5} M[c])									0.227		
			Stellate ganglion: Homogenate	Cytochrome *c*									2.12		
			Muscle: Homogenate	Succinate (0.017 M[c]) + cytochrome *c* (1.7×10^{-5} M[c])									0.155		
			Muscle: Homogenate	Cytochrome *c*									1.53		
Loligo pealeii Squid	16	Continous flow respirometer (oxygen cathode)	Stellar nerve: Giant axons alone	Endogenous							0.068			Mean value from 8 nerves	Connelly (1952)
			Giant axons plus accompanying small nerve fibers	Endogenous							0.074			Mean value from 5 nerves	
Loligo pealeii Squid	Not specified	Spectrophotometer	Giant nerve fiber: Homogenate of: Whole nerve	Cytochrome *c*									14.7	All assays: For units of enzymatic activity, see footnote g	Foster (1956)[t]
			Isolated sheath	Cytochrome *c*									2.3	All assays: Protein determination by method of Lowry *et al.* (1951)	
			Mitochondria of: Axoplasm	Cytochrome *c*									83.4		
			Isolated sheath	Cytochrome *c*									18.0		
			Axoplasm	Cytochrome *c*									10.2		
Loligo pealeii Squid	15	Micro-volumeter (see Scholander Claff, Andrews, and Wallach, 1952)	Giant nerve fiber: Entire fiber	Endogenous		3-4				2.7	0.112[a]			Based on total protein	Coelho *et al.*, cited by Schmitt and Geschwind (1957)[t] Also Coelho (personal communication)
			Entire fiber	Endogenous							0.106[a]				
			Isolated sheath	Endogenous		6				4.4	0.200[a]			Based on protein of non-collagenous component	
			Isolated sheath	Endogenous							0.125[a]				
Loligo pealeii Squid	38	Fluormetric measurement of TPNH	Giant nerve fiber: Isolated sheath: Homogenate	*iso* Citrate									4.8	All assays: For units of enzymatic activity, see footnote h	Roberts, Coelho, Lowry, and Crawford (1958)[t]
			Axoplasm	*iso* Citrate									0.36	All assays: Protein determination by method of Lowry *et al.* (1951)	
	38	Fluormetric measurement of DPN^+	Giant nerve fiber: Isolated sheath: Homogenate	Malate									147		
			Axoplasm	Malate									103		

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[n] $m\mu$ moles DPNH oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[o] $m\mu$ moles cytochrome c oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} $\text{cm.}^2/\text{mol.}$).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Squid (Sci. name not given)	23	Warburg	Head ganglion (minced)	Glucose (0.01 M)	38.0[a] mg. wet wt.	5						7.5[a]			Nachmansohn, Steinbach, Machado, and Spiegelman (1943)[t]
			(Same as above)	Pyruvate (0.05 M[c])	41.7[a] mg. wet wt.	3						8.0[a]			
			(Same as above)	Pyruvate (0.05 M[c])+ cytochrome *c* (8×10^{-5} M[a,c])	89.0 mg. wet wt.	1						9.7			
			Trunk containing giant axon (minced)	Pyruvate (0.05 M[c])	45.0[a] mg. wet wt.	2						1.11[a]			
			(Same as above)	Pyruvate (0.05 M[c])+ cytochrome *c* (8×10^{-5} M[a,c])	131.0[a] mg. wet wt.	2						1.34[a]			
			Axoplasm (extruded)	Pyruvate (0.05 M[c])+ cytochrome *c* (8×10^{-5} M[a,c])	44.0[a] mg. wet wt.	3						3.23			
			Remaining tissue (minced)	Pyruvate (0.05 M[c])+ cytochrome *c* (8×10^{-5} M[a,c])	98.0[a] mg. wet wt.	2						0.63[a]			
			Head ganglion (ground)	Cytochrome *c* (8×10^{-5} M[a,c])	55.0[a] mg. wet wt.	3						10.6[a]			
			Trunk containing giant axon (ground)	Cytochrome *c* (8×10^{-5} M[a,c])	110.0[a] mg. wet wt.	2						0.94[a]			
			Axoplasm (extruded)	Cytochrome *c* (8×10^{-5} M[a,c])	44.0[a] mg. wet wt.	3						3.23[a]			
			Remaining tissue (ground)	Cytochrome *c* (8×10^{-5} M[a,c])	58.0[a] mg. wet wt.	2						0.50[a]			
Squid (Sci. name not given)	28	Not specified	Heart: Slices	Endogenous								9.0		Gas phase: O_2	Barron (1958)
Octopus sp. Octopus	16	Warburg; also differential manometer	Mantle nerve	Endogenous	18.7 mg. dry wt.	1						0.48		Nerve unstimulated; in *Maja* serum (presumably *Maja* blood)	Meyerhof and Schulz (1929)
			Mantle nerve	Endogenous	24.5 mg. dry wt.	1						0.28		Nerve unstimulated; in artificial sea water lacking urea or bicarbonate	
Octopus macropus Octopus	24	Warburg	Salivary gland: Slices (from frozen tissue)	Endogenous								0.88		Gas phase: 95% N_2 and 5% O_2	Ghiretti-Magaldi, Giuditta, and Ghiretti (1958)[t]
			(Same as above)	Endogenous								0.54		Gas phase: 95% CO and 5% O_2; in darkness	
			(Same as above)	Endogenous								0.83		Gas phase: 95% CO and 5% O_2; in light	
Octopus vulgaris Octopus	20	Warburg	Retina	Glucose (0.011 M[a])		4						0.88			Vincentiis (1952)
			Optic ganglion: Slices	Glucose (0.011 M[a])		7						1.42			
			Midgut gland: Slices	Glucose (0.011 M[a])		3						0.86			

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Octopus vulgaris Octopus	24	Manometer	Mantle and tentacles (skinned muscle): Particle suspension (from frozen tissue)	Succinate (0.05 M[c])								1.8[a]			Ghiretti-Magaldi, Giuditta, and Ghiretti (1957)[t]
			(Same as above)	Succinate (0.05 M[c])+ cytochrome *c* (2.5×10^{-5} M[c])								3.3[a]			
			(Same as above)	Ascorbic acid								0.33[a]			
			(Same as above)	Ascorbic acid + cytochrome *c* (2.5×10^{-5} M[c])								4.56[a]			
			(Same as above)	Quinol								0.14[a]			
			(Same as above)	Quinol + cytochrome *c* (2.5×10^{-5} M[c])								4.28[a]			
			(Same as above)	*p*-phenylenediamine								0.19[a]			
			(Same as above)	*p*-phenylenediamine + cytochrome *c* (2.5×10^{-5} M[c])								2.00[a]			
Octopus vulgaris Octopus	24	Warburg	Optic ganglion	Endogenous								1.86		Gas phase: Air	Ghiretti-Magaldi, Giuditta, and Ghiretti (1958)[t]
			Optic ganglion	Endogenous								4.76		O_2	
			Kidney	Endogenous								2.07		Air	
			Kidney	Endogenous								3.05		O_2	
			Salivary gland	Endogenous								0.83		Air	
			Salivary gland	Endogenous								2.81		O_2	
			Gill	Endogenous								1.64		Air	
			Gill	Endogenous								2.43		O_2	
			Branchial heart	Endogenous								1.78		Air	
			Branchial heart	Endogenous								1.74		O_2	
			Branchial gland	Endogenous								1.13		Air	
			Branchial gland	Endogenous								1.42		O_2	
			Midgut gland	Endogenous								0.67		Air	
			Midgut gland	Endogenous								1.02		O_2	
			Mantle muscle	Endogenous								0.42		Air	
			Mantle muscle	Endogenous								0.88		O_2	
			Central heart	Endogenous								1.57		Air	
Sepia officinalis Cuttlefish	20-22	Warburg	Nerve	Endogenous	50-100 mg. wet wt.	4						0.63[a]		In sea water	Cardot, Faure, and Arvanitaki (1950)[t]
			Nerve	Endogenous	50-100 mg. wet wt.	1						0.18		In isotonic $MgCl_2$	
			Nerve	Endogenous								0.73		In salt solution: $\frac{Na^+ + Ca^{++} + Mg^{++}}{K^+} = 40$	
			Nerve	Endogenous								0.61		$\frac{Na^+ + Ca^{++} + Mg^{++}}{K^+} = 53$	
ANNELIDA															
Polychaeta															
Chaetopterus sp. Parchment worm	25	Warburg	Muscle: Thin sheets or slices	Glucose (0.011 M[a])		10					0.116[a]				Villee, Lichtenstein, Nathanson, and Rolander (1950)
Sabella pavonina Feather-duster worm or peacock-worm	17	Micro-Winkler	Isolated crown	Endogenous		21					0.167[a]	1.152[a]			Fox (1938)

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log$ [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Sabella pavonina Feather-duster worm or peacock-worm	17	Barcroft	Body wall: Slices	Succinic acid (0.001 M)		11						0.504[a]		First hour: in air	Ewer and Fox (1940)
			Body wall: Slices	Succinic acid (0.001 M)		11						0.430[a]		Second hour: in CO	
			Body wall: Slices	Succinic acid (0.001 M)		11						0.539[a]		First hour: in air	
			Body wall: Slices	Succinic acid (0.001 M)		11						0.444[a]		Second hour: in air	
Clitellata															
Eisenia foetida Manure worm or brandling	Not specified	Warburg	Viscera: Mince		Wet wt.									All assays: Segmentation approximate	O'Brien (1957)[t]
			Segments 1-9	Endogenous	100 mg.			Clitellate worms			0.12[a]				
			Segments 30-34 (clitellum)	Endogenous	100 mg.			Clitellate worms			0.01[a]				
			Segments 40-49	Endogenous	100 mg.			Clitellate worms			0.04[a]				
			Segments 60-69	Endogenous	100 mg.			Clitellate worms			0.05[a]				
			Segments 90-100	Endogenous	100 mg.			Clitellate worms			0.08[a]				
	Not specified	Warburg	Body wall: Mince		Wet wt.									All assays: Segmentation approximate	
			Segments 1-9	Endogenous	100 mg.			Clitellate worms			0.48[a]				
			Segments 10-19	Endogenous	100 mg.			Clitellate worms			0.30[a]				
			Segments 20-29	Endogenous	100 mg.			Clitellate worms			0.27[a]				
			Segments 40-49	Endogenous	100 mg.			Clitellate worms			0.23[a]				
			Segments 60-69	Endogenous	100 mg.			Clitellate worms			0.31[a]				
			Segments 90-100	Endogenous	100 mg.			Clitellate worms			0.44[a]				
	27	Warburg	Body wall: Mince											All assays: Segmentation approximate	
			Segments 1-9	Succinate + cytochrome *c*				Clitellate worms			0.78[a]				
			Segments 10-19	Succinate + cytochrome *c*				Clitellate worms			0.69[a]				
			Segments 30-34 (clitellum)	Succinate + cytochrome *c*				Clitellate worms			0.63[a]				
			Segments 35-40	Succinate + cytochrome *c*				Clitellate worms			0.62[a]				
			Segments 55-60	Succinate + cytochrome *c*				Clitellate worms			0.55[a]				
			Segments 100-110	Succinate + cytochrome *c*				Clitellate worms			0.76[a]				
	Not specified	Warburg	Viscera: Homogenate		Wet wt.									All assays: Segmentation approximate	
			Segments 1-9	Endogenous	200 mg.			Clitellate worms			0.046[a]				
			Segments 30-34 (clitellum)	Endogenous	200 mg.			Clitellate worms			0.025[a]				
			Segments 40-49	Endogenous	200 mg.			Clitellate worms			0.028[a]				
			Segments 60-69	Endogenous	200 mg.			Clitellate worms			0.029[a]				
			Segments 90-100	Endogenous	200 mg.			Clitellate worms			0.031[a]				
	Not specified	Warburg	Body wall: Homogenate		Wet wt.									All assays: Segmentation approximate	
			Segments 1-9	Endogenous	200 mg.			Clitellate worms			0.053[a]				
			Segments 40-49	Endogenous	200 mg.			Clitellate worms			0.026[a]				
			Segments 60-69	Endogenous	200 mg.			Clitellate worms			0.041[a]				
			Segments 90-100	Endogenous	200 mg.			Clitellate worms			0.076[a]				
	27	Warburg	Body wall: Homogenate											All assays: Segmentation approximate	
			Segments 1-9	Succinate + cytochrome *c*				Clitellate worms			1.020[a]				
			Segments 10-19	Succinate + cytochrome *c*				Clitellate worms			0.870[a]				
			Segments 30-34 (clitellum)	Succinate + cytochrome *c*				Clitellate worms			0.700[a]				
			Segments 35-40	Succinate + cytochrome *c*				Clitellate worms			0.660[a]				
			Segments 55-60	Succinate + cytochrome *c*				Clitellate worms			0.550[a]				
			Segments 100-110	Succinate + cytochrome *c*				Clitellate worms			0.860[a]				

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Lumbricus terrestris Earthworm or night crawler	15-18	Barcroft	Body wall: Slices	Endogenous	83 mg. dry wt.	32 (2 per exp.)		Large worms (2.5-5 g.)				0.632[a]		In gas mixture of 20% O_2 and 80% N_2	Johnson (1942)
			Body wall: Slices	Endogenous	83 mg. dry wt.	32 (2 per exp.)		Large worms (2.5-5 g.)				0.685[a]		In gas mixture of 20% O_2, 20% CO, and 60% N_2	
Octolasium cyaneum Blue worm	27	Warburg	Body wall: Mince Segments 1-9 Segments 35-40 Segments 55-60 Segments 100-110	 Succinate + cytochrome *c* Succinate + cytochrome *c* Succinate + cytochrome *c* Succinate + cytochrome *c*				 Clitellate worms Clitellate worms Clitellate worms Clitellate worms			 0.55[a] 0.34[a] 0.41[a] 0.52[a]			All assays: Segmentation approximate	O'Brien (1957)[t]
			Body wall: Homogenate Segments 1-9 Segments 35-40 Segments 55-60 Segments 100-110	 Succinate + cytochrome *c* Succinate + cytochrome *c* Succinate + cytochrome *c* Succinate + cytochrome *c*				 Clitellate worms Clitellate worms Clitellate worms Clitellate worms			 0.680[a] 0.410[a] 0.420[a] 0.590[a]			All assays: Segmentation approximate	
Earthworm (Sci. name not given)	Not specified	Microrespirometer	Ventral nerve cord	Endogenous		21					0.372[a]			R.Q. 0.8-0.9	Winterstein and Basoglu (1939)
Leech (Sci. name not given)	20-22	Polarograph	Smooth muscle of back: Fragments	Endogenous		8					0.096[a]			Muscle at rest	Brecht, Behrens, and Bartels (1954)[t]
ARTHROPODA															
Merostomata															
Limulus polyphemus Horseshoe crab	25	Warburg	Cardiac ganglion	Endogenous	100 mg. wet wt. (5 + ganglia pooled)						0.104			Mean resting value from 3 experiments	Dann and Gardner (1930)
			Cardiac ganglion	Endogenous	100 mg. wet wt. (5 + ganglia pooled)						0.114			Mean resting value from 3 experiments	
Limulus polyphemus Horseshoe crab	24	Warburg	Claw nerve	Endogenous							0.082[a]				Chang (1931)
Limulus polyphemus Horseshoe crab	31	Differential volumeter (see Gerard and Hartline (1934)	Optic nerve: Pieces Proximal 1/5 Medial 1/5 Distal 1/5	 Endogenous Endogenous Endogenous		 2 2 2	 ♂ ♂ ♂				 0.101[a] 0.118[a] 0.082[a]				Guttman (1935)[t]
	28	(Same as above)	Optic nerve: Pieces Proximal 1/5 Medial 1/5 Distal 1/5	 Endogenous Endogenous Endogenous		 2 2 2	 ♂ ♂ ♂				 0.067[a] 0.076[a] 0.050[a]				
	16	(Same as above)	Optic nerve: Pieces Proximal 1/5 Medial 1/5 Distal 1/5	 Endogenous Endogenous Endogenous		 2 5 5	 ♂ ♂ ♂				 0.032[a] 0.022[a] 0.018[a]				

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Limulus polyphemus Horseshoe crab	24	Differential volumeter (see Gerard and Hartline, 1934)	Optic nerve: Pieces												Shapiro (1937)[t]
			Axon:												
			Proximal 1/5	Endogenous		8	♂	Adult			0.107[a]				
			Medial 1/5	Endogenous		8	♂	Adult			0.110[a]				
			Distal 1/5	Endogenous		8	♂	Adult			0.086[a]				
			Sheath:												
			Proximal 1/5	Endogenous		8	♂	Adult			0.035[a]				
			Medial 1/5	Endogenous		8	♂	Adult			0.036[a]				
			Distal 1/5	Endogenous		8	♂	Adult			0.031[a]				
	20	(Same as above)	Retina	Endogenous							0.129[a]				
	24	(Same as above)	Forebrain	Endogenous							0.134[a]				
	24	(Same as above)	Foregut	Endogenous							0.123[a]				
	24	(Same as above)	Muscle	Endogenous							0.036[a]				
Limulus polyphemus Horseshoe crab	28	Not specified	Heart: Slices	Endogenous								2.1		Gas phase: O_2	Barron (1958)
Crustacea															
Astacus sp. Crayfish	16	Warburg; also differential manometer	Nerve	Endogenous	2.72 mg. dry wt.	1						0.77		Nerve unstimulated; in Ringer's solution Δ f.p.=−0.8° C.	Meyerhof and Schulz (1929)
Callinectes sapidus Blue crab	26	Fenn (modified)	Claw nerve	Endogenous	36[a] mg. wet wt.	11					0.136[a]			Mean value for 19 claw nerves	Lindeman (1939)
	20	(Same as above)	Claw nerve	Endogenous	34[a] mg. wet wt.	11					0.105[a]			Mean value for 20 claw nerves	
	20	(Same as above)	Claw nerve	Endogenous		11					0.099[a]			Mean value for 11 claw nerves	
	20	(Same as above)	Leg nerve (1st walking leg)	Endogenous		11					0.156[a]			Mean value for 11 leg nerves	
Callinectes sapidus Blue crab	27	Warburg	Gill	Endogenous		40					0.351[a]				Vernberg (1956)
			Gill	Endogenous		15	♂				0.345[a]				
			Gill	Endogenous		25	♀				0.357[a]				
			Midgut gland	Endogenous		48					0.734[a]				
			Midgut gland	Endogenous		15	♂				0.626[a]				
			Midgut gland	Endogenous		33	♀				0.782[a]				
Carcinus maenas (formerly *Carcinides maenas*) Green crab	24	Warburg	Gill	Endogenous		19						2.61[a]		In artificial sea water (S=32‰)	Pieh (1936)[t]
			Gill	Endogenous		8						3.91[a]		In brackish water (S=15‰)	
			Gill	Endogenous		6						4.55[a]		In NaCl solution	
Carcinus maenas (formerly *Carcinides maenas*) Green crab	20-25	Warburg	Muscle: Homogenate	Endogenous				With eyestalks			0.010[a]			All assays: Arbitrarily selected pairs (bracketed) of simultaneous determinations on tissues prepared at same time. Eyestalk extract added to homogenate	Scheer, Schwabe, and Scheer, (1952)[t]
			Muscle: Homogenate	Succinate + cytochrome *c*				With eyestalks			0.019[a]				
			Muscle: Homogenate	Succinate + cytochrome *c*				With eyestalks			0.015[a]				
			Muscle: Homogenate	Succinate + cytochrome *c*				Without eyestalks			0.011[a]				
			Muscle: Homogenate	Succinate + cytochrome *c*				With eyestalks			0.010[a]				
			Muscle: Homogenate	Succinate + cytochrome *c*				With eyestalks			0.014[a]				

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] Δ log [cytochrome *c*]/mg. wet wt./min.
[g] −Δ log [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] Δ log [ferricytochrome *c*]/mg. protein/min.
[j] Δ log [$CyFe^{++}$]/min.
[k] $\text{Activity/mg. N when standard activity} = \frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] $\text{Activity/mg. protein when activity} = \frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Carcinus maenas (formerly *Carcinides maenas*) Green crab	20	Barcroft	Muscle: Extract	Fructose		4		Molting				0.392[a]		With KCN	Krishnan (1954)[t]
			(Same as above)	Fructose		6		Soft-shelled (postmolt)				0.400[a]		With KCN	
			(Same as above)	Fructose		6		Hard-shelled (intermolt)				0.770[a]		With KCN	
			(Same as above)	Fructose		6		Premolt				0.274[a]		With KCN	
								With eyestalks							
			Muscle: Extract	Fructose		12		0 da.				0.784[a]		With KCN	
			(Same as above)	Fructose		12		3 da.				0.636[a]		With KCN	
			(Same as above)	Fructose		12		9 da.				0.226[a]		With KCN	
			(Same as above)	Fructose		12		15 da.				0.384[a]		With KCN	
								Without eyestalks							
			(Same as above)	Fructose		12		0 da.				0.784[a]		With KCN	
			(Same as above)	Fructose		12		3 da.				0.236[a]		With KCN	
			(Same as above)	Fructose		12		9 da.				0.310[a]		With KCN	
			(Same as above)	Fructose		12		15 da.				0.342[a]		With KCN	
Clibinarius vittatus (formerly *Clibinarius vittatius*) Hermit crab	27	Warburg	Gill	Endogenous		17					0.325[a]				Vernberg (1956)
			Midgut gland	Endogenous		22					0.622[a]				
Gecarcinus lateralis Purple land crab	25	Warburg	Integumentary tissues	Endogenous		8	♂	Intermolt				0.53			Skinner [MS]
			Integumentary tissues	Endogenous		11	♂	Premolt				0.85			
Homarus americanus American lobster	24	Warburg	Ventral ganglionated nerve cord	Endogenous							0.123[a]				Chang (1931)
			All peripheral leg nerves	Endogenous							0.081[a]				
			Claw nerves	Endogenous							0.086[a]				
			Nerves of walking legs	Endogenous							0.071[a]				
Homarus americanus American lobster	Not specified	Spectrophotometer	Leg and claw nerves: Homogenate	Succinate (0.017 M^c) + cytochrome *c* (1.7×10^{-5} M^c)									0.052[l]	For units of enzymatic activity, see footnotes indicated All assays: Protein determination by method of Lowry *et al.* (1951)	Foster (1956)[t]
			Leg and claw nerves: Homogenate	Cytochrome *c*									1.4[g]		
			Leg and claw nerves: Nuclear fraction	Cytochrome *c*									1.8[g]		
			Leg and claw nerves: Mitochondria	Succinate (0.017 M^c) + cytochrome *c* (1.7×10^{-5} M^c)									0.837[l]		
			Leg and claw nerves: Mitochondria	Cytochrome *c*									11.9[g]		
			Leg and claw nerves: Supernatant	Succinate (0.017 M^c) + cytochrome *c* (1.7×10^{-5} M^c)									0.057[l]		
			Leg and claw nerves: Supernatant	Cytochrome *c*									1.0[g]		

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
	20	Spectrophotometer	Leg and claw nerves: Mitochondria	Succinate (8.3×10^{-3} M[a,c])						3.54[a] 0.93[a]				All assays: Cytochrome *c* (8.3×10^{-6} M[a,c]) present All assays: P/O ratios in original paper All assays: Protein determination by method of Lowry *et al.* (1951)	
			Mitochondria	Fumarate (8.3×10^{-3} M[a,c])						6.06[a] 1.34[a]					
			Mitochondria	Malate (8.3×10^{-3} M[a,c])						0.90[a] 2.59[a]					
			Mitochondria	Citrate (8.3×10^{-3} M[a,c])						0.57[a] 4.46[a]					
			Mitochondria	α-Ketoglutarate (8.3×10^{-3} M[a,c])						0.76[a] 0.49[a] 0.61[a]					
Homarus gammarus (formerly *Homarus vulgaris*) Lobster	20-25	Warburg	Muscle: Homogenate	Succinate + cytochrome *c*				With eyestalks			0.040[a]			Arbitrarily selected pair of simultaneous determinations on tissues prepared at same time	Scheer, Schwabe, and Scheer (1952)[t]
			Muscle: Homogenate	Succinate + cytochrome *c*				Without eyestalks			0.036[a]				
Lobster (Sci. name not given)	Not specified	Warburg	Muscle	Endogenous							<0.01				Kermack, Lees, and Wood (1954)[t]
	25 and 37	Warburg	Midgut gland	Endogenous							0.08				
	Not specified	Warburg	Midgut gland	Cytochrome *c*							0.14[a]				
	Not specified	Warburg	Midgut gland	Cytochrome *c* + *p*-phenylenediamine							0.54				
Libinia dubia Spider crab	27	Warburg	Gill	Endogenous		21					0.214[a]				Vernberg (1956)
			Gill	Endogenous		14	♂				0.208[a]				
			Gill	Endogenous		7	♀				0.266[a]				
			Midgut gland	Endogenous		20					0.346[a]				
			Midgut gland	Endogenous		13	♂				0.354[a]				
			Midgut gland	Endogenous		7	♀				0.391[a]				
Libinia emarginata Spider crab	23	Thunberg, modified (see Hopkins and Handford, 1943)	Claw nerve	Endogenous	70 mg. wet wt. (nerves of 4 specimens pooled)	8[a]					0.116[a]			In sea water containing *ca.* 12 mM K^+ In artificial sea water with the following mM/liter of K^+:	Shanes and Hopkins (1948)[t]
			Claw nerve	Endogenous	(Same as above)	36[a]					0.0906[a]			0	
			Claw nerve	Endogenous	(Same as above)	8[a]					0.131[a]			15	
			Claw nerve	Endogenous	(Same as above)	24[a]					0.162[a]			30	
			Claw nerve	Endogenous	(Same as above	8[a]					0.144[a]			40	
			Claw nerve	Endogenous	(Same as above)	4[a]					0.0697[a]			70	
			Claw nerve	Endogenous	(Same as above)	12[a]					0.0479[a]			100	

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] $\text{Activity/mg. N when standard activity} = \frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] $\text{Activity/mg. protein when activity} = \frac{\Delta \log [\text{cytochrome c}]}{\Delta t\ (\text{min.})}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
									Microliters of Oxygen per Hour per Milligram						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Maja sp. Spider crab	16	Warburg; also differential manometer	Leg nerve	Endogenous	12.93[a] mg. dry wt.	4						0.87[a]		Nerve unstimulated; in artificial sea water with urea and bicarbonate	Meyerhof and Schulz (1929)
			Leg nerve	Endogenous	22.93[a] mg. dry wt.	5						1.12[a]		Nerve unstimulated; in *Maja* serum (presumably *Maja* blood)	
Menippe mercenaria Stone crab	27	Warburg	Gill	Endogenous		32					0.329[a]				Vernberg (1956)
			Gill	Endogenous		16	♂				0.310[a]				
			Gill	Endogenous		16	♀				0.348[a]				
			Midgut gland	Endogenous		33					0.623[a]				
			Midgut gland	Endogenous		20	♂♀				0.618[a]				
			Midgut gland	Endogenous		13	♀				0.631[a]				
Ocypode quadrata (formerly *Ocypode albicans*) Ghost crab	27	Warburg	Gill	Endogenous		25					0.914[a]				Vernberg (1956)
			Gill	Endogenous		11	♂♀				9.945[a]				
			Gill	Endogenous		14					0.885[a]				
			Midgut gland	Endogenous		32					0.772[a]				
			Midgut gland	Endogenous		17	♂♀				0.782[a]				
			Midgut gland	Endogenous		15	♀				0.760[a]				
Pachygrapsus crassipes Striped shore crab	20	Scholander-Wennesland microrespirometer (see Wennesland, 1951)	Brain	Endogenous	13.4 mg. wet wt. (3 brains pooled)	6	♂	Adult			0.268[a]			8.5 (Acclimatization temp. (°C.))	Roberts (1957)
			Brain	Endogenous	13.5 mg. wet wt (3 brains pooled)	6	♂	Adult			0.258[a]			16.0 (Acclimatization temp. (°C.))	
			Brain	Endogenous	12.5 mg. wet wt. (3 brains pooled)	7	♂	Adult			0.242[a]			23.5 (Acclimatization temp. (°C.))	
			Leg muscle (teased)	Endogenous	293 mg. wet wt.	14	♂	Adult			0.0475[a]			8.5 (Acclimatization temp. (°C.))	
			(Same as above)	Endogenous	291 mg. wet wt.	19	♂	Adult			0.0500[a]			16.0 (Acclimatization temp. (°C.))	
			(Same as above)	Endogenous	297 mg. wet wt.	17	♂	Adult			0.0270[a]			23.5 (Acclimatization temp. (°C.))	
Palaemon squilla (formerly *Leander adspersus*) Shrimp	20-25	Warburg	Muscle: Homogenate	Endogenous				With eyestalks			0.005[a]			All assays: Arbitrarily selected pairs (bracketed) of simultaneous determination on tissues prepared at same time Eyestalk extract added to homogenate	Scheer, Schwabe, and Scheer (1952)[t]
			(Same as above)	Succinate + cytochrome *c*				With eyestalks			0.013[a]				
			(Same as above)	Succinate + cytochrome *c*				With eyestalks			0.010[a]				
			(Same as above)	Succinate + cytochrome *c*				Without eyestalks			0.007[a]				
			(Same as above)	Succinate + cytochrome *c*				With eyestalks			0.004[a]				
			(Same as above)	Succinate + cytochrome *c*				With eyestalks			0.006[a]				

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Pandalus borealis Prawn	6	Not specified	Dorsal extensor abdominal muscle	Endogenous							0.038[a]			Specimens from Kristineberg, Sweden	Fox and Wingfield (1937)
	10	Not specified	(Same as above)	Endogenous							0.065[a]			Specimens from Kristineberg, Sweden	
Pandalus montagui Pink shrimp	6	Not specified	Dorsal extensor abdominal muscle	Endogenous							0.040[a]			Specimens from Kristineberg, Sweden	Fox and Wingfield (1937)
	10	Not specified	(Same as above)	Endogenous							0.070[a]			Specimens from Kristineberg, Sweden	
	10	Not specified	(Same as above)	Endogenous							0.077[a]			Specimens from Plymouth, England	
	16	Not specified	(Same as above)	Endogenous							0.094[a]			Specimens from Plymouth, England	
Panopeus herbstii Mud crab	27	Warburg	Gill	Endogenous		32					0.319[a]				Vernberg (1956)
			Gill	Endogenous		17	♂				0.314[a]				
			Gill	Endogenous		15	♀				0.325[a]				
			Midgut gland	Endogenous		32					0.536[a]				
			Midgut gland	Endogenous		18	♂				0.565[a]				
			Midgut gland	Endogenous		12	♀				0.552[a]				
Panulirus argus Spiny lobster	25	Warburg	Midgut gland	Endogenous		4						3.0			Robbie (1949)[t]
			Leg nerve	Endogenous		5						1.1			
			Leg muscle	Endogenous		2						1.0			
Pugettia producta Kelp crab	15	Warburg	Midgut gland: Slices	Endogenous		61						1.73			Belding, Field, Weymouth, and Allen (1942)[t]
			(Same as above)	Endogenous		28	♂					1.92			
			(Same as above)	Endogenous		33	♀					1.57			
Sesarma cinereum (formerly *Sesarma cinerea*) Marsh crab	27	Warburg	Gill	Endogenous		10					0.911[a]				Vernberg (1956)
			Midgut gland	Endogenous		14					0.357[a]				
Uca minax Red-jointed fiddler crab	27	Warburg	Gill	Endogenous		33					0.373[a]				Vernberg (1956)
			Gill	Endogenous		26	♂				0.359[a]				
			Gill	Endogenous		7	♀				0.422[a]				
			Midgut gland	Endogenous		41					0.383[a]				
			Midgut gland	Endogenous		32	♂				0.419[a]				
			Midgut gland	Endogenous		9	♀				0.255[a]				
Uca pugilator Fiddler crab	27	Warburg	Gill	Endogenous		27					0.550[a]				Vernberg (1956)
			Gill	Endogenous		15	♂				0.613[a]				
			Gill	Endogenous		12	♀				0.471[a]				
			Midgut gland	Endogenous		34					0.360[a]				
			Midgut gland	Endogenous		24	♂				0.401[a]				
			Midgut gland	Endogenous		10	♀				0.263[a]				

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Insecta															
Acheta domesticus (formerly *Gryllus domesticus*) House cricket	30	Fenn	Fat body: Residues (mitochondria)	α-Ketoglutarate				Nymph		30.6				Protein determination by method of Lowry *et al.* (1951)	Young (1959)[t]
Apis mellifera Honeybee	37	Warburg	Flight muscle: Mitochondria	Citrate (1×10^{-3} M[a,c])						3.7[a]				All assays: Cytochrome *c* (2.7×10^{-5} M[a,c]) present All assays: Protein determination by method of Weichselbaum (1946)	Hoskins, Cheldelin, and Newburgh (1959)[t]
			(Same as above)	*Iso* Citrate (1.3×10^{-3} M[a,c])						3.6[a]					
			(Same as above)	α-Ketoglutarate (1×10^{-3} M[a,c])						1.8[a]					
			(Same as above)	Succinate (1×10^{-3} M[a,c])						3.0[a]					
			(Same as above)	Malate (1×10^{-3} M[a,c])						2.6[a]					
			(Same as above)	Fumarate (1×10^{-3} M[a,c])						2.9[a]					
Belostoma spp. Giant water bug	25	Volumetric microrespirometer (see Scholander, 1942)	Flight muscle (teased)	Endogenous	10-20 mg. wet wt.	3		Adult			1.16	4.23		In Wilder and Smith saline	Pérez-González and Edwards (1954)[t]
			Leg muscle (coxal levator, teased)	Endogenous	10-20 mg. wet wt.	3		Adult			0.308	1.43		In Wilder and Smith saline	
Blattella germanica German cockroach	30	Fenn	Fat body: Residues (mitochondria)	α-Ketoglutarate				Nymph		10.0				Protein determination by method of Lowry *et al.* (1951)	Young (1959)[t]
Bombyx mori Silkworm	30	Manometer	Midgut: Homogenate	Endogenous				5th instar larva	27[a]					In distilled water	Ito, Horie, and Ishikawa (1958)[t]
			(Same as above)	Endogenous				5th instar larva	68[a]					In sucrose (0.25 M)	
			(Same as above)	Endogenous				5th instar larva	46[a]					In NaCl (0.125 M)	
			(Same as above)	Endogenous				5th instar larva	32[a]					In KCl (0.125 M)	
			(Same as above)	Succinate (0.045 M[a,c])				5th instar larva	12.3[a]					All assays: Nitrogen determination by micro-Kjeldahl procedure	
			(Same as above)	Cytochrome *c* (5.5×10^{-5} M[a,c]) + *p*-phenylenediamine (4.5×10^{-3} M[a,c])				5th instar larva	29.4[a]						
			Midgut: Mitochondria	Succinate (0.045 M[a,c])				5th instar larva	15.6[a]					Fractionating medium: KCl (0.9%)	
			(Same as above)	Succinate (0.045 M[a,c])				5th instar larva	14.0[a]					Sucrose (0.25 M)	
			(Same as above)	Succinate (0.045 M[a,c])				5th instar larva	25.8[a]					KCl (0.9%) + EDTA (0.01 M)	
			(Same as above)	Cytochrome *c* (5.5×10^{-5} M[a,c]) + *p*-phenylenediamine (4.5×10^{-3} M[a,c])				5th instar larva	139.4[a]					KCl (0.9%)	
			(Same as above)	Cytochrome *c* (5.5×10^{-5} M[a,c]) + *p*-phenylenediamine (4.5×10^{-3} M[a,c])				5th instar larva	37.5[a]					Sucrose (0.25 M)	
			(Same as above)	Cytochrome *c* (5.5×10^{-5} M[a,c]) + *p*-phenylenediamine (4.5×10^{-3} M[a,c])				5th instar larva	161.3[a]					KCl (0.9%) + EDTA (0.01 M)	
			(Same as above)	Cytochrome *c* (2.5×10^{-3} M[a,c])				5th instar larva	31.5					Without cyanide	
			(Same as above)	Cytochrome *c* (2.5×10^{-5} M[a,c])				5th instar larva	14.4					With cyanide ($1. \times 10^{-3}$ M)	
			(Same as above)	Succinate (0.01 M[a,c])				5th instar larva	229					All assays: Nitrogen determination by micro-Kjeldahl procedure	
			(Same as above)	Fumarate (0.01 M[a,c])				5th instar larva	158						
			(Same as above)	Malate (0.01 M[a,c])				5th instar larva	122						
			(Same as above)	α-Ketoglutarate (0.01 M[a,c])				5th instar larva	101						
			(Same as above)	Citrate (0.01 M[a,c])				5th instar larva	35						

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log \text{[cytochrome c]}}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Calliphora erythrocephala Bluebottle fly	25	Differential manometer	Flight muscle: Sarcosomes	α-Ketoglutarate	Sarcosomal protein content: 1.0-1.5 mg.			Adult: 1-7 da.		18.6				All assays: P/O ratios in original paper All assays: Method of protein determination not specified	Lewis and Slater (1954)[t]
			Flight muscle: Sarcosomes	α-Ketoglutarate	(Same as above)			Adult: 8-10 da.		9.4					
			Flight muscle: Sarcosomes	α-Ketoglutarate	(Same as above)			Adult: 15-17 da.		12.0					
Calliphora erythrocephala Bluebottle fly	25	Differential manometer	Flight muscle: Sarcosomes	α-Ketoglutarate	Sarcosomal protein content: 1.0-1.5 mg	5		Adult: 1-2 da.		17.4[a]				All assays: P/O ratios in original paper All assays: Method of protein determination not specified	Slater and Lewis (1954)[t]
			Flight muscle: Sarcosomes	α-Ketoglutarate	(Same as above)	2		Adult: 9 da.		8.8[a]					
Carpocapsa pomonella (cited as *Cydia pomonella*) Codling moth	20	Warburg	Muscle	Endogenous		7	♀	Larva				0.972[a]			Graham (1946)[t]
			Muscle	Endogenous		5	♂	Larva				0.785[a]			
			Muscle	Endogenous		60-120[a]		Larva						R.Q. 1.17	
			Fat body	Endogenous		7	♀	Larva				0.607[a]		Based on total dry weight	
			Fat body	Endogenous		7	♀	Larva				1.228[a]		Based on defatted dry weight	
			Fat body	Endogenous		5	♂	Larva				0.544[a]		Based on total dry weight	
			Fat body	Endogenous		5	♂	Larva				1.100[a]		Based on defatted dry weight	
			Fat body	Endogenous		60-120[a]		Larva						R.Q. 1.22	
Galleria mellonella Greater wax moth	30	Fenn	Fat body: Residues (mitochondria)	α-Ketoglutarate				Larva		26.2				Protein determination by method of Lowry *et al.* (1951)	Young (1959)[t]
Hyalophora cecropia (formerly *Platysamia cecropia*) Cecropia moth	25	Warburg												All assays: Method of nitrogen determination not specified	Sanborn and Williams (1950)[t]
			Midgut: Washed homogenate	Succinate (0.013 M[c]) + cytochrome *c* (4.8×10^{-5} M[c])				Larva	29					Without malonate	
			(Same as above)	Succinate (0.013 M[c]) + cytochrome *c* (4.8×10^{-5} M[c])				Larva	20					With malonate (0.01 M[c])	
			(Same as above)	Ascorbate (0.014 M[c]) + cytochrome *c* (1.6×10^{-4} M[c])				Larva	424					Without malonate	
			(Same as above)	Ascorbate (0.01 M[c]) + cytochrome *c* (1.6×10^{-4} M[c])				Larva	306					With malonate (0.01 M[c])	
Hyalophora cecropia (formerly *Platysamia cecreopia*) Cecropia moth	25	Warburg	Wing	Endogenous		4	♀	Diapausing pupa				5.1			Harvey (MS b)

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] Δ log [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta$ log [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] Δ log [ferricytochrome *c*]/mg. protein/min.
[j] Δ log [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] $m\mu$ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] $m\mu$ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] $m\mu$ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 $m\mu$.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Hyalophora cecropia (formerly *Platysamia cecropia*) Cecropia moth	Not specified	Spectrophotometer						Unchilled pupae: Time after pupation:						All assays: For units of enzymatic activity, see footnote m All assays: Nitrogen determination by method of Kabat and Mayer (1948) All assays: With KCN (1×10^{-3} M[c])	Shappirio and Williams (1957b)[t]
			Wing epithelium: Homogenate	Succinate (0.01 M[c]) + cytochrome *c* (3×10^{-5} M[c])		2-4		2-3 da.					<4		
			(Same as above)	(Same as above)		6-12		10 wks.					<2		
								Chilled pupae: Length of chilling:							
			Wing epithelium: Homogenate	Succinate (0.01 M[c]) + cytochrome *c* (3×10^{-5} M[c])		6-12		11 wks.					<6		
			(Same as above)	(Same as above)		6-12		36 wks.					16		
								Pupae chilled for 11 wks. and then returned to 25° C.: Time after return:							
			Wing epithelium: Homogenate	Succinate (0.01 M[c]) + cytochrome *c* (3×10^{-5} M[c])		6-12		1 da.					<4		
			(Same as above)	(Same as above)		6-12		5 da.					19		
								Developing adults: Time after initiation of development:							
			Wing epithelium: Homogenate	Succinate (0.01 M[c]) + cytochrome *c* (3×10^{-5} M[c])		2-4		2 da.					35		
			(Same as above)	(Same as above)		2-4		7 da.					58		
			(Same as above)	(Same as above)		2-4		13-14 da.					74		
			(Same as above)	(Same as above)		2-4		18-19 da.					130		
								Unchilled pupae: Time after pupation:						All assays: For units of enzymatic activity, see footnote n All assays: Nitrogen determination by method of Kabat and Mayer (1948)	
			Wing epithelium: Homogenate	DPNH (7.5×10^{-5} M[c])		6-12		2-3 wks.					<8		
			(Same as above)	(Same as above)		6-12		10 wks.					<4		
			(Same as above)	DPNH (7.5×10^{-5} M[c]) + cytochrome *c* (7.5×10^{-5} M[c])		6-12		2-3 wks.					96		
			(Same as above)	(Same as above)		6-12		10 wks.					51		
								Chilled pupae: Length of chilling:							
			Wing epithelium: Homogenate	DPNH (7.5×10^{-5} M[c])		6-12		5 wks.					<5		
			(Same as above)	(Same as above)		6-12		37 wks.					4		
			(Same as above)	DPNH (7.5×10^{-5} M[c]) + cytochrome *c* (7.5×10^{-5} M[c])		6-12		5 wks.					24		
			(Same as above)	(Same as above)		6-12		37 wks.					93		
								Developing adults: Time after initiation of development:							
			Wing epithelium: Homogenate	DPNH (7.5×10^{-5} M[c])		2-4		2 da.					14		
			(Same as above)	(Same as above)		2-4		9 da.					19		
			(Same as above)	(Same as above)		2-4		18-19 da.					27		
			(Same as above)	DPNH (7.5×10^{-5} M[c]) + cytochrome *c* (7.5×10^{-5} M[c])		2-4		2 da.					180		
			(Same as above)	(Same as above)		2-4		9 da.					350		
			(Same as above)	(Same as above)		2-4		18-19 da.					240		

[e] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log$ [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
								Unchilled pupae: Time after pupation:						All assays: For units of enzymatic activity, see footnote m	
			Wing epithelium: Homogenate	DPNH (7.5×10^{-5} M[c]) + cytochrome *c* (3×10^{-5} M[c])		2-4		2-3 da.					100	All assays: Nitrogen determination by method of Kabat and Mayer (1948)	
			(Same as above)	(Same as above)		6-12		10 wks.					16	All assays: With KCN (1×10^{-3} M)	
			(Same as above)	(Same as above)		2-4		2-3 da.					63	With antimycin A (1.2 μg./ml.)	
			(Same as above)	(Same as above)		6-12		10 wks.					10	(Same as above)	
								Chilled pupae: Length of chilling:							
			Wing epithelium: Homogenate	DPNH (7.5×10^{-5} M[c]) + cytochrome *c* (3×10^{-5} M[c])		6-12		5 wks.					56		
			(Same as above)	(Same as above)		6-12		36 wks.					110		
			(Same as above)	(Same as above)		6-12		5 wks.					39	With antimycin A (1.2 μg./ml.)	
			(Same as above)	(Same as above)		6-12		36 wks.					89	(Same as above)	
								Pupae chilled for 11 wks. and then returned to 25° C.: Time after return:							
			Wing epithelium: Homogenate	DPNH (7.5×10^{-5} M[c]) + cytochrome *c* (3×10^{-5} M[c])		6-12		1 da.					44		
			(Same as above)	(Same as above)		6-12		5 da.					89		
			(Same as above)	(Same as above)		6-12		1 da.					35	With antimycin A (1.2 μg./ml.)	
			(Same as above)	(Same as above)		6-12		5 da.					48	(Same as above)	
								Developing adults: Time after initiation of development:							
			Wing epithelium: Homogenate	DPNH (7.5×10^{-5} M[c]) + cytochrome *c* (3×10^{-5} M[c])		2-4		2 da.					52		
			(Same as above)	(Same as above)		2-4		7 da.					270		
			(Same as above)	(Same as above)		2-4		13-14 da.					160		
			(Same as above)	(Same as above)		2-4		18-19 da.					440		
			(Same as above)	(Same as above)		2-4		2 da.					38	With antimycin A (1.2 μg./ml.)	
			(Same as above)	(Same as above)		2-4		7 da.					220	(Same as above)	
			(Same as above)	(Same as above)		2-4		13-14 da.					140	(Same as above)	
			(Same as above)	(Same as above)		2-4		18-19 da.					100	(Same as above)	

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
			Wing epithelium: Homogenate	Cytochrome *c* (2×10^{-5} M[c])		2-4		Unchilled pupae: Time after pupation: 2-3 da.					520	All assays: For units of enzymatic activity, see footnote o All assays: Nitrogen determination by method of Kabat and Mayer (1948)	
			(Same as above)	(Same as above)		6-12		10 wks.					270		
			Wing epithelium: Homogenate	Cytochrome *c* (2×10^{-5} M[c])		6-12		Chilled pupae: Length of chilling: 11 wks.					1200		
			(Same as above)	(Same as above)		6-12		36 wks.					220		
			Wing epithelium: Homogenate	Cytochrome *c* (2×10^{-5} M[c])		6-12		Pupae chilled for 11 wks. and then returned to 25° C.: Time after return: 1 da.					360		
			(Same as above)	(Same as above)		6-12		5 da.					890		
			Wing epithelium Homogenate	Cytochrome *c* (2×10^{-5} M[c])		2-4		Developing adults: Time after initiation of development: 2 da.					1000		
			(Same as above)	(Same as above)		2-4		7 da.					2000		
			(Same as above)	(Same as above)		2-4		13-14 da.					1200		
			(Same as above)	(Same as above)		2-4		18-19 da.					1400		
Hydrophilus ater Water scavenger beetle	25	Volumetric microrespirometer (see Scholander 1942)	Flight muscle (teased)	Endogenous	10-20 mg. wet wt.	6		Adult			1.91	5.71		In Wilder and Smith saline	Pérez-González and Edwards (1954)[t]
			Leg muscle (coxal levator, teased)	Endogenous	10-20 mg. wet wt.	6		Adult			0.416	1.91		In Wilder and Smith saline	
Leucophaea maderae Madeira cockroach	38	Warburg	Thoracic muscle: Homogenate	Succinate (0.2 M) + cytochrome *c* (2×10^{-5} M[c])			♀	Adult: Various ages				199			McShan, Kramer, and Schlegel (1954)[t]
			(Same as above)	Cytochrome *c* (8.7×10^{-5} M[c]) + ascorbic acid (0.0114 M[c])			♀	Adult: 30 da.				1770			
Leucophaea maderae Madeira cockroach	26	Warburg	Thoracic muscle (teased)	Endogenous	*ca.* 150 mg. wet wt.	11	♂					3.25		In Belar's solution	Samuels (1956)
			(Same as above)	Endogenous	*ca.* 150 mg. wet wt.	10	♀					3.35		(Same as above)	
			(Same as above)	Endogenous	*ca.* 150 mg. wet wt.	18		With corpora allata				3.50		(Same as above)	
			(Same as above)	Endogenous	*ca.* 150 mg. wet wt.	18		Without corpora allata				4.26		(Same as above)	
Locusta migratoria Migratory locust	32	Manometer	Muscle: Suspension	Endogenous	Tissue equiv. to 1 mg. N		♂♀	Adult	40[a]-150[a]					All assays: P/O ratios in original paper All assays: Method of nitrogen determination not specified	Rees (1954)[t]
			(Same as above)	Succinate (0.033 M[c]) + cytochrome *c* (1×10^{-5} M[c])	Tissue equiv. to 1 mg. N		♂♀	Adult	320[a]						
			Sarcosomes	Succinate (0.033 M[c]) + cytochrome *c* (1×10^{-5} M[c])	Sarcosomes equiv. to 0.3 mg. N		♂♀	Adult	1093[a]						

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log$ [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log \text{[cytochrome } c\text{]}}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10° C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Melanoplus differentialis Differential locust	23 23	Differential volumeter (see Rotta and Stannard, 1939)	Muscle of hind femur	Endogenous		29		Adult			0.197[a]			R.Q. 0.82	Gilmour (1941)
Melanoplus femur-rubrum Red-legged grasshopper	23	Differential volumeter (see Rotta and Stannard, 1939)	Muscle of hind femur	Endogenous		26		Adult			0.180[a]				Gilmour (1941)
Musca domestica House fly	25	Warburg	Muscle: Homogenate	Endogenous	10-15 mg. dry wt./ml.		♂♀	Adult				4.0		All assays: Cytochrome *c* (2.5×10^{-5} M[a,c]) present	Sacktor (1955)[t]
			(Same as above)	Hexoses (0.13 M[a,c])	(Same as above)		♂♀	Adult				7.8			
			Muscle: Soluble fraction (sarcoplasm)	Endogenous			♂♀	Adult				0.6[a]			
			Muscle: Particulate fraction	Endogenous	Equiv. to 10-15 mg. dry wt./ml.		♂♀	Adult				0.8[a]			
			(Same as above)	Succinate (0.13 M[a,c])	(Same as above)		♂♀	Adult				5.3[a]			
			(Same as above)	Fumarate (0.13 M[a,c])	(Same as above)		♂♀	Adult				8.3[a]			
Periplaneta americana American cockroach	25	Warburg	Leg muscle (teased)	Endogenous	*ca.* 200 mg. wet wt.	10	♂	Adult				5.04		In Belar-phosphate buffer	Barron and Tahmisian (1948)[t]
			(Same as above)	Endogenous	*ca.* 200 mg. wet wt.	16	♀	Adult				2.62		(Same as above)	
			(Same as above)	Glucose (0.01 M[c])	*ca.* 200 mg. wet wt.	16	♂	Adult				5.14		R.Q. 0.96[a]. In Belar-phosphate buffer	
			(Same as above)	Glucose (0.01 M[c])	*ca.* 200 mg. wet wt.	18	♀	Adult				3.56		R.Q. 0.99[a]. In Belar-phosphate buffer	
			(Same as above)	Pyruvate (0.01 M[c])	*ca.* 200 mg. wet wt.		♂	Adult				8.2		In Belar-phosphate buffer	
			(Same as above)	Pyruvate (0.01 M[c])	*ca.* 200 mg. wet wt.		♀	Adult				4.2		(Same as above)	
			(Same as above)	Citrate (0.01 M[c])	*ca.* 200 mg. wet wt.		♂	Adult				5.6		(Same as above)	
			(Same as above)	Citrate (0.01 M[c])	*ca.* 200 mg. wet wt.		♀	Adult				3.6		(Same as above)	
			(Same as above)	α-Ketoglutarate (0.01 M[c])	*ca.* 200 mg. wet wt.		♂	Adult				8.9		(Same as above)	
			(Same as above)	α-Ketoglutarate (0.01 M[c])	*ca.* 200 mg. wet wt.		♀	Adult				5.5		(Same as above)	
			(Same as above)	Malate (0.01 M[c])	*ca.* 200 mg. wet wt.		♂	Adult				8.3		(Same as above)	
			(Same as above)	Malate (0.01 M[c])	*ca.* 200 mg. wet wt.		♀	Adult				5.9		(Same as above)	
			(Same as above)	Succinate (0.01 M[c])	*ca.* 200 mg. wet wt.		♂	Adult				12.8		(Same as above)	
			(Same as above)	Succinate (0.01 M[c])	*ca.* 200 mg. wet wt.		♀	Adult				5.4		(Same as above)	

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[n] mμ moles DPNH oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[o] mμ moles cytochrome *c* oxidized $(\text{mg. N})^{-1}\ \text{min.}^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.²/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Periplaneta americana American cockroach	Not specified	Spectrophotometer	Homogenate of: Nerve cord	Cytochrome *c* (1.3×10^{-5} M[a,c])		10	♂	Adult					2.11	All assays: For units of enzymatic activity, see footnote k All assays: Nitrogen determination by modified micro-Kjeldahl procedure (see Folin and Farmer, 1912)	Sacktor and Bodenstein (1952)[t]
			Brain	(Same as above)		10	♂	Adult					3.38		
			Muscle	(Same as above)		10	♂	Adult					6.80		
			Heart	(Same as above)		10	♂	Adult					2.55		
			Fat body	(Same as above)		10	♂	Adult					0.87		
			Testes	(Same as above)		10	♂	Adult					1.39		
			Accessory glands	(Same as above)		10	♂	Adult					0.36		
			Foregut	(Same as above)		10	♂	Adult					2.02		
			Midgut	(Same as above)		10	♂	Adult					2.38		
			Hindgut	(Same as above)		10	♂	Adult					4.08		
			Malpighian tubules	(Same as above)		10	♂	Adult					1.44		
Periplaneta americana American cockroach	38	Warburg	Coxal muscle: Homogenate	Succinate (0.0187 M)	3 mg. wet wt.		♂	Adult: 2-4 mo.				158		Cytochrome *c* (3.2×10^{-5} M) present	Harvey and Beck (1953)[t]
			(Same as above)	Succinate (0.187 M)	3 mg. wet wt.		♂	Adult: 2-4 mo.				302		(Same as above)	
			(Same as above)	Succinate (0.187 M) + malonate (3.3×10^{-4} M)	3 mg. wet wt.		♂	Adult: 2-4 mo.				207		(Same as above)	
			Coxal muscle: Homogenate	Cytochrome *c* (0.8×10^{-5} M)	3 mg. wet wt.		♂	Adult: 2-4 mo.				231		Succinate (0.11 M) present	
			(Same as above)	Cytochrome *c* (9.4×10^{-5} M)	3 mg. wet wt.		♂	Adult: 2-4 mo.				274		(Same as above)	
			Coxal muscle: Homogenate	Succinate (0.11 M) + cytochrome *c* (3.2×10^{-5} M)	3 mg. wet wt.		♂	Adult: 2-4 mo.				261		With antimycin A: 0.001 μg./flask	
			(Same as above)	(Same as above)	3 mg. wet wt.		♂	Adult: 2-4 mo.				249		0.01 μg./flask	
			(Same as above)	(Same as above)	3 mg. wet wt.		♂	Adult: 2-4 mo.				162		0.03 μg./flask	
			(Same as above)	(Same as above)	3 mg. wet wt.		♂	Adult: 2-4 mo.				8		0.05 μg./flask	
			Coxal muscle: Homogenate	Succinate (0.1 M)	3 mg. wet wt.		♂	Adult: 2-4 mo.				187		With KCN (0.02 M[a])	
			(Same as above)	Cytochrome *c* (4.78×10^{-5} M) + ascorbate (0.026 M[a])	0.75 mg. wet wt.		♂	Adult: 2-4 mo.				1520			
Periplaneta americana American cockroach	30	Warburg	Leg muscle: Homogenate	Succinate (0.025 – 0.05 M) + cytochrome *c* (1×10^{-5} M)		14	♂	Adult: 10-20 da.	648		14.5			All assays: Nitrogen determination by method of Ma and Zuazaga (1942)	Allen and Richards (1954)[t]
			(Same as above)	(Same as above)		12	♀	Adult: 10-20 da.	167		3.4				
			(Same as above)	(Same as above)		6	♂	Adult: 95-185 da.	638		16.2				
			(Same as above)	(Same as above)		7	♀	Adult: 95-185 da.	172		3.8				
Periplaneta americana American cockroach	27	Warburg	Four coxal muscles: Homogenate	Cytochrome *c* (8.4×10^{-5} M[a,c]) + ascorbate (0.4 M[a,c])	30 mg. wet wt. (10 mg. dry wt.)	50	♂					3.6[a] – 6.6[a]			Morrison and Brown (1954)[t]
Periplaneta americana American cockroach	25	Volumetric microrespirometer (see Scholander, 1942)	Flight muscle (teased)	Endogenous	10-20 mg. wet wt.	3	♂	Adult			1.88	7.30		In Wilder and Smith saline	Pérez-González and Edwards (1954)[t]
			(Same as above)	Endogenous	10-20 mg. wet wt.	3	♀	Adult			1.21	4.54		(Same as above)	
			Leg muscle (coxal levator, teased)	Endogenous	10-20 mg. wet wt.	5	♂	Adult			1.55	6.2		(Same as above)	
			(Same as above)	Endogenous	10-20 mg. wet wt.	3	♀	Adult			1.04	4.41		(Same as above)	

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log \text{[cytochrome } c\text{]}}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
Periplaneta americana American cockroach	"Room temp."	Spectrophotometer	Leg muscle: Homogenate	Cytochrome *c*			♀	Adult					0.156	All assays: For units of enzymatic activity, see footnote j Homogenate diluted 1:10,000	Ludwig, Barsa, and Cali (1955)[t]
			(Same as above)	Cytochrome *c*			♀	Adult					0.174	Homogenate (1:10,000) in alcohol (10%)	
			(Same as above)	Cytochrome *c*			♀	Adult					0.087	Homogenate (1:10,000) in alcohol (10%) + DDT (1×10^{-3} M)	
Periplaneta americana American cockroach	Not specified	Spectrophotometer	Homogenate of: Muscle	Cytochrome *c* (2×10^{-5} M) + succinate (1.5×10^{-4} M)		10	♂	Adult					0.177	All assays: For units of enzymatic activity, see footnote l All assays: With KCN (1×10^{-3} M) All assays: Protein determination by method of Lowry *et al.* (1951) as modified by Sacktor, Thomas, Moser, and Block (1953)	Sacktor and Thomas (1955)
			Foregut	(Same as above)		10	♂	Adult					0.034		
			Midgut	(Same as above)		10	♂	Adult					0.045		
			Hindgut	(Same as above)		10	♂	Adult					0.125		
			Malpighian tubules	(Same as above)		20	♂	Adult					0.054		
			Fat body	(Same as above)		10	♂	Adult					0.063		
			Brain	(Same as above)		20	♂	Adult					0.033		
			Nerve cord	(Same as above)		10	♂	Adult					0.033		
			Homogenate of: Muscle	(Same as above)		10	♀	Adult					0.045		
			Foregut	(Same as above)		10	♀	Adult					0.054		
			Midgut	(Same as above)		10	♀	Adult					0.038		
			Hindgut	(Same as above)		10	♀	Adult					0.066		
			Malpighian tubules	(Same as above)		20	♀	Adult					0.029		
			Fat body	(Same as above)		10	♀	Adult					0.049		
			Brain	(Same as above)		20	♀	Adult					0.026		
			Nerve cord	(Same as above)		10	♀	Adult					0.019		
Periplaneta americana American cockroach	25	Warburg	Metathorax	Endogenous		8	♂	Adult			0.63[a]				Kubišta (1956)
			Metathorax	Endogenous		6	♀				0.44[a]				
			Metathorax	Endogenous		6		Nymph			0.46[a]				
			Prothorax	Endogenous		4		Adult			0.88[a]			Same 4 animals	
			Mesothorax	Endogenous		4		Adult			0.80[a]				
			Metathorax	Endogenous		4		Adult			0.54[a]				
			Abdomen	Endogenous		4		Adult			0.61[a]				
Periplaneta americana American cockroach	30	Warburg	Leg and wing muscle destined to be pigmented ("pink"): Homogenate	Succinate (0.05 M) + cytochrome *c* (1×10^{-5} M)	7.5 mg. wet wt.		♂	Adult: 1-5 da.				29			Brooks (1957)[t]
			Leg and wing pigmented ("pink") muscle: Homogenate	Succinate (0.05 M) + cytochrome *c* (1×10^{-5} M)	7.5 mg. wet wt.		♂	Adult: 15-65 da.				68			
			Leg and wing non-pigmented ("white") muscle: Homogenate	Succinate (0.05 M) + cytochrome *c* (1×10^{-5} M)	7.5 mg. wet wt.		♂	Adult: 1-60 da.				10.4			

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log [\text{cytochrome c}]$/mg. wet wt./min.
[g] $-\Delta \log [\text{ferricytochrome c}]$/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log [\text{ferricytochrome c}]$/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2} mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D. mg. protein min.
[s] Moles DPN reduced/g. wet wt. hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS					REMARKS	REFERENCE
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity		
			Leg and wing muscle anatomically identical with "pink" muscle of older adult males: Homogenate	Succinate (0.05 M) + cytochrome *c* (1×10^{-5} M)	7.5 mg. wet wt.		♀	Adult: 1-70 da.				13.0			
			Leg and wing pigmented ("pink"): muscle: Homogenate	Succinate (0.05 M) + cytochrome *c* (1×10^{-5} M)	7.5 mg. wet wt.		♂	Nymph				9.2			
Periplaneta americana American cockroach	Not specified	Warburg	Fat body: Homogenate (Same as above) Fat body: Mitochondria	Succinate + cytochrome *c* Ascorbate + cytochrome *c* Ascorbate + cytochrome *c*					53 150[a] 700[a]					All assays: Nitrogen determination by microdiffusion (see Conway, 1950)	Nelson (1958)
Periplaneta americana American cockroach	29-30	Spectrophotometer	Fat body: Homogenate	Malate	10 μg. wet wt.		♂	Nymph					1.63×10^{-3}	For units of enzymatic activity, see footnote s	Young (1958)
			Fat body: Homogenate	Malate	10 μg. wet wt.		♀	Nymph					1.21×10^{-3}		
Periplaneta americana American cockroach	30	Warburg	Fat body: Homogenate (Same as above) Fat body: Residues (mitochondria) (Same as above)	Endogenous Succinate α-Ketoglutarate *iso* Citrate				Nymph Nymph Nymph Nymph		1.8 5.5 18.8 8.3				All assays: Protein determination by method of Lowry *et al.* (1951)	Young (1959)[t]
Phormia regina Black blow fly	25	Warburg	Muscle: Sarcosomes (Same as above) (Same as above) (Same as above) (Same as above) (Same as above) (Same as above) (Same as above)	Ascorbate + cytochrome *c* (Same as above) Succinate (0.013 M[c]) + cytochrome *c* (1×10^{-5} M[c]) (Same as above) Malate (0.04 M) + cytochrome *c* (4×10^{-5} M) (Same as above) Succinate (0.013 M[c]) + cytochrome *c* (1×10^{-5} M[c]) (Same as above)				Adult: 1 da. Adult: 3-22 da. Adult: 21 da. Adult: 26 da. Adult: 13 da. Adult: 19 da. Adult: 5 da. Adult: 9 da.	7900[a] 4000[a]–4500[a] 1172 1780 461 726 708 1420					All assays: Nitrogen determination by semimicro-Kjeldahl technique	Watanabe and Williams (1951)[t]
Sarcophaga bullata Fleshfly	30	Warburg	Thoracic muscle, including flight muscle: Homogenate (Same as above)	Succinate (0.05 M) + cytochrome *c* (1.5×10^{-5} M) (Same as above)	2.5-5.0 mg./ml. wet wt. (Same as above)	9 5	♂ ♀	Adult: 4-8 da. Adult: 4-8 da.	778 814		15.0 15.6			All assays: Nitrogen determination by method of Ma and Zuazaga (1942)	Allen and Richards (1954)[t]
Sceliphron cementarius Mud dauber wasp	38	Warburg	Flight muscle: Homogenate	Succinate (0.2 M[c]) + cytochrome *c* (2×10^{-5} M[c])			♀	Adult				128			Kramer (1954)
Schistocerca gregaria Desert locust	10	Spectrophotometer	Fat body: Homogenate	DPNH (2.5×10^{-4} M) + cytochrome *c* (2.4×10^{-5} M[a])									7×10^{-9}	For units of enzymatic activity, see footnote p With KCN (9×10^{-4} M)	Kilby and Neville (1957)[t]

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome *c* per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome *c* per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome *c*]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome *c*]/mg. protein/min.
[j] $\Delta \log [CyFe^{++}]$/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome } c]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome *c* reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome *c* oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome *c* reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome *c* taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

ANIMAL	PROCEDURE					SPECIMEN			RESULTS						
PHYLUM Class *Scientific name* Common name	Temp. °C.	Method and Apparatus	Tissue and Type of Preparation	Endogenous Respiration or Substrate Added	Amount of Tissue	No.	Sex	Stage, Size, or Age	Microliters of Oxygen per Hour per Milligram: Nitrogen	Protein	Wet Weight	Dry Weight	Enzymatic Activity	REMARKS	REFERENCE
Schistocerca infumata South American locust	25	Volumetric microrespirometer (see Scholander, 1942)	Flight muscle (teased) Leg muscle (coxal levator, teased)	Endogenous Endogenous	10-20 mg. wet wt. 10-20 mg. wet wt.	4 3		Adult Adult			1.67 1.22			In Wilder and Smith saline In Wilder and Smith saline	Pérez-González and Edwards (1954)[t]
Tachycines asynamorus (formerly *Diestrammena japanica)* Japanese or greenhouse stone cricket	25	Warburg	Femur, intact Femur, intact Femur, cut	Endogenous Endogenous Endogenous		6 7 7					0.16[a] 0.16[a] 0.23[a]			Gas phase: Air O_2 O_2	Kubišta (1956)
Telea polyphemus Polyphemus moth	25	Warburg	Wing	Endogenous		3	♀	Pupa				3.2			Harvey (MSb)
Tenebrio molitor Yellow mealworm	30	Warburg	Flight and leg muscle: Homogenate (Same as above)	Succinate (0.25−0.75M) + cytochrome *c* ($1.5-3\times10^{-5}$ M) (Same as above)		10 8	♂ ♀	Adult: 15-30 da. Adult: 15-30 da.	963 1115		14.6 15.5			All assays: Nitrogen determination by method of Ma and Zuazaga (1942)	Allen and Richards (1954)[t]
Tenebrio molitor Yellow mealworm	30	Fenn	Fat body: Residues (mitochondria)	α-Ketoglutarate				Larva		61.8				Protein determination by method of Lowry *et al.* (1951)	Young (1959)[t]
ECHINODERMATA															
Holothuroidea															
Isostichopus badionotus (formerly *Stichopus möbii)* Sea cucumber	25	Warburg	Intestine Branchial tree	Endogenous Endogenous		12 11						0.7 0.6			Robbie (1949)[t]
Thyone sp. Sea cucumber	25	Warburg	Muscle: Thin sheets or slices	Glucose (0.011 M[a])		30					0.0314[a]				Villee, Lichtenstein, Nathanson, and Rolander (1950)

[a] Estimated or calculated from available data.
[b] Initial concentration.
[c] Final concentration.
[d] Decrease in log of molar concentration of oxidized cytochrome c per minute for 1:150 tissue dilution.
[e] Decrease in log of molar concentration of reduced cytochrome c per minute for 1:100 tissue dilution.
[f] $\Delta \log$ [cytochrome c]/mg. wet wt./min.
[g] $-\Delta \log$ [ferricytochrome c]/mg. protein/min.
[h] Moles substrate converted/kilo protein/hour (For axoplasm, protein = total protein; for sheath, protein of non-collagenous component).
[i] $\Delta \log$ [ferricytochrome c]/mg. protein/min.
[j] $\Delta \log$ [$CyFe^{++}$]/min.
[k] Activity/mg. N when standard activity = $\frac{\Delta \log (CyFe^{++})}{\Delta t} \times \frac{\text{final tissue dilution}}{100}$.
[l] Activity/mg. protein when activity = $\frac{\Delta \log [\text{cytochrome c}]}{\Delta t \text{ (min.)}}$.
[m] mμ moles cytochrome c reduced (mg. N)$^{-1}$ min.$^{-1}$
[n] mμ moles DPNH oxidized (mg. N)$^{-1}$ min.$^{-1}$
[o] mμ moles cytochrome c oxidized (mg. N)$^{-1}$ min.$^{-1}$
[p] Moles cytochrome c reduced/mg. tissue/5 min. at 10°C. (extinction coefficient of reduced cytochrome c taken as 2.8×10^{-7} cm.^{2}/mol.).
[q] O. D. of clear supernatant when measured at 520 mμ.
[r] Δ O. D./mg. protein/min.
[s] Moles DPN reduced/g. wet wt./hr.
[t] Additional respiratory data on invertebrate tissues present in original paper and not included in Section 2.

Section 3: ANALYSIS OF DATA

EFFECTS OF CERTAIN INHIBITORS ON RESPIRATORY RATE

2, 4-DINITROPHENOL (DNP)

Effect: Respiration maximally stimulated by the concentration of DNP that produces maximal inhibition of ciliary activity; this effect noted in:

Mollusca
Pelecypoda
Crassostrea virginica: Mantle; Maroney, Barber, and Wilbur, 1957
Mytilus: Gill; Weller and Ronkin, 1952

Effect: Rise in respiratory rate; this effect noted in:

Aschelminthes
Nematoda
Ascaris lumbricoides: Muscle; Chin and Bueding, 1954
Mollusca
Pelecypoda
Pinctada martensii: Gill; Kawai, 1957

Effect: Stability of rate of esterification of phosphate in suspension to which DNP has been added; suggests that the phosphorylations result from anaerobic reactions; this effect noted in:

Mollusca
Gastropoda
Helix pomatia: Midgut gland; Rees, 1953

CARBON MONOXIDE (CO)

Effect: Photoreversible inhibition of respiration, i.e., inhibition of respiration by CO in darkness but not in light; strongly suggests the involvement of cytochrome oxidase in the electron transport system; this effect noted in:

Mollusca
Pelecypoda
Crassostrea gigas: Gill, mantle; Kawai, 1958
Cephalopoda
Octopus macropus: Salivary gland; Ghiretti-Magaldi, Giuditta, and Ghiretti, 1958

CYANIDE

Effect: Inhibition of endogenous respiration; may indicate the involvement of cytochrome oxidase in the electron transport system; effect noted in:

Porifera
Demospongia
Cinachyra cavernosa, Dysidea crawshayi, Geodia gibberosa, Ircinia fasciculata, Lissodendoryx isodictyalis, Pseudaxinella rosacea, Spheciospongia sp., *Tedania ignis, Terpios fugax, Tethya aurantia*: Slices; Robbie, 1949

Coelenterata
Hydrozoa
Physalia physalis: Tentacles; Robbie, 1949
Anthozoa
Condylactis gigantea: Tentacles; Robbie, 1949
Gorgonia flabellum: Branches; Robbie, 1949
Plexaura flexuosa: Slices; Robbie, 1949
Mollusca
Pelecypoda
Crassostrea virginica: Mantle; Jodrey and Wilbur, 1955
Isognomon alata: Gill; Robbie, 1949
Mercenaria mercenaria: Gill, mantle, adductor muscle; Hopkins, 1949
Pinctada martensii: Gill; Kawai, 1957. Heart; Navez, Crawford, Benedict, and DuBois, 1941
Cephalopoda
Loligo pealeii: Gill; also retina, lens and "cornea" of eye; Robbie, 1949
Arthropoda
Crustacea
Panulirus argus: Leg nerve, leg muscle, midgut gland; Robbie, 1949

Effect: Inhibition of endogenous respiration and complete or partial reversal of this inhibition by methylene blue; suggests the involvement of cytochrome oxidase; this effect noted in:

Mollusca
Pelecypoda
Crassostrea gigas: Mantle, gill; Kawai, 1958
Cristaria plicata: Gill; Higashi and Kawai, 1959
Hyriopsis schlegelii: Gill; Higashi and Kawai, 1959
Arthropoda
Crustacea
Homarus americanus: Leg nerves and nerve cord; Chang, 1931

Effect: Inhibition of endogenous respiration by cyanide but the inhibition not reversible by methylene blue; suggests that some terminal oxidase other than cytochrome oxidase may be involved in electron transport; this effect noted in:

Mollusca
Pelecypoda
Crassostrea gigas: Gill; Okamura, 1959
Crassostrea virginica: Mantle; Jodrey and Wilbur, 1955

ANTIMYCIN A

Effect: Inhibition of respiration because the oxidation of succinate via the pathway involving the Slater factor is blocked; this effect noted in:

Arthropoda
Insecta
Hyalophora cecropia: Wing epithelium of pupa and adult, Shappirio and Williams, 1957b
Periplaneta americana: Coxal muscles of legs of adult; Harvey and Beck, 1953

COMPARISON OF RESPIRATORY RATES OF VARIOUS TISSUES

The following studies are concerned with the comparative endogenous respiratory rates of various tissues of invertebrates; *the results of no study are given here in their entirety.*

Mollusca
Gastropoda
Helix pomatia: Cerebral ganglion > midgut gland > muscle of foot; Kerkut and Laverack, 1957
Pelecypoda
Crassostrea gigas: Gill > heart > mantle; Kawai, 1959
Cristaria plicata: Gill > heart > mantle > adductor muscle; Higashi and Kawai, 1959
Gryphaea angulata: Gill > midgut gland > mantle > muscle; Chapheau, 1932
Hyriopsis schlegelii: Gill > heart > mantle > adductor muscle; Higashi and Kawai, 1959
Mercenaria mercenaria: Gill > mantle > muscle; Hopkins, 1946
Pinctada martensii: Gill > midgut gland > muscle of foot; Kawai, 1957
Cephalopoda
Octopus vulgaris: Optic ganglion > branchial heart > gill > central heart > midgut gland > mantle muscle; Ghiretti-Magaldi, Giuditta, and Ghiretti, 1958
Arthropoda
Merostomata
Limulus polyphemus: Forebrain > foregut > optic nerve (axon) > muscle > optic nerve (sheath); Shapiro, 1937
Crustacea
Callinectes sapidus: Midgut gland > gill; Vernberg, 1956
Clibinarius vittatus: Midgut gland > gill; Vernberg, 1956
Lobster (sci. name not given): Midgut gland > muscle; Kermack, Lees, and Wood, 1954
Libinia dubia: Midgut gland > gill; Vernberg, 1956
Menippe mercenaria: Midgut gland > gill; Vernberg, 1956
Ocypode quadrata: Gill > midgut gland; Vernberg, 1956
Panopeus herbstii: Midgut gland > gill; Vernberg, 1956
Sesarma cinereum: Gill > midgut gland; Vernberg, 1956
Uca minax: Midgut gland > gill in male; gill > midgut gland in female; Vernberg, 1956
Uca pugilator: Gill > midgut gland; Vernberg, 1956
Insecta
Belostoma spp.: Flight muscle of adult > leg muscle; Pérez-González and Edwards, 1954
Hydrophilus ater: Flight muscle of adult > leg muscle; Pérez-González and Edwards, 1954
Periplaneta americana: Flight muscle of adult > leg muscle; Pérez-González and Edwards, 1954
Schistocerca infumata: Flight muscle of adult > leg muscle; Pérez-González and Edwards, 1954

SEX DIFFERENCES IN RESPIRATORY RATE

The following studies deal in part with the differences in respiratory rate between males and females; in some cases the differences are slight.

Arthropoda
Crustacea
Callinectes sapidus: Midgut gland, gill; female > male; Vernberg, 1956
Libinia dubia: Midgut gland, gill; female > male; Vernberg, 1956
Menippe mercenaria: Midgut gland, gill; female > male; Vernberg, 1956
Ocypode quadrata: Midgut gland, gill; male > female; Vernberg, 1956
Panopeus herbstii: Midgut gland, male > female; gill, female > male; Vernberg, 1956
Pugettia producta: Midgut gland; male > female; Belding, Field, Weymouth, and Allen, 1942
Uca minax: Midgut gland, male > female; gill, female > male; Vernberg, 1956
Uca pugilator: Midgut gland, gill; male > female; Vernberg, 1956
Insecta
Carpocapsa pomonella: Muscle, fat body of larva; female > male; Graham, 1946
Leucophaea maderae: Thoracic muscle; rate of female approximately equal to rate of male; Samuels, 1956
Periplaneta americana: Leg muscle of adult; male > female; Barron and Tahmisian, 1948. Leg

muscle of adult; male > female; Allen and Richards, 1954. Flight and leg muscles of adult; male > female; Pérez-González and Edwards, 1954. Many tissues of adult; with exception of foregut, male > female; Sacktor and Thomas, 1955. Metathorax of adult; male > female; Kubišta, 1956. Fat body of nymph; male > female; Young, 1958

Sarcophaga bullata: Thoracic muscles of adult; female > male; Allen and Richards, 1954

Tenebrio molitor: Flight and leg muscles of adult; female > male; Allen and Richards, 1954

VARIATION IN RESPIRATORY RATE WITH AGE

Mollusca

Pelecypoda

Crassostrea virginica: Adductor muscle; decline in endogenous respiratory rate with age (from shell length of 5.0 cm. to one of 14.7 cm.); Hopkins, 1930

Gryphaea angulata: Mantle, gill, muscle, midgut gland; decline in endogenous respiratory rate with age (from 10-15 mos. to 6 yrs.); Chapheau, 1932

Mercenaria mercenaria: Posterior adductor muscle; decline in endogenous respiratory rate with age (from shell length of 6.5 cm. to one of 9 cm.); Hopkins, 1930. Adductor muscle, mantle, gill; decline in endogenous respiratory rate with age (from 2-6 yrs. to 7-20 yrs.), except respiratory rate of gill tissue of both size classes essentially the same during winter and spring; Hopkins, 1946

VARIATION IN RESPIRATORY RATE DURING CRUSTACEAN MOLT CYCLE

Arthropoda

Crustacea

Carcinus maenas: Muscle; cyanide-insensitive respiration (with added fructose) lowest just before ecdysis, then rising during ecdysis and in the post-ecdysial, soft-shelled stage, with maximum rate during intermolt; no oxygen uptake in the absence of fructose or glucose; Krishnan, 1954

Gecarcinus lateralis: Integumentary tissues; endogenous respiration just before ecdysis 1.6 times that during intermolt period; Skinner (MS.)

VARIATION IN RESPIRATORY RATE DURING INSECT LIFE CYCLE

Arthropoda

Insecta

Calliphora erythrocephala: Flight muscle; α-ketoglutaric oxidase activity relatively high during first seven days after adult emergence, lower during eighth to tenth day, then up again at 15 to 17 days; Lewis and Slater, 1954; Slater and Lewis, 1954

Hyalophora cecropia: Wing epithelium; fall in the activity of several enzymes within 24 hours of pupation, and then a marked rise in their activity during adult development; Shappirio and Williams, 1957b

Periplaneta americana: Leg muscle; no marked difference in respiratory activity between 10- to 20-day adults and 95- to 185-day adults; Allen and Richards, 1954

Periplaneta americana: Leg and wing muscle, pigmented ("pink") or destined to be pigmented; respiratory activity low in nymphs, higher in 1- to 5-day adults, and still higher in 15- to 65-day adults; Brooks, 1957

Phormia regina: Muscle; cytochrome oxidase activity higher in 1-day adults than in 3- to 22-day adults; activity of certain other enzymes higher in older than in younger adults; Watanabe and Williams, 1951

VARIATION IN RESPIRATORY RATE WITH SEASON

Mollusca
Pelecypoda
Mercenaria mercenaria: Gill, mantle, muscle; in general, endogenous respiratory rate highest in winter and early spring and lowest in August and September; Hopkins, 1946
Pinctada martensii: Gill; rise in endogenous respiratory rate from June to the middle of January; Kawai, 1957

VARIATION IN RESPIRATORY RATE WITH SALINITY

Mollusca
Pelecypoda
Mercenaria mercenaria: Gill, mantle, increase in endogenous respiratory rate with lowered salinity; adductor muscle, decrease in rate with lowered salinity; Hopkins, 1949
Arthropoda
Crustacea
Carcinus maenas: Gill; increase in endogenous respiratory rate with lowered salinity; Pieh, 1936

EFFECTS OF VARIOUS IONS ON RESPIRATORY RATE

Mollusca
Gastropoda
Helix aspersa: Heart; rise in endogenous respiratory rate with increasing concentration of K^+ ion, compared to the concentrations of Na^+, Ca^{++}, and Mg^{++}; Cardot, Faure, and Arvanitaki, 1950
Pelecypoda
Mytilus galloprovincialis: Ventricle of heart; same as above; Cardot, Faure, and Arvanitaki, 1950
Cephalopoda
Sepia officinalis: Nerve; same as above; Cardot, Faure, and Arvanitaki, 1950
Arthropoda
Crustacea
Libinia emarginata: Claw nerve; rise in endogenous respiratory rate with increasing concentration of K^+ ion to a maximum at 40 mM K^+, then sharp drop in endogenous respiratory rate; Shanes and Hopkins, 1948

GRADIENT OF RESPIRATORY RATE ALONG LONG AXIS OF BODY

Annelida
Clitellata
Eisenia foetida: Viscera and body wall; U-shaped gradient in the endogenous respiratory rate and in succinoxidase activity along the long axis of the body; O'Brien, 1957
Octolasium cyaneum: Body wall; U-shaped gradient in succinoxidase activity; O'Brien, 1957
Arthropoda
Insecta
Periplaneta americana: Prothorax, mesothorax, metathorax, abdomen; decrease in endogenous respiratory rate from prothorax through metathorax, and then a rise in respiratory rate in abdomen; Kubišta, 1956

GRADIENT OF RESPIRATORY RATE ALONG A NERVE

Arthropoda
Merostomata
Limulus polyphemus: Optic nerve; at 31° and 28° C., endogenous respiratory rate highest in

medial region of nerve, but at 16° C. rate highest in proximal region; endogenous respiratory rate at distal end lower than at proximal end; Guttman, 1935

Limulus polyphemus: Optic nerve; at 24° C., endogenous respiratory rate highest in medial region of nerve; gradient much more pronounced for axon than for sheath; Shapiro, 1937

RESPIRATORY RATE AFTER REMOVAL OF ENDOCRINE GLANDS

Arthropoda

Crustacea

Carcinus maenas: Muscle; respiration (with added succinate) lower after eyestalk removal, higher again after addition of eyestalk extract; Scheer, Schwabe, and Scheer, 1952

Carcinus maenas: Muscle; cyanide-insensitive respiration (with added fructose) much lower than its pre-surgical level three days after eyestalk removal; remains low (but shows a gradual slight increase in level) up to 15 days after surgery; Krishnan, 1954

Homarus gammarus: Muscle; respiration (with added succinate) lower after eyestalk removal; Scheer, Schwabe, and Scheer, 1952

Palaemon squilla: Muscle; respiration (with added succinate) lower after eyestalk removal, in some cases higher again after addition of eyestalk extract; Scheer, Schwabe, and Scheer, 1952

Insecta

Leucophaea maderae: Thoracic muscle; endogenous respiration of animals without corpora allata 1.2 times that of animals with corpora allata; Samuels, 1956

RESPIRATORY RATE FOLLOWING INJURY

Arthropoda

Insecta

Tachycines asynamorus: Muscles of hind femur; endogenous respiratory rate of cut muscles 1.4 times that of the intact muscles; Kubišta, 1956

Section 4: DISCUSSION

In Section 2, data on tissue respiration in invertebrates are presented; in Section 3 some of these data plus others from the same investigations are analyzed. In the present section we discuss the broader implications of certain studies presented here and suggest some conclusions regarding invertebrate tissue respiration that may be drawn from them.

ENZYMES OF CITRIC ACID CYCLE

Respiratory activity of a tissue preparation, or fraction thereof, when measured in the presence of added substrate, can be attributed solely to an enzyme acting on the added substrate only if controls are included to indicate any increment of respiratory activity due to action of other enzymes on other substrates that may result from oxidation of the original substrate. For example, in order to determine the authentic α-ketoglutaric dehydrogenase activity of insect sarcosomes, one should measure, as did Lewis and Slater (1954), the respiratory rate of the preparation first in the presence of α-ketoglutarate and subsequently in the presence of α-ketoglutarate plus malonate, the latter being a substance that inhibits succinic dehydrogenase. One may then attribute a difference in respiratory rate to authentic α-ketoglutaric dehydrogenase activity (although one must still recognize the possibility that, with malonate present, accumulation of succinate may affect the rate at which α-ketoglutarate is oxidized).

Without controls such as described above, one may not necessarily conclude that, because a particular citric cycle substrate is metabolized, only the enzyme acting specifically upon that substrate is being assayed. Other components of the chain of enzymes may be concerned with the reaction, and the assay may be a measure of their activity as well.

Consequently in Section 2 we make no mention of individual enzymes or enzyme systems. We indicate merely that a given assay measures endogenous respiration or, alternatively, respiration in the presence of added substrate or substrates.

Although the data of Section 2 do not always justify a conclusion regarding the activity of any *particular* enzyme of the citric acid cycle, nevertheless they clearly indicate that at least some enzymes of that cycle are present in the tissues of invertebrates.

For other reviews dealing with this subject, see Krebs (1954), Gumbman, Brown, and Tappel (1958), and Hammen and Osborne (1959).

CYTOCHROME SYSTEM

There is convincing evidence for the presence of cytochrome oxidase as the terminal oxidase in tissues of certain mollusks and arthropods (see data of Section 2; see also Shappirio and Williams, 1957a, 1957b: Tappel, 1960; Pablo and Tappel, 1961; Sacktor, 1961). The possibility that cytochrome oxidase may be part of the terminal electron transfer system of other invertebrates, including some sponges and coelenterates, is suggested by the work of Robbie (1949). Cyanide sensitivity is usually taken to indicate that cytochrome oxidase and certain other enzymes may be involved in the terminal electron transport system. Except under unusual conditions (see pp. 82-83) cyanide insensitivity is generally considered evidence for the noninvolvement of these enzymes. With cyanide as a respiratory poison, Robbie recorded marked inhibition of endogenous respiration in all invertebrate tissues so treated, with the exception

of the subumbrella of the jellyfish (*Cassiopea frondosa*) and the branchial tree of the sea cucumber (*Isostichopus badionotus*). Concentrations of cyanide employed by Robbie ranged from 1×10^{-2} to 1×10^{-5} M. The fact that even the lower concentrations of cyanide were inhibitory suggests that the cyanide may have been acting on cytochrome oxidase.

It should be added here parenthetically that cyanide is a less specific inhibitor of cytochrome oxidase than is azide. Furthermore, although both cytochrome oxidase and tyrosinase are inhibited by carbon monoxide, the inhibition of cytochrome oxidase is reversible by light, whereas the inhibition of tyrosinase is not.

Possibly the inhibition of endogenous respiration produced by cyanide in Robbie's study was due to an inhibition of catalase, peroxidase, or tyrosinase. Such a possibility, however, is slight, for the concentration of these enzymes in animal tissues is too low for them to be playing a major role in respiration. The lower concentrations of cyanide that Robbie found to be effective (e.g., 1×10^{-5} M) also rule out the possibility that the inhibition depended upon a reaction of this poison with carbonyl groups in keto acids of the citric acid cycle.

Laser (1944) has found that cyanide can cause an *increase* in respiratory activity. When he added 0.01 M cyanide to muscle homogenates of *Ascaris lumbricoides* containing methylene blue, Laser noted an increase in the rate of respiration greater than that shown by homogenates containing methylene blue but lacking high concentrations of cyanide. Apparently cyanide can combine with oxaloacetate to form a complex that, unlike oxaloacetate itself, is incapable of competitively inhibiting succinic dehydrogenase.

Neither cytochrome oxidase nor cytochrome *c* is enzymatically detectable in muscle homogenates of the nematodes *Ascaris lumbricoides* and *Litomosoides carinii*, although a low level of cytochrome *c* and cytochrome oxidase activity is apparent in muscle homogenates of the trematode *Schistosoma mansoni* (Bueding and Charms, 1952). However, a pigment with the same absorption maxima as reduced cytochrome *c* has been demonstrated spectroscopically in tissues of *Parascaris equorum* and *A. lumbricoides* (Keilin, 1925) and in those of *A. lumbricoides* at the temperature of liquid air (Keilin and Hartree, 1949). Thus the conclusion that these parasitic nematodes have a unique terminal electron transport system (Bueding and Charms, 1952) remains open to question.

Because the respiration of the diapausing Cecropia moth is unaffected by cyanide and carbon monoxide, Schneiderman and Williams (1954a, 1954b) postulated that a terminal oxidase other than cytochrome oxidase functions during pupal diapause. Subsequently, by use of low temperature spectroscopy (see Keilin and Hartree, 1949), which intensifies the absorption bands of the cytochromes 10- to 20-fold, Shappirio and Williams (1957a) observed that cytochrome oxidase is still present in diapausing Cecropia pupae. During their study, in which they carefully traced the activity of the enzymes of the terminal electron transport system in wing epithelium during a portion of the life cycle, Shappirio and Williams (1957b) found that the *activity* of cytochrome oxidase falls to low (but still detectable) levels during diapause and then rises during adult development. They also found (1957a) that the *concentration* of this and other respiratory enzymes drops markedly during pupal diapause and then rises again during adult development. Significantly, however, whereas during diapause the concentration of cytochrome *c* is less than 5 per cent of its pre-diapause level, that of cytochrome oxidase remains relatively high (20% of its non-diapause level).

Recently Harvey and Williams (1958a, 1958b) and Kurland and Schneiderman (1959) reinvestigated the question of the terminal oxidase in diapausing pupae. Respiration of the whole animal throughout diapause is relatively insensitive to inhibition by carbon monoxide, azide, and cyanide. Nonetheless, Harvey (1956), Kurland and Schneiderman (1959), and Harvey and Williams (1961) showed that injury-stimulated and dinitrophenol-stimulated uptake of oxygen by diapausing pupae is indeed sensitive to carbon monoxide. Furthermore, in their independent investigations, Kurland and Schneiderman (1959), studying total uptake of oxygen, and Harvey and Williams (1958b), studying the heart beat of uninjured diapausing pupae, demonstrated that at low oxygen tensions the diapausing pupa is carbon monoxide sensitive. The manometric studies were measurements of the *total* gas uptake in the presence of either oxygen or oxygen and carbon monoxide mixtures. That diapausing pupae may consume carbon monoxide as well as oxygen has

recently been shown by Harvey (1961), who found that carbon monoxide can stimulate oxygen uptake (see also Kurland and Schneiderman, 1959) and that 5 per cent of the total gas consumed may be carbon monoxide.

On the basis of their findings, these several workers have concluded that during pupal diapause in Cecropia (and also in three closely related species of saturniid moths) cytochrome oxidase does serve as the terminal oxidase. They account for the fact that respiration of diapausing pupae at reasonable oxygen tensions and when unstimulated by dinitrophenol or by injury is apparently carbon monoxide-, azide- and cyanide-insensitive by pointing to the excess of cytochrome oxidase in most tissues of diapausing pupae compared to the low concentrations of cytochrome *c* (Shappirio and Williams, 1957a, 1957b). Thus, although a large portion of the oxidase may be inhibited by a respiratory poison, enough oxidase remains unbound to permit the transfer of electrons from cytochrome *c* to molecular oxygen. Clearly the apparent insensitivity of diapausing pupal respiration to the inhibitors of cytochrome oxidase is not an actual insensitivity. Provided that respiration is stimulated or, alternatively, provided that the oxygen tension is lowered sufficiently for the concentration of uninhibited cytochrome oxidase to become rate-limiting, a sensitivity to carbon monoxide, azide, and cyanide during pupal diapause can be demonstrated.

COMPARISON OF RESPIRATORY RATES OF VARIOUS TISSUES

Let us leave the subject of respiratory enzymes and their inhibitors at this point and discuss certain other aspects of invertebrate tissue respiration that have been investigated in the papers cited in this volume. Among the most interesting work is that which concerns the comparative respiratory rates of different tissues. In three investigations (Shapiro, 1937, on *Limulus polyphemus*; Kerkut and Laverack, 1957, on *Helix pomatia*; Ghiretti-Magaldi, Giuditta, and Ghiretti, 1958, on *Octopus vulgaris*) ganglionic tissue proved to have the greatest endogenous respiratory activity. In general, ganglionic tissue respires most rapidly, foot or leg muscle most slowly, and various other tissues at intermediate rates (Chapheau, 1932; Shapiro, 1937; Hopkins, 1946; Kawai, 1957; Kerkut and Laverack, 1957; Ghiretti-Magaldi, Giuditta, and Ghiretti, 1958; Higashi and Kawai, 1959; Kawai, 1959). Among insects, flight muscles have consistently higher endogenous respiratory rates than have leg muscles (Pérez-González and Edwards, 1954). In most brachyuran crustaceans the midgut gland has a higher endogeneous metabolic rate than has the gill. However, in certain active terrestrial and intertidal species, the gill exhibits a greater respiratory activity (Kermack, Lees, and Wood, 1954; Vernberg, 1956).

A comment concerning the particulate fractions assayed by Ghiretti-Magaldi, Giuditta, and Ghiretti (1957) is advisable. In order to facilitate homogenization, these investigators chose to freeze the tough muscles from the mantle and tentacles of *Octopus vulgaris* before fractionating them. In later work on *Octopus* (Ghiretti-Magaldi, Giuditta, and Ghiretti, 1958), they again used frozen muscle tissue for their preparations. In still later studies on *Aplysia*, the sea hare (Ghiretti, Ghiretti-Magaldi, and Tosi, 1959), frozen buccal mass muscle, frozen midgut gland, and frozen gizzard muscle were employed in the preparation of slices and particles. Since freezing disrupts both cells and intracellular organelles of most tissues, the particulate material used in these investigations may well have been fragmented.

SEX DIFFERENCES IN RESPIRATORY RATE

The results of studies dealing in part with sex differences in respiratory rate present no clear picture. In some species of brachyuran crustaceans, the respiratory rate of both midgut gland and gill is higher in the female than in the male; in other species the reverse is true; in still

other species the respiratory rate of the midgut gland is higher in the male while that of the gill is higher in the female (Vernberg, 1956; Belding, Field, Weymouth, and Allen, 1942).

Among insects, the cockroach (*Periplaneta americana*) exhibits a certain consistency as regards sex differences in the respiratory rate of its various tissues. With the exception of the foregut, all tissues in the male cockroach respire at a higher rate than do those in the female (Barron and Tahmisian, 1948; Allen and Richards, 1954; Pérez-González and Edwards; 1954; Sacktor and Thomas, 1955; Kubišta, 1956; Young, 1958). In several other species of insects, however, tissues of the female have a higher respiratory rate than have those of the male (Graham, 1946; Allen and Richards, 1954), Furthermore, Samuels (1956) found that the endogenous respiration of teased thoracic muscle is approximately equal in both sexes of the Madeira cockroach (*Leucophaea maderae*).

VARIATION IN RESPIRATORY RATE WITH AGE

Studies on the variation in endogeneous respiratory rate with age have been carried out on three species of pelecypod mollusks, namely, the oysters *Crassostrea virginica* (Hopkins, 1930) and *Gryphaea angulata* (Chapheau, 1932), and the quahog *Mercenaria mercenaria* (Hopkins, 1930, 1946). In each of these species the respiratory rate was found generally to decline with advancing age.

What effect aging may have on the respiratory rate of arthropods is not easy to evaluate. The level of respiratory metabolism in crustaceans and insects depends so completely upon the stage of an animal in the molt cycle or life cycle that its relation to the animal's chronological age is often obscure.

VARIATION IN RESPIRATORY RATE DURING CRUSTACEAN MOLT CYCLE

Increase in size in arthropods is discontinuous and periodic. It occurs only at the time of ecdysis when the old exoskeleton is cast off, to expose the new soft one underneath. Through uptake of water, as in some crustaceans, or uptake of air, as in some crustaceans and insects, the soft new exoskeleton is rapidly enlarged to greater dimensions before it becomes hardened by tanning and, in the case of crustaceans, calcification. Growth (i.e., increase in the amount of body tissue), although a more extended process than is increase in size, nevertheless is timed to coincide with other preparations for ecdysis and with subsequent post-ecdysial events.

Two studies involving the respiration of crustacean tissues during the molt cycle are cited in Section 2. In the first (Krishnan, 1954), the cyanide-insensitive respiration (with added fructose) of muscle from the green crab (*Carcinus maenas*) proved to be lowest during the period just preceding ecdysis; the rate of respiration rose during the soft-shelled stage immediately following ecdysis and reached a maximum during the intermolt period. In a second study, Skinner (MS) traced changes in endogenous respiration shown by integumentary tissues of the land crab (*Gecarcinus lateralis*). Oxygen uptake is highest during the period just preceding ecdysis, being 1.6 times that recorded during the intermolt period. The apparent contradiction between these two sets of results can be explained as follows: metabolism of muscle can be expected to be maximal during the non-growth, intermolt stage when the animal is active, while the metabolism of integumentary tissues presumably will be highest during the premolt period when these tissues are synthesizing the new exoskeleton.

To induce pre-ecdysial changes, ecdysis, and (if the animal survives) post-ecdysial alterations in a decapod crustacean, one need only remove both eyestalks, for in these structures are certain neurosecretory cells (X organ cells) that synthesize and release a neurohormone capable of inhibiting molting. Before its release, the molt-inhibiting hormone is stored within the eyestalks in the sinus glands, which consist of

swollen endings of neurosecretory cells that synthesize the hormone.

Krishnan (1954) has studied the effects of eyestalk removal on the rate of tissue respiration. Three days after performing this operation on *Carcinus maenas*, he found the respiratory rate of muscle from animals without eyestalks to be decidedly lower than that of muscle from unoperated crabs. Krishnan noted, nevertheless, that when all his data were plotted, the resulting curves for the two groups of animals were similar. They differed mainly in that the curve for unoperated crabs was displaced to the right of the curve for operated crabs by a distance representing six days. In other words, comparable decreases (and subsequent increases) in respiratory rate of muscle occur in operated and unoperated animals, although in the latter only after a lag of six days. Krishnan did not offer an explanation of these observations. The levels may be related to the stage of the animals in their molt cycle. If the unoperated crabs were gradually approaching molt, the respiratory rate of their muscle would reflect this and would yield a curve resembling that of premolt crabs without eyestalks. Because eyestalk removal accelerates molt-preparatory processes, however, the two curves would remain separated in time.

It may be noted that Bliss (1953), working with whole specimens of *Gecarcinus lateralis*, found the respiratory rate to be high immediately after eyestalk removal and to remain high throughout the entire period preceding ecdysis. Thus a difference exists between the respiratory rates of animals without eyestalks and of their isolated tissues during the premolt period.

As mentioned above, a molt-inhibiting hormore occurs in the eyestalks of crustaceans. In the preparation of an extract, the eyestalks are homogenized, boiled, and centrifuged, and then the supernatant is removed for use. In this way, an investigator obtains a protein-free extract, the chemical composition of which is in other respects unknown.

Several workers have attempted to demonstrate a direct effect of crustacean molt-inhibiting hormone on tissue respiration by the addition of such eyestalk extracts to homogenates. Scheer, Schwabe, and Scheer (1952) have reported that, in general, homogenates of muscle from eyestalkless individuals of the green crab (*Carcinus maenas*), the lobster (*Homarus gammarus*), and the shrimp (*Palaemon squilla*) respire at a lower rate than do homogenates of muscle from unoperated individuals, and that the rate increases after the addition of eyestalk extract to the homogenates. However, the data submitted by these authors show that the effects are rather small and quite variable. Furthermore, their data indicate that the addition of eyestalk extracts to homogenates of muscle from *Palaemon squilla* in some cases increases and in others decreases the respiratory rate. As noted above, crustaceans and their excised tissues respire at different rates according to stage in the molt cycle. Variability in results, therefore, may be related to stage. Schwabe, Scheer, and Scheer (1952) consider that synthesis of the new exoskeleton begins during the late intermolt period, that is, in late stage C. This concept does not agree with that of Drach (1939), according to whom the synthesis of a new exoskeleton begins during the early premolt period, that is, in early stage D. If Drach's criteria, which are accepted by the majority of workers (see Renaud, 1949; Travis, 1955; Charniaux-Cotton, 1957; Skinner, 1958, [MS]; Passano, 1960), are valid, the variability in the results of Scheer, Schwabe, and Scheer (1952) may be attributed to the fact that some of their animals were in the intermolt stage and some were in the premolt stage.

For several species of crustaceans, Kuntz (1946) noted that low concentrations of sinus gland extract increased the rate of reduction of methylene blue by midgut gland and that high concentrations decreased the rate. A more complete report of this work has not appeared.

In a series of experiments on *Carcinus maenas* (Skinner and Bliss, unpublished data), we found that homogenates of midgut gland containing extracts of one to five sinus glands reduced methylene blue at essentially equivalent rates. On the other hand, homogenates that contain leg muscle equal in wet weight to two sinus glands carry out this reduction one and one-half times faster.

The variability of results in experiments of this kind emphasizes the need for the use of (1) more highly purified hormonal preparations, and (2) more definitive systems, such as those containing isolated mitochondria or submitochondrial particles.

VARIATION IN RESPIRATORY RATE DURING INSECT LIFE CYCLE

Just as the respiratory metabolism of crustaceans is correlated closely with the stage of the animal in the intermolt cycle, so the respiratory rate of an insect varies with the phase of the insect in its life cycle (see also pp. 82-83). Brooks (1957) reported the respiratory activity of the cockroach (*Periplaneta americana*) to be low in pink muscles of the leg and wing from nymphs, higher in those of adults just after emergence, and still higher in those of older adults. On the other hand, no clear difference was detected by Allen and Richards (1954) in the leg muscle of young (10- to 20-day) adults when compared with older (95- to 185-day) adults. Lewis and Slater (1954) and Slater and Lewis (1954) found that the activity of the α-ketoglutaric oxidase system in the flight muscle from adults of the bluebottle fly (*Calliphora erythrocephala*) was relatively high right after adult emergence, lower from the eighth to the tenth day, and high again from the fifteenth to the seventeenth day.

RESPIRATORY RATE FOLLOWING INJURY

Kubišta (1956) reported that the endogenous respiratory rate shown by isolated muscle of a cut femur in the stone cricket (*Tachycines asynamorus*) was 1.4 times that shown by muscle of an uncut femur.

When making respiratory measurements on tissues of a diapausing pupa, one must exercise caution, for injury alone can increase the metabolic rate both of the pupa (whole or subdivided) and of its isolated tissues (see Schneiderman and Williams, 1953; Harvey, 1956, 1961, MS a; Shappirio, 1960).

EFFECT OF ENVIRONMENT ON RESPIRATORY RATE

With regard to the magnitude of the respiratory rate at various seasons, it appears that endogenous oxygen uptake is greater in certain tissues of pelecypod mollusks found in the North Temperate Zone during the winter and early spring than at other times during the year (Hopkins, 1946; Kawai, 1957). Two investigations concerned with the effects of salinity on respiratory rate have revealed a general rise with increasing dilution, as in the gill and mantle of the quahog *Mercenaria mercenaria* (Hopkins, 1949) and the gill of the green crab *Carcinus maenas* (Pieh, 1936), or a fall, as in the adductor muscle of *M. mercenaria* (Hopkins, 1949).

EFFECT OF VARIOUS IONS ON RESPIRATORY RATE

Increasing concentrations of the potassium (K^+) ion induce a rise in endogenous respiration in the heart of *Helix aspersa*, the dented garden snail, and *Mytilus galloprovincialis*, a mussel, as well as in the nerve of *Sepia officinalis*, the cuttlefish (Cardot, Faure, and Arvanitaki, 1950). With the claw nerve of the spider crab (*Libinia emarginata*) there is a rise in endogenous respiratory rate with increasing concentrations of K^+ ion up to a maximum of 40 mM per liter, then as a sharp drop (Shanes and Hopkins, 1948).

GRADIENTS IN RESPIRATORY RATE

In the brandling or manure worm (*Eisenia foetida*) the respiratory rate varies along the length of the worm. If one plots respiratory rate against distance from the head, a U-shaped curve with maxima at head and tail results. A similar U-shaped curve of succinoxidase activ-

ity occurs along the length of the blue worm, *Octolasium cyaneum* (O'Brien, 1957). Guttman (1935) and Shapiro (1937) recorded inverted, U-shaped curves in respiratory rate along the length of the optic nerve of *Limulus polyphemus*, the horseshoe crab, at 28° C. to 31° C. (but not at 16° C.). The axon of *Limulus* shows most of the activity when compared with the sheath. Lastly, Kubišta (1956) found a decrease in the rate of oxygen uptake along the thorax of the cockroach (*Periplaneta americana*), with a rise again in the region of the abdomen.

Section 5: ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

For the most part, the abbreviations listed below are identical with those given in Webster's New International Dictionary, second edition, unabridged, 1958.

ca., *circa*
cm., centimeter, centimeters
$cm.^2$, square centimeter or centimeters
da., day, days
equiv., equivalent
exp., experiment
f.p., freezing point
g., gram, grams
hr., hour, hours
log, logarithm
max., maximum
mg., milligram, milligrams
μg., microgram, micrograms
μl., microliter, microliters
min., minute, minutes
ml., milliliter, milliliters
mo., month, months
mol., mole, moles
no., number
O.D., optical density
R.Q., respiratory quotient
S, salinity
sci. name, scientific name
s.g., specific gravity
sp., species (singular) not indicated by author
spp., species (plural) not indicated by author
temp., temperature
wks., weeks
wt., weight
yrs., years

SYMBOLS

CHEMICAL SYMBOLS AND FORMULAS

ADP, adenosine diphosphate
ATP, adenosine triphosphate
Ca^{++}, calcium ion
$CaCl_2$, calcium chloride
CO, carbon monoxide
$CyFe^{++}$, ferrocytochrome *c* (reduced cytochrome *c*)
$CyFe^{+++}$, ferricytochrome *c* (oxidized cytochrome *c*)
DDT, dichlorodiphenyltrichloroethane
DNP, 2, 4-dinitrophenol
DPN or DPN^+, oxidized diphosphopyridine nucleotide
DPNH, reduced diphosphopyridine nucleotide
EDTA, ethylenediaminetetraacetic acid (versene)
HCN, hydrocyanic acid
H_2O_2, hydrogen peroxide
K^+, potassium ion
KCl, potassium chloride
KCN, potassium cyanide
M, molar concentration; molarity; molar
mM, millimol, millimols
Mg^{++}, magnesium ion
$MgCl_2$, magnesium chloride
N, nitrogen (element)
N_2, nitrogen (gas)
Na^+, sodium ion
NaCl, sodium chloride
Na^+/K^+, ratio of sodium ions to potassium ions
O_2, oxygen (gas)
P/O, ratio of phosphate formed to oxygen utilized; referred to as the P/O ratio
TPN, triphosphopyridine nucleotide
TPNH, reduced triphosphopyridine nucleotide

MISCELLANEOUS SYMBOLS

♂, male
♀, female
α, alpha
Δ, delta
μ, micron
mμ, millimicro- (prefix)
$(mg.N)^{-1}$, 1/mg.N
p, para
10^{-5}, 1/100,000 or 0.00001
>, more than
<, less than
/, per
‰, parts per thousand
t, time
$\times g$, times the acceleration of gravity
° C, degrees Centigrade

Section 6: GLOSSARY

absorbancy: Synonymous with optical density; equal to $-\log_{10} T$, where T=transmittancy; molar absorbancy index or extinction coefficient is the absorbancy of a 1-molar solution through a 1-cm. light path.

accessory glands: In insects and other invertebrates; secretory organs associated with reproductive function.

adductor muscle: In bivalve mollusks, a muscle that closes the valves of the shell.

albuminous or albumen gland: In the higher gastropod mollusks; a part of the female reproductive system, it secretes an albuminous material around the egg before the shell is added. The albuminous material serves as food for the developing embryo.

antimycin A: An antibiotic isolated from *Streptomyces* spp.; inhibits the oxidation of succinate at the level of the Slater factor.

ascorbate: The salt of ascorbic acid; a reducing agent used to reduce cytochrome *c*.

axoplasm: The cytoplasm of a nerve fiber.

Barcroft respirometer: A differential respirometer consisting of two flasks connected to a manometer. In this closed system one flask serves as a thermobarometer; the other, as a tissue chamber. As the tissue consumes oxygen and produces carbon dioxide, which is absorbed by alkali, both volume and pressure in the respiration chamber change. The difference in pressure between the two flasks is measured on the column of the manometer.

brachyuran: Pertaining to the true crabs or Brachyura.

branchial or respiratory tree: In sea cucumbers (Echinodermata), consists of two long, branching tubes that arise from the cloaca and terminate blindly in the anterior portion of the body cavity; functions in respiration and excretion.

buccal mass: In mollusks, exclusive of bivalves; a more or less compact mass of muscles and cartilage that supports and operates the radula.

catalase: An enzyme that catalyzes the conversion of hydrogen peroxide to water and molecular oxygen.

citric acid cycle: Another name for tricarboxylic acid cycle or Krebs cycle; the primary mechanism by which the aerobic oxidation of metabolic intermediates to carbon dioxide and water takes place.

clitellate: Indicative of the fact that an annelid, such as an earthworm or a leech, is sexually mature and bears a clitellum.

clitellum: A glandular thickened region that secretes a capsule for eggs and may assist in attachment during copulation.

collagenous: Pertaining to collagen, a protein that is found in large amounts in connective tissue.

columella muscle: In gastropod mollusks; is attached to the columella (central column) and serves to retract the body of the animal into the shell.

corpora allata: In insects; glands that secrete a hormone (juvenile hormone) capable of preventing metamorphosis while permitting larval molting; also involved in the control of reproduction.

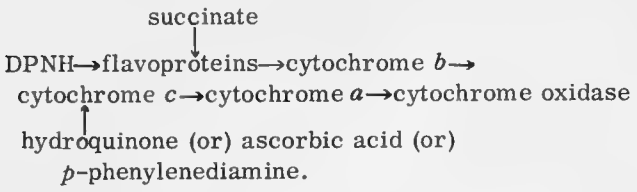
coxal muscles: In insects, crustaceans, and other arthropods; muscles of the coxa, which is the first segment of a leg and which effects the articulation of the leg with the body.

cytochrome *c*: A heme protein, the position of which in the terminal electron transport chain is such that it may be reduced from the ferric (Fe^{+++}) to the ferrous (Fe^{++}) form by cytochrome c_1, cytochrome *b*, flavoproteins, or certain added reducing agents; also may be oxidized by cytochrome oxidase or by certain added oxidizing agents.

cytochrome oxidase (cytochrome a_3): A heme protein that oxidizes cytochrome *c* and reduces molecular oxygen; its activity is inhibited by cyanide, azide, and carbon monoxide, the inhibition by carbon monoxide being light reversible.

cytochrome system: A group of respiratory

enzymes of primary importance in cellular respiration. The members of the chain are thought to be aligned as follows:



dart sac: Found in one superfamily of land snails, the Helicacea; consists of a muscular caecum arising from the vagina and contains a fine-pointed calcareous shaft. The shaft is exchanged by the hermaphroditic partners during courtship and serves as a releaser stimulus for courtship behavior.

dehydrogenases: Enzymes that are generally DPN- or TPN-linked and that catalyze the oxidation of certain metabolites. Neither DPN nor TPN, however, is required by succinic dehydrogenase, which transfers electrons to the cytochrome chain directly.

dialysis: A method for the separation of large molecules from small by means of their unequal rates of diffusion through natural or synthetic membranes.

diapause: The condition of arrested growth, development, or reproductive activity that occurs at a given stage in the life cycle of many arthropods, notably certain hemimetabolous and holometabolous insects.

differential manometer: See Barcroft, Fenn, and Thunberg respirometers.

digestive diverticula: See midgut gland.

2, 4-dinitrophenol (DNP): Dissociates or uncouples ATP synthesis from aerobic respiration.

diphosphopyridine nucleotide (DPN): Or coenzyme I; a hydrogen acceptor that is reduced by a variety of substrates in the presence of specific dehydrogenases; in turn, it reduces a flavoprotein.

ecdysis: In arthropods, the act of shedding or casting the exoskeleton (shell).

electron transport system: See cytochrome system.

endogenous respiration: Respiration without added substrate.

endoplasmic reticulum: An intracellular cytoplasmic system consisting of tubules and vesicles that form a continuous network of membrane-bound cavities; some of the membranes have small granules (ribonucleoprotein particles) attached to them, so that these membranes may appear rough-surfaced.

ethylenediaminetetraacetic acid (EDTA): Or versene; a complexing agent used to chelate divalent metals and so effectively remove them from solution.

extinction coefficient: See absorbancy.

eyestalk extract: The supernatant obtained when eyestalks of a decapod crustacean are homogenized, boiled, and centrifuged.

fat body: In insects, a tissue that fills the body cavity and contains large amounts of fat, protein, and glycogen.

femur: The third (counting distad) and often the broadest segment of the leg of an insect. In the metathoracic leg, the femur may be considerably enlarged to contain the muscles used in jumping (as in a grasshopper or cricket).

Fenn respirometer: A type of differential respirometer; consists of two vessels connected by a horizontal capillary tube containing an oil drop. As volume or pressure changes within the respiration chamber, the oil drop moves.

flavoproteins: A group of conjugated proteins of primary importance in the electron transport system.

fluorescence: The light emitted by a molecule as a result of absorption of radiation from an external source; persists only during irradiation; is of longer wave length than is the incident light.

giant axon: A type of nerve fiber of exceptionally large diameter; found in lower vertebrates and in certain invertebrates, including annelids, crustaceans, insects, and cephalopod mollusks; permits rapid conduction of nerve impulses.

gizzard: In *Aplysia* and other Aplysiomorpha (opisthobranchiate mollusks), most of which feed by cropping live seaweeds with paired jaws and radula. The gizzard has two chambers, an anterior one for masticating and a posterior one with delicate teeth for straining.

hemimetabolous: Refers to an insect that undergoes incomplete metamorphosis (egg→nymph→adult).

hepatopancreas: See midgut gland.

holometabolous: Refers to an insect that under-

goes complete metamorphosis (egg→larva→pupa→adult).

homogenate: Ideally, a cell-free suspension obtained by grinding tissues in such a way that cell structure is destroyed.

hydroquinone: A reducing agent used to reduce cytochrome *c*.

Krebs cycle: See citric acid cycle.

larva: Immature, wingless, generally worm-like form into which holometabolous insects hatch from the egg and in which they remain until they change into pupae.

liver: See midgut gland.

malonate: The salt of malonic acid; a dicarboxylic acid that competitively inhibits the oxidation of succinic acid.

Malpighian tubules: Tubular organs opening into the midgut or hindgut of insects; generally believed to be excretory in function.

mantle: In mollusks, the fold of the body wall which, in shell-bearing forms, lines and secretes the shell.

microsomes: An operational term referring to the fraction obtained when homogenates freed of large particulate matter are centrifuged at high centrifugal forces; the fraction obtained is composed essentially of fragments of ruptured endoplasmic reticulum (see definition) and its attached particles.

midgut gland: Name preferred by many invertebrate zoologists for the digestive gland of mollusks and crustaceans; in mollusks, sometimes called hepatopancreas, digestive diverticula, or liver; in crustaceans, often called hepatopancreas or liver.

mitochondria: Intracellular particles (average diameter, 1μ) containing the enzymes and coenzymes that comprise the electron transport system; involved in oxidative phosphorylation, and citric and fatty acid oxidations; can be collected in a relatively homogeneous fraction by centrifugation (at 5000 × *g*) of a homogenate from which nuclei and cellular debris have been removed by a low-speed centrifugation.

molt: A term frequently used, as in this volume, to indicate the growth processes undergone by arthropods both before and after ecdysis, as well as during ecdysis.

nymph: Immature stage into which hemimetabolous insects hatch from the egg.

optical density: See absorbancy.

oxidative phosphorylation: The process by which adenosine diphosphate (ADP) and inorganic orthophosphate are converted to the high-energy compound adenosinetriphosphate (ATP); energy for this conversion is derived from the transport of electrons through the terminal electron transport system.

pallial: Refers to the mantle, especially of a mollusk.

particulate fraction: Any of several fractions that are usually obtained from a tissue homogenate by differential centrifugation.

pedal retractor: In mollusks, a muscle that retracts the foot.

perienteric: Refers to the cavity that surrounds the digestive tract.

***p*-phenylenediamine**: A reducing agent used to reduce cytochrome *c*.

P/O ratio: Ratio of inorganic phosphate esterified (to ATP) to the oxygen consumed during the aerobic oxidation of a metabolite; denotes the efficiency of utilization of energy made available by the transfer of electrons through the electron transport system.

polarograph: An instrument used in polarography, which is concerned with oxidation-reduction reactions at an electrode. If potentials are measured while known currents are flowing through the cell, and these two parameters are plotted against each other, a curve is obtained from which the character and concentration of a given material can be ascertained.

pupa: The intermediate, quiescent form assumed by holometabolous insects following the larval stage, or stages, and prior to the adult stage.

quinol: See hydroquinone.

radula: A chitinous, tooth-bearing ribbon used by mollusks, exclusive of bivalves, for rasping food into minute particles.

respiratory quotient: Ratio of the volume of carbon dioxide produced to the volume of oxygen consumed during respiration.

retractor muscle of foot: See pedal retractor.

sarcosomes: Mitochondria of muscle.

Slater factor: A component of the electron transport chain operative between cytochrome *b* and cytochrome *c*; inhibited by antimycin A.

spectrophotometer: An instrument for the quantitative measurement of the transmission of light of a given wave length through a solution,

the transmission of the solvent being set at unity or at 100 per cent.

stellar nerve (see Connelly, 1952): In cephalopod mollusks; this term presumably refers to the large nerve trunks that run from the brain to each stellate ganglion; these nerve trunks are usually called the mantle or pallial nerves.

subumbrella: In jellyfishes; the concave or oral surface of the umbrella (see definition).

succinoxidase system: An enzyme system that includes succinic dehydrogenase and part of the electron transport system; catalyzes the oxidation of succinate to fumarate and transfers the electrons so removed to oxygen via a portion of the terminal electron transport system.

Thunberg respirometer: A type of differential respirometer.

tricarboxylic acid cycle: See citric acid cycle.

triphosphopyridine nucleotide (TPN): Or coenzyme II; a hydrogen acceptor which is reduced by a variety of substrates in the presence of specific dehydrogenases; in turn, it reduces a flavoprotein.

umbrella: The gelatinous bell-shaped or disk-shaped structure that comprises the greater part of the body of a jellyfish.

volumeter: A closed-system, constant-pressure respirometer with two flasks connected by a manometer and with an additional calibrated arm permitting direct measurement of changes in volume that result from respiration in one flask; the second flask serves as a thermobarometer.

Warburg respirometer: A single-flask, constant-volume manometer in which the consumption of oxygen is measured as a function of a change in pressure.

Winkler method: A chemical method for the determination of dissolved oxygen based on the oxidation of manganese.

Section 7: GUIDE TO LITERATURE

Popular, semi-popular, and semi-technical references are indicated by an asterisk.

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Section 9: INDEXES

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