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FORMER EXTERNE OF THE HOSPITALS OF PARIS
AND OF THE MATERNITY OF LARIBOSIÈRE

THE ARTIFICIAL INCUBATOR

IN

NEWBORNS

(La Couveuse artificielle chez les nouveau-nés)

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Translator's Note

This is an English machine translation of Victor Pascaud's 1899 Paris medical thesis, *La Couveuse artificielle chez les nouveau-nés*, prepared from page scans of the printed original (Poitiers: Imprimerie Blais et Roy). The translation aims to be faithful rather than modernized; period terminology (e.g., *sclerema*, *athrepsia*, *congenital debility*) is retained.

Bracketed gray markers such as [p. 14] indicate where each page of the original begins, so passages can be cited against the French edition. Pages 18, 32, 50, 54, and 74 of the original are blank versos. The front matter between the title page and p. 7 was not included in the scans supplied.

Temperatures are in degrees Celsius, as in the original; decimal values printed in the French style (e.g., 36°5) are rendered as 36.5°. Weights are in grams. Footnotes are placed at the end of the page section on which they appear and are labeled with the original page and note number. Bibliographic titles are left in their original language. Obvious printer's errors are noted in square brackets.

The author uses *couveuse* for the incubator and the informal *couveux* for an infant being raised in one; the latter is rendered "incubator infant."

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THE ARTIFICIAL INCUBATOR IN THE NEWBORN

PRELIMINARY CONSIDERATIONS

"Since the number of children being born is steadily diminishing, let us at least try to save them all and raise them for the fatherland." (Dr. Vallin, *Bulletin de l'Académie de Médecine de Paris*, November 1895.)

At the moment when, under the authoritative leadership of TARNIER, the artificial incubator became popular in France with the well-known enthusiasm that accompanied it, there was perhaps too much haste to extend its benefits to every infant born before term, or regarded as such; and, in order to produce fine statistics, the task of laying down the precepts that might later serve as a line of conduct for practitioners more or less new to the question was left, perhaps also a little too much, to chance. Indeed, if one consults the memoirs published at that time on the incubator, one finds scarcely a few principles, [p. 8] based solely on the weight or the age of the newborn!

Little by little, fairly numerous publications have come to shed light on this question, which is still under study; the various morbid conditions that could arise have been considered. Bacteriology, as it advanced, revealed the dangers faced by infants placed in the incubator, through the many infections to which this apparatus may expose them.

At the present time, it seems that almost everything has been said on this interesting chapter of infant pathology; but what rules are to be followed?

Where are these principles to be found, formulated?

What line of conduct should one adopt in the case of an infant, let us suppose not at term, and placed in conditions of manifest inferiority for struggling against the many causes of destruction that attack it on every side, whether on the one hand cold, sclerema, or cyanosis, or on the other septic infections, or again the overly confined air of the incubator?

What are, or may be, the dangers the infant runs in this incubator?

These are so many questions we asked ourselves when, placed in one of the obstetric services of Paris most favored by the number of women in childbed who stay there in a year, we had the opportunity each day to examine and treat infants who were candidates for the incubator.

Our research showed that every possible condition had been considered, and often well studied, either by the many obstetricians who have [p. 9] occupied themselves with this interesting question, or by the physiologists who have extended the scope of their research on the fetus to every period of gestation.

Only, the whole is scattered across various branches of medical science, and unless one compiles, as we have done, a bibliography that is often tedious, the practitioner who needs immediate information finds himself at a loss.

To bring matters up to date, taking advantage of the modern progress achieved by antisepsis and bacteriology; to group in a short memoir the many indications furnished by the experience of our

teachers, while taking into account at the same time the progress achieved by mechanics in perfecting the incubator itself: such is the aim we set ourselves, and we have made it the subject of our thesis.

The general idea is this: to DRAW, from all the conditions of INFERIORITY in which a newborn finds itself (preterm, at term, or considered in all the morbid states of the pathology of the fetus and the newborn), USEFUL RULES. We do not say *precise* rules, for we shall show precisely that there can be none.

We begin, for the sake of completeness, with a short *history*, whose purpose is to show the probable origins of the incubator, origins we have not found in any modern classic text; this will at the same time give a brief overview of the road traveled through the different stages in the evolution of the artificial incubator.

Immediately afterward we enter upon the study of our subject.

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In a *first part* we have considered:

1. The various precepts given at the time the incubator came into general use, and the possible relations of age and weight in the newborn.
2. The other possible physiological conditions, that is, the state of the various organs of the newborn at term from the physiological point of view; its functions, that is, its nutrition, its circulation, the state of its temperature, etc.

Since the study of these various chapters shows that no single criterion can be relied upon, because each varies with the many morbid affections that assail the fetus, we were led to study the states or diseases that can cause them to vary.

The *second part* is devoted to the study of congenital debility, sclerema, edema and cyanosis, syphilis and albuminuria, septic infections and infectious diseases: so many affections that alter the general condition of the newborn, demonstrating at the same time that it is on this general condition alone that one can rely.

In a *third part*, we shall examine some of the indications necessary for placing an infant in the incubator. A special chapter is devoted to the real or imaginary dangers of the incubator.

The *conclusion* that emerges is this:

When one has an infant to place in an incubator, one must choose the apparatus that gives the best guarantees as regards both its operation and antisepsis.

We do not conceal from ourselves that there are many gaps in our work: first, because it is difficult to be complete on so vast a subject, and because we [p. 11] lack above all the personal experience that confers sufficient authority. We can affirm, however, that we have relied solely on facts and rules given by our most authoritative teachers.

There is no need, moreover, to insist on justifying pretensions we do not have, our only aim having been to produce something personal that is not at the same time devoid of practical interest.

But before undertaking this study, we wish to pay public tribute of our gratitude to all our Teachers of the Faculty and of the Hospitals.

Let us first thank those who gave us our first lessons and initiated us into the secrets of the clinic: we are happy to mention in particular Dr. LETULLE, *professeur agrégé*, physician at the Boucicaut Hospital; Dr. SCHWARTZ, *professeur agrégé*, surgeon at the Cochin Hospital; and Dr. DESCROIZILLES, physician at the Hôpital des Enfants-Malades.

Dr. LEGUEU, *professeur agrégé*, surgeon at Saint-Louis, kindly accepted us for six months as a volunteer *externe*; we shall retain a deep gratitude to him for the excellent advice he lavished on us and for the kindness he always showed us.

We cannot thank enough our dear Teacher Dr. BARIÉ, physician at the Laennec Hospital, with whom we learned a great deal in clinical medicine.

Dr. BONNAIRE, *professeur agrégé*, obstetrician at the Lariboisière Hospital, kindly accepted us as [p. 12] *externe* in his service; we thank him most sincerely.

We take this opportunity to pay public tribute of our gratitude to our fellow countryman Dr. FLORAND, physician of the Hospitals, for his good advice and for the kindness he has always shown us.

Professor PINARD has done us the honor of accepting the Presidency of our thesis: we beg him to accept this tribute of our respectful gratitude.

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I. HISTORY

It is very difficult to know what the first incubator for infants was. It is from Alexandria, so it is said, that incubators for birds' eggs come to us, and it is possible that it occurred to the Egyptians to apply the method to newborns, as has been done in France.

One cannot, however, presume as much, for no author of that time mentions it, and HIPPOCRATES (1), whose assertions were authoritative in that era, declared "that no fetus coming into the world before the seventh month of pregnancy could be kept alive." Modern classic texts attribute the paternity of the first incubator to DENUCE of Bordeaux, who in 1857 described the first model. We would have done as they did, had chance not led us to a very curious observation on this subject.

We found it in a thesis from Year XI of the Republic, in which the author, HUDELLET (2), relates the following account, which we have thought it proper to quote in full; he himself borrows it from BAILLET (3).

p. 13 (1) HIPPOCRATES. *De Septimestri et Octimestri partu*.

p. 13 (2) HUDELLET. *De la viabilité du fœtus*. Thesis, Paris, Year XI.

p. 13 (3) BAILLET. *Jugemens des Savans*. Paris, 1722, vol. VI, p. 135.

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Here is that observation:

"Among the histories of celebrated children, BAILLET relates that of Fortunio Liceti, whom his mother brought into the world long before the ordinary term, during the fatigue and the jolting of a sea voyage. This fetus was no larger than the palm of the hand, but his father, who was a physician, having examined him, had him carried to the place that was to be the end of his journey. There he had him seen by other physicians. It was found that he lacked nothing essential to life, and his father undertook to complete the work of nature and to labor at the formation of the child with the same artifice used to hatch chickens in Egypt... He instructed a nurse in everything she had to do, and, having had his son suitably accommodated, he succeeded in raising him and in making him attain the necessary growth by the uniformity of an external heat exactly measured. He lived 79 years and distinguished himself in science by a great number of works."

Obviously this is a story, but a story in which one finds all the elements of an incubator. We refrain, moreover, from any commentary, and shall content ourselves with mentioning the fact, quoting the reflection of the historian himself: "One must admit," says the author, ending the narrative I have just summarized, "that everything incredible is not always false, and that likelihood is not always on the side of truth."

This reflection applies only to the viability of the fetus in question, but it may perfectly well be applied to [p. 15] the apparatus itself, to which we shall henceforth give the name *incubator* (*couveuse*).

It must be supposed, however, that our author had not taken out a patent for his invention and that it had fallen back into oblivion, for we come at a single stroke to 1857, the date at which DENUCE described the first incubator, since it is to him that its paternity is granted today.

This incubator, like those described by CREDE of Leipzig in 1884 and by WINCKEL in 1879, was a bathtub filled with water at a temperature of 36° to 38°.

At about the same time, a similar incubator was in use at the Moscow Maternity.

We shall not dwell on the results obtained, nor on the details of these various devices, and we shall come straight to the incubator I would call *modern*, for the improved devices of our day differ from it only in details: I mean the incubator that TARNIER had built in 1878 and installed in 1881 at the Maternité of Paris.

We shall not dwell further on its description, which can be found in all the classic texts; this incubator, moreover, is still in operation in many obstetric services and above all in private practice in the city.

It is from this period that the principal works undertaken on the incubator date, and the most varied modifications have followed one another almost without interruption to our own day; we shall mention only the principal ones.

The first important work on the question is a [p. 16] memoir by AUVARD (1) in 1883. In this very interesting work, on which we have drawn extensively in the course of our study, the author gives the first statistics on the use of the incubator at the Maternité at that time, under the scientific direction of TARNIER.

BERTHOD, an *interne* of TARNIER, in an excellent thesis (2), continued this study, adding new data on the conditions for placing infants in the incubator and the new ideas of the Master; his statistics are still more imposing, covering nearly a thousand cases of incubator placement.

These are, one may say, the only two important works dealing with the study of incubators.

Since then, a large number of authors have returned to this question, but these many publications have appeared rather to modify certain details or to propose new models of apparatus than to provide new rules.

Let us cite a few of them, in chronological order.

We set aside first the TARNIER incubator, which has undergone various modifications at the hands of his pupils.

I shall content myself with citing those of Professor BUDIN, who modified the incubator with respect to the mode of heating and the mode of ventilation.

EUSTACHE (3) described a new model in [p. 17] 1885. This incubator can be heated indifferently by gas, oil, or petroleum; it is widespread in England under the name "Hearson's Thermostatic Nurse."

In 1896 metal incubators appeared.

DIFFRE (1) of Montpellier advocates a model that he claims is free of all the defects attributed to the incubator, and LION puts into circulation an incubator provided with the latest improvements.

Moreover, models have sprung up on every side, each practitioner possessing one more or less perfect; we shall therefore refrain from pushing this perhaps useless list any further.

We shall, however, say a word in closing about a quite special incubator that is perhaps destined for a great future: we mean the giant incubator, formed by an entire room of an apartment, having all the advantages of the small incubator without its drawbacks.

An incubator of this kind was built in Lyon for the first time in 1896 by M. COLRAT (2). We mention it only briefly here, as we shall return to it at greater length at the end of this study; suffice it to say that it is a room 4 m long by 2.50 m wide, with a constant temperature of about 30° and a ventilation system allowing a considerable mass of air to renew that of the room constantly.

p. 16 (1) AUVARD, *Archives de tocologie*, October 1883.

p. 16 (2) BERTHOD, Thesis, Paris, 1887.

p. 16 (3) EUSTACHE, *Journal des sciences médicales de Lille*, 1885.

p. 17 (1) DIFFRE, *Montpellier médical*, vol. V, 1896.

p. 17 (2) COLRAT, *Société des Sciences médicales de Lyon*, session of July 1896.

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II. FIRST PART

THE INCUBATOR AND THE NEWBORN CONSIDERED IN ITS PHYSIOLOGICAL FUNCTIONS

CHAPTER ONE

Relation of Age and Weight

A young woman, in good health at the time of delivery, without any hereditary or personal taint, gives birth *before term*, for whatever cause, to a well-formed infant of good external appearance, with all its physiological functions normal, but weighing only 1600 g. Should it, on account of its weight alone, be placed in the incubator?

Another mother gives birth, this time *at term*, to an infant of puny and wizened appearance, with edema or cyanosis, or some morbid affection, but weighing 2500 or 3000 g. Should one try to raise it without an incubator because its weight is close to normal?

In a word, should one rely on the age or on the weight of an infant in deciding to place it in the incubator?

These are the first two questions that arise in our work; let us first study them separately.

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1. AGE. The history of medicine furnishes many examples proving that this factor has almost always been neglected. Thus, without going back to the time of Hippocrates, one finds in HUDELLET's thesis on the viability of the fetus the following assertion due to LEVRET: "It is incontestably proven that there are women who give birth at 7 months to infants as strong and as vigorous as if they were nine months old, and conversely."

The same author reports several interesting observations on this subject, among others the following, borrowed from CARDON: "The wife of a wine merchant of Milan showed him her daughter Claire, aged 18, whom she had borne on the 168th day following a miscarriage in the 4th month."

Let us say at once that few authors have insisted on this sign, because of the difficulty of knowing at exactly what period of gestation an infant may be born.

2. WEIGHT. This question is much more important, for it is on weight almost alone that the obstetricians who laid down the first rules for placing newborns in the incubator relied.

AUVARD (1), in one of the most thoroughly documented memoirs to have appeared on the incubator, said in 1883:

"Since the installation of incubators at the Maternité, all infants, whatever they may be, weighing less than 2000 g are, with very few exceptions, placed in the incubator."

This rule, quite categorical, was therefore the one that [p. 21] had been adopted, and our research leads us to believe that it was also the only one.

Well then, can one, as was done at that time, rely solely on the weight of a newborn in deciding to place it in the incubator? We do not think so.

Without dwelling on this question, it is easy for us to show its exaggeration.

Simple reflection suffices, first, to know that various morbid states, as we shall see further on, can cause the weight of an infant to vary considerably.

We have found in the medical literature many examples contrary to this theory. We find a quite remarkable one cited by TARNIER himself, who in his practice placed one twin in the incubator although she weighed 83 grams more than her elder sister, who was not placed in it and who outlived the first.

Professor PINARD cites another remarkable example (1).

3. RELATION OF AGE AND WEIGHT. We pass at once to a third question: the relation that may exist between the weight and the age of a newborn.

Can there be one, and what is it?

We have gathered most instructive documents in this respect by going through all the statistics published in France from 1881 to the present day.

We shall give the result of our research, and the reading of these few figures will be far more eloquent than the most extensive considerations.

The first statistic in date is that of AUVARD, in [p. 22] 1883. It covers 145 cases; here is what we find in it:

1. 26 infants, boys or girls, weighing less than 2000 g although they were 8 months of age or more.
2. 9 weighing more than 2000 g and less than 8 months of age.

Let us add that no particular disease is mentioned for these various infants. So even at that time weight was not always relied upon.

The second statistic, that of BERTHOD, is much more imposing; it covers 608 cases. Here is what we have drawn from it:

1. Infants of 8 months or more weighing less than 2000 g: 48, of whom 7 were at term.
2. Infants of less than 8 months weighing more than 2000 g: 52, of whom 2 were of *six months*.

We note among other examples: a fetus of 9 months weighing only 1600 grams, which was saved. Another of only 7 months weighed 2500 grams.

It is twins that have shown us the most striking contradictions; thus one notes two twins of eight and a half months, one of whom weighs 1560 g and the other 2280 g.

One also finds, among triplets, one of 1800 grams: he is the smallest of the three and alone survived.

These various contradictory examples amply suffice to show that one can rely neither on the age nor on the weight of infants. We shall therefore not insist further. Modern theories having cast new light on the dangers to which the incubator exposed the fetus (above all from the point of view of infection), a good number of practitioners, more or less hostile to the

p. 20 (1) AUVARD, *Archives de tologie*, October 1883.

p. 21 (1) PINARD, article "Fœtus" in the *Dictionnaire* of DECHAMBRE.

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incubator, have published quite interesting cases concerning how infants weighing only 1200 and 1500 g had fared, raised perfectly well without the aid of the artificial incubator.

We shall end our considerations on this point there, and boldly lay down the following conclusions:

One cannot and must not rely solely on the weight or the age of a fetus to derive a sufficient rule of conduct; but neither is to be neglected, for they will be an excellent means of verification and a useful source of information to set us on the track of the other indications that we are now going to review in turn, drawing from each, as far as possible, a conclusion useful for our subject.

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CHAPTER II

Fetometry

What we have just said about the weight and age of the fetus applies equally to other factors that have more or less been brought into play in order to arrive at a sufficient estimate of an infant's age or maturity. Thus its length, which varies in proportion to its weight and its age, may be of some use.

But here again, very complete studies on this subject have shown that it can vary according to the age of the mother, the number of her deliveries, etc.

Comparisons have even been attempted between the weight or the age of the fetus and the weight or the development of the placenta. But thorough research, foremost among which we cite that of Professor PINARD, has shown that the latter varies infinitely, both physiologically and in the domain of pathology (1).

Much attention has been given recently, above all in Germany, to what can be learned from various measurements of the fetus compared at different periods of gestation.

One of our colleagues at the Lariboisière Hospital, Dr. [p. 25] BRUYÈRE (1), made a thorough study of this question this year, and by a rather ingenious procedure succeeded in determining exactly the weight of an infant by measuring the distance between its malleoli and the condyles at the level of the knee. This very interesting result, from which the greatest benefit can be drawn in certain cases of pelvic deformity, does not seem to us to be of very great help to our cause. We see in it, however, one small advantage: that of showing the degree of perfection the development of an infant may have reached, above all as regards its bony framework, which must always be taken into consideration.

p. 24 (1) CORREA DIAZ, Thesis, Paris, 1892.

p. 25 (1) BRUYÈRE, *Un procédé de fœtométrie*, Thesis, Paris, 1898.

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CHAPTER III

Physiological Functions and State of the Functional Organs of the Newborn

1. CIRCULATION AND RESPIRATION. At the time when one still relied on the frequency or irregularity of the pulse to judge the febrile state of a patient, one might have been justified in drawing conclusions from it for placing infants in the incubator. The fact is mentioned nowhere, but it is likely that it would have been otherwise had the incubator been more in favor at that time. Yet as early as 1844, H. ROGER (1), in a series of observations and experiments that have kept all their value, showed "that temperature alone could be the sole object of monitoring, and that a newborn may have 140 pulsations per minute, and 40 and even 80 respirations, in what is to all appearances the most perfect state of health."

The more or less perfect pulmonary functions, and the state of the pulmonary parenchyma itself, are often of great use, and very practical deductions can be drawn from them for placing an infant in the incubator. But we shall not dwell on this here, as we must return to the question in connection with cyanosis and edema in the newborn.

p. 26 (1) H. ROGER, "Chaleur animale," *Archives générales de Médecine*, 1844.

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2. BLOOD. Examination of the blood could certainly give the most useful indications regarding the inner maturation of the newborn since, as the fetus progresses, hematopoiesis progresses at the same time. It would be interesting to know at what period the nucleated red mother cells disappear, and at what period the hematoblasts and red corpuscles are formed; and from the comparative study of these various elements, which must appear at almost fixed periods at the different ages of the fetus, one could learn the state of maturation of the fetus and draw very practical deductions from it.

But let us admit that this is a very complex study, and putting such monitoring into practice, possible as it may be, would be, if not very difficult, at least very lengthy and often too meticulous. It is therefore only an idea that we content ourselves with putting forward and that we submit to those who seek vast fields of study and scientific interest (PASCAUD).

3. STATE OF THE ORGANS OF THE FETUS. The state of the stomach and the digestive tract at the moment of a newborn's birth, and the way it may tolerate food, is of great importance from the medico-legal point of view or for the nutritional treatment of the fetus, but this question is of no interest, at least not directly, from the point of view of the incubator.

The perfection of the limbs and skeleton, the state of the cranial sutures, the more or less considerable extent of the fontanelles, the definitive descent of the testicles into the scrotum are so many characteristics of the fetus at term that can serve as useful indications for estimating its age, but they are of no interest for our [p. 28] subject, except when, taken together, they constitute the general condition of the subject, which must always be considered when placing newborns in the incubator.

4. PHYSIOGNOMY OF THE FETUS. Very useful deductions can be drawn from it if one considers that the infant born before term is more or less somnolent, stupefied, "astonished" (*étonné*), to use an expression that has become classic in obstetrics; even its cry has a quite special timbre

according to its vitality. But we shall return to this question when summarizing the special state that characterizes the *couveux* (the incubator infant) properly speaking.

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CHAPTER IV

Temperature of the Newborn

Infants at birth have a temperature roughly equal to that of their mother, but this temperature falls almost immediately afterward because of the little heat they produce.

The newborn cools very quickly if it is not surrounded by protective clothing. Experience, before physiology, demonstrated this: instinct has led mothers, among humans as among the higher animals, to maintain a mild temperature around newborns and to shield them as far as possible from the action of atmospheric vicissitudes (ROGER, 1844). "However, the infant born at term, vigorous and well formed, resists this cause of destruction effectively; if it loses heat in the new environment in which it is placed, it produces new heat by virtue of its native energy. Soon the functioning of its digestive organs allows it to store and use materials that are a source of calories (1)."

But instead of a vigorous infant at term, let us suppose a puny premature one, barely viable, and in a manifest state of inferiority for the struggle.

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"The infant cools from the extremities toward the center, ever increasingly, and death ensues. It is known that this cooling need not be very intense to be fatal."

This greater ease of cooling in infants born before term was brought to light long ago by several physiologists: W. EDWARDS, having examined from this point of view a newborn at term and well swaddled, is said to have found only 32°.

This fall in temperature is often considerable, as we shall see further on, in certain affections of the newborn (see Sclerema, page 37).

There is therefore an absolute necessity to remedy this drawback, and here the incubator has its full *raison d'être*. It was to maintain this heat that DENUCÉ built the first incubator we know of, and today everyone is agreed on this point.

Yet this question has not always been viewed as clearly as one might have supposed.

BERTHOD, in his thesis, which we have already mentioned, deals only with the morbid causes that can make the temperature of the newborn vary. It was only in 1895 that the question was erected into a method by Professor BUDIN (1).

He shows, following an interesting statistic, the necessity of placing in the incubator infants even weighing more than 2000 g, but having a rectal temperature below 32°.

We are thus in possession of a good landmark; we

p. 29 (1) EUSTACHE, *Journal des sciences médicales de Lille*, 1885.

p. 30 (1) BUDIN, *Obstétrique*, no. 2.

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could almost say of an absolute rule, if numerous morbid causes did not cause this rule to vary, a rule I might call one of the great laws of the incubator. These causes are, for the most part, infectious diseases such as typhoid fever, intermittent fever, etc. But these are exceptions which alone can still admit controversy.

On the other hand, we shall see further on how far down the scale the temperature of newborns can fall in certain affections, as in a case of LETOURNEAU, who saw the temperature fall to 20°. Statistics and experience prove to us what services the incubator has rendered in such cases (1).

p. 31 (1) Thus, without insisting further, we may affirm with Professor BUDIN that, apart from very rare exceptions, every newborn whose rectal temperature is below 32° centigrade must be placed in the incubator, whatever its weight and age.

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III. SECOND PART

THE INCUBATOR AND PATHOLOGY

Up to this point we have considered the state of the newborn from the point of view of its physiological functions; but since each of them can vary with the various morbid affections that assail the fetus, it is of the first necessity to know how this infant will fare in its struggle with these various enemies, and to know what benefit it can derive from the incubator in each particular case.

We shall dwell on the most important questions, those most directly related to our subject, and shall mention the others only for the sake of completeness.

We shall begin with the earliest in date, those that, so to speak, gave birth to the incubator: congenital debility, sclerema, edema, cyanosis; and we shall end with the infectious diseases, which have given rise to some interesting discussions whose clarification may yield some practical results.

[p. 34]

CHAPTER ONE

Congenital Debility

Congenital debility is easily recognizable by certain characteristics. One of the most important is the inferior weight of the infant born before term compared with that of the infant born at term.

In general, when the weight ranges between 1000 and 2500 g, there is congenital debility.

But to assess the vitality of a newborn, one must not rely solely on its weight.

Indeed, certain infants, although of young gestational age, may have a considerable weight and yet their organs are incompletely developed; they breathe poorly and feed poorly.

Other infants, on the contrary, remain longer in the uterine cavity and have an equal or even lesser weight, but, their organs being more developed, they breathe and digest better. Knowledge of the infants' age is therefore also of great interest, and one should seek to establish it with the greatest care: we have seen what to think on this subject; we know, for example, that of two twins the heavier is sometimes the weaker and the only one suitable for the incubator.

On what, then, should one rely?

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Without neglecting the indications that both the weight and the age of the newborn may give us, there are, says GUÉNIOT (1), "certain external characteristics which hardly ever deceive a practiced eye and which allow the diagnosis to be made even before weighing."

To proceed by comparison, let us first see what the characteristics of the fetus at term are; we borrow them in part from M. PINARD (2).

Generally the plumpness is fairly pronounced; the skin is pinkish white, sometimes showing a fine down, above all at the shoulders; sometimes the skin is clean, most often covered with a sebaceous

coating, the "vernix caseosa"; the hair, most often colored, is 1 to 3 cm long. The cartilages of the ear and nose are firm to the touch; the insertion of the cord does not correspond to the midpoint of the body length; the scrotum, which contains the testicles, is covered by thick, wrinkled, pink skin; the nails have the hardness of horn and extend beyond the tips of the fingers, but not beyond those of the toes. The average weight is 3000 to 3500 g.

Here now, in a few words, are the principal characteristics that distinguish a premature infant from a fetus at term:

Slender body; soft, delicate skin; red color of the skin, a uniform bright red allowing the vessels to be seen by transparency; smaller quantity of hair, its short length and lesser coloring. The face is wrinkled; on the pupils persist more or less marked vestiges of the pupillary membrane. One finds in the scrotum one or two testicles, but they are not

p. 35 (1) GUÉNIOT, *Gazette des Hôpitaux*, 22 October 1872.

p. 35 (2) PINARD, article "Fœtus" in the *Dictionnaire* of DECHAMBRE.

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descended to the bottom of the scrotum. The fontanelles are more open.

Their cry lacks vigor; one might compare it to the cheeping of a young chick. Respiration is weak, barely perceptible; the thorax is immobile, with respiratory movement barely sketched and irregular. Inertia of the external muscles.

The infant does not have the strength to suckle.

Finally, an important characteristic to note here: if one takes the temperature of an infant presenting these characteristics, one finds it below normal.

In such a case there is no doubt: the incubator is necessary, it is imperative. It is the basis of the treatment of congenital debility, which we could not complete without straying from our subject.

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CHAPTER II

Sclerema

This chapter follows naturally from the one dealing with congenital debility, and could be attached to it as a corollary, for it is among premature infants, and in particular infants affected by congenital debility, that this rather common affection of newborns rages.

It is above all in cases of sclerema that the incubator has given marvelous statistics, one might say the best, and we shall see that these results are due to the very nature of sclerema.

It is indeed characterized by an induration of the integuments and of the subcutaneous cellular-adipose layer, which may be generalized but is usually localized to the extremities of the limbs.

Sclerema develops silently; it usually occurs in a premature infant who has not been surrounded with all the care its condition required; it is generally observed in the first days following birth.

The influence of cold is incontestable. The most frequent cases are indeed observed in winter. "It is probable that this complication is produced by a disturbance of the general circulation; there results a diminution of animal heat, which shows itself in serous [p. 38] effusions and a partial coagulation of the fat on the inner surface of the skin" (RIBEMONT-DESSAIGNES).

The temperature falls as the disease progresses. PAROT saw the rectal temperature fall to 21.8° in one case. The pulse diminishes in frequency; respiratory movements slow in direct proportion to the fall in temperature.

The causes of the disease (cold and congenital debility) would suffice here to demonstrate the need for the incubator. Experience amply proves it. Under the influence of the temperature of the incubator, one sees the sclerema melt away, so to speak, before one's eyes.

BERTHOD observed a case in which a stay of 12 hours in an incubator, for an infant at term, it is true, sufficed to make the slightest traces of it disappear.

If one consults the statistics, one is astonished at the result; here is what emerged from our research in those of the Maternité from 1877 to 1885.

Before the incubator, from 1877 to 1880, 181 infants died at the Maternité with sclerema.

From 1882 to 1885, with the incubator, we find, analyzing Berthod's thesis, which covers 605 cases, that only nine succumbed while presenting the signs of this affection.

During our stay at the Lariboisière Maternity, we were surprised by the speed with which the induration disappeared, and we recorded only a single death, and even then the infant presented, along with its sclerema, all the signs of an infectious diarrhea.

How, then, are we to explain the objections to the use of the [p. 39] incubator in this case, and above all the observations published in support of these objections?

It is because cases are met in which, to the two great causes invoked, a third is often added: insufficient or ill-conceived feeding. It is also possible that sclerema has sometimes been confused with edema due to swaddling bands that were too tight, or even with erysipelas; but here again the error is easy to avoid, since the temperature, instead of being lowered as in true sclerema, is generally several degrees above the average.

In the case of sclerema, the incubator must be used, and as promptly as possible.

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CHAPTER III

Edema and Cyanosis

1. EDEMA OF THE NEWBORN. Edema considered as a morbid entity of the newborn consists of an infiltration of serous fluid effused into the meshes of the subcutaneous cellular tissue; what characterizes it is its great extent, its near generalization. The general symptoms that follow it allow us at once to exclude certain compression edemas, of which we have already spoken in connection with sclerema.

Ordinarily the affected newborns are premature, most often born in the 8th month, sometimes puny twins. In weight and in length both are inferior to the normal newborn by about a third. Other causes invoked include neglect of the rules of hygiene, chilling, and lack of nourishment. Intercurrent diseases and anemia have been brought in; DEPAUL described an interesting case of syphilitic edema.

The disease begins almost immediately after birth. A violaceous color gradually invades the whole body and coincides with a rather hard edema having the same progressive course. Pulmonary symptoms are noted that allow differentiation from sclerema; finally, and this is the pathognomonic symptom, *the temperature, from [p. 41] the outset below normal, falls gradually and to extraordinary degrees*, to such an extent that in one case, shortly before death, LETOURNEAU (1) saw the thermometer placed in the axilla register only 20°. Professor HUTINEL (2) cites several similar cases.

The pulse is slow and weak; it may fall to 60 beats per minute; respiration is also much altered. LETOURNEAU (3) published a very interesting note on this question; here is what he found:

"At autopsy, all the tissues and all the organs are found engorged with venous blood. But it is above all *the state of the respiratory organs* that is revealing. Always a more or less large portion of the lungs, most often the lower lobes, is violaceous and completely hepatized without the slightest trace of inflammation being found; and indeed if, instead of incising and cutting up the lungs, one inflates them through the trachea, the hepatization and the violaceous color disappear as if by magic; the pulmonary sac then expands normally and takes on a fine vermilion tint. The conclusion to be drawn is simple and inescapable: edema of the newborn, fatal as it is, is not a disease; it is simply slow asphyxia, and its cause was revealed long ago by PALETTA of Milan, in 1823. This cause is simply the incomplete unfolding of the pulmonary sac; the newborn, almost always a puny premature, does not have the strength to take sufficient breaths, and a more or less [p. 42] large portion of the respiratory organs retains the fetal state."

This way of viewing the question explains to us why the incubator has not always given the results one might have expected from it, as it did for sclerema for example, given the great fall in temperature in this affection. The only statistic giving figures in this regard is that of AUVARD: two recoveries and three deaths out of five cases.

Far from doing away with the incubator, which we consider absolutely necessary in cases of severe hypothermia, we believe it useful to add the treatment given by LETOURNEAU himself; it is extremely simple: it is insufflation as it is performed in infants born in a state of apparent death.

This treatment may be continued by using the method employed by M. BONNAIRE at Lariboisière. It consists of delivering oxygen over a broad surface into the incubator by means of a glass funnel connected to an oxygen bag by a rubber tube and suspended a few centimeters above the infant's head.

2. CYANOSIS. A simple corollary of the preceding chapter, cyanosis often has the same causes and presents symptoms in common; hence the same course of action is used in both cases.

It will suffice to add that it is often the consequence of various anomalies of the heart (persistence of the ductus arteriosus, of the foramen of Botall, etc.) and of the vessels (abnormal openings of the veins and arterial trunks).

In this case the infant, above all in the cold seasons, will do well in the incubator, which will protect it from edema and above all from sclerema.

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Let us add, so as to omit nothing, that there is a cyanosis independent of anomalies of the heart and vessels. It is the kind that occurs after a long labor during which strong uterine contractions have been repeated. It is sometimes also due to swaddling that is too tight. Here, of course, the incubator would rather be contraindicated.

p. 41 (1) LETOURNEAU, Congrès de Blois, 1884.

p. 41 (2) HUTINEL, *Thèse d'Agrégation*, 1880.

p. 41 (3) *Loco citato*.

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CHAPTER IV

Syphilis, Albuminuria, Jaundice, Athrepsia

We deliberately group in a single chapter all these affections, very different from one another, because they are connected more or less directly with the preceding diseases: some are their cause, like syphilis and albuminuria, two great factors of congenital debility and premature birth; others are, or appear to be, their consequence, like jaundice and athrepsia.

1. SYPHILIS. Syphilis is one of the great causes of premature birth and, as such, it must be ranked among the affections that the incubator improves, provided that the premature syphilitic fetus placed in an apparatus is in well-defined morbid conditions, for example in a state of manifest congenital debility, or presenting the signs of one of the diseases we have just described: sclerema or edema. For apart from these quite particular states, syphilis by itself in no way requires the use of an incubator as regards the various lesions it can produce in a newborn: mucous patches, chancres, or pemphigus. The same is true of a certain syphilitic edema, of which DEPAUL cited an interesting case, which does much better with specific treatment.

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2. ALBUMINURIA. It has no special effect on the fetus, and we mention it only as a cause of premature delivery giving birth to fetuses affected by congenital debility.

3. JAUNDICE. The weaker the infant, the more predisposed it is to jaundice: jaundice coincides with sclerema and edema of newborns; of 240 infants with jaundice, BAUZON found that more than 90 had been born before term or were twins.

Can one rely on the causes of jaundice to deduce therapeutic indications from them? Authors do not agree on this point; however, it emerges from the whole discussion of this disease that the majority blame a deficiency in fetal organization, whether a defect of the blood (theory of PORAK, FRIEDRICH) or an anatomical lesion (theory of QUINKE, on the persistence of the ductus venosus of ARANZI).

In this case the incubator can give good results (L. RENON) (1).

One must beware of jaundice following umbilical infections or hepatic syphilis.

4. ATHREPSIA. Here a distinction must be made. Indeed, the definition of this affection has changed completely since DEPAUL. For him and the practitioners of his time, athrepsia was a complication of edema of the newborn. For those who still understand it so, the incubator should be used.

Today this name designates a special [p. 46] form of the cachexia following the common chronic gastroenteritis of nurslings.

If these athreptic infants are puny or premature, they will be suitable for the incubator, but their condition will require quite special care and supervision.

p. 45 (1) RENON (L.), *Traité des maladies de l'enfance* of GRANCHER [printed "Granger"], vol. III.
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CHAPTER V

Infectious Diseases and Septic Infections

One could almost entitle this chapter "Contraindications to the incubator," so true is it that no microbial disease is improved by the incubator, which on the contrary seems a favorable medium for the spread of contagion. The matter deserves all the more attention because the infant's temperature, which is so often of great help in putting us on the track of danger, remains almost always silent in this respect, when it is not a cause of error by sometimes staying below normal, as we shall see.

We shall not go into the detail of each of the many infectious diseases observed in the newborn. We shall dwell a little only on pneumonia, the microbial disease at once the most frequent and the most dangerous in the fetus, contenting ourselves with a few sufficient considerations on septic infections in general, which are so often the unrecognized cause of infants' deaths.

1. PNEUMONIA. All acute diseases can run their course without fever in premature infants, but pneumonia could almost claim this privilege for itself alone, so rare is a rise in temperature in the course of this affection. It is not even accompanied by

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fever, so that it is often confused with atelectasis. Careful auscultation reveals barely a faint respiratory sound, which moreover does not reach the character of a bronchial breath; rarely does one hear a sharp, fine crackle; so that it goes unrecognized 9 times out of 10 (BERTHOD).

One has a fetus in the incubator that is beginning to thrive; its weight curve is excellent, its general condition was improving daily, almost visibly; then one fine day it declines, no longer takes the breast with the same eagerness, though its stools remain good, and it dies without anyone being able to guess the cause. At autopsy one discovers a well-developed pneumonia and nothing else.

2. SEPTIC INFECTIONS. Various authors have sought the causes of the infant's poor resistance to the attacks of the bacillus and to all other microbial infections, so that what we have just said of pneumonia may be applied to all of them. Among the clinical phenomena showing the newborn's poor resistance to microbial infection, I would cite above all the absence or weakness of the febrile reaction (RUDOLF).

The slight alkalinity of the blood found in newborns, their less plastic blood containing little fibrin, and the decrease in this alkalinity in infected infants are further facts supporting the poor natural resistance of the newborn's organism!

What other causes may be invoked?

Delayed separation of the cord, which tends to break down by putrefaction. A still more [p. 49] important source of infection is infection by the air, whose role, discounted for some time, has been brought to light by the research of recent years.

This last consideration alone opens our eyes not only to the uselessness but also to the danger of the incubator. We shall not insist further, moreover, because not only has this danger been pointed out, but it is on this point that the incubator has found its most relentless detractors: "The incubator, a cause of septic infection."

We shall return to it, moreover, in connection with the dangers that the artificial incubator presents or may present.

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IV. THIRD PART

PLACEMENT IN THE INCUBATOR

We have examined in turn the various states in which newborn infants may present; we have considered successively the general and particular physiological conditions, whether or not the fetus is at term. From there we passed to the study of the morbid states in which the incubator had been tried and those in which it seemed absolutely necessary. And from this enumeration, perhaps a little long, there has emerged what we announced in our introduction: that there can be no fixed rules, everything varying at every moment according to the caprice of a pathology whose field is so extensive at this period of life.

Now a new question arises.

Why so complex a study to determine whether infants should be placed in the incubator?

We shall answer at once that it is because of the great dangers the fetus may encounter there. We touched on them in connection with infectious diseases; we shall enumerate a few others. Let us say, however, that without concealing their seriousness, these dangers have been exaggerated, and the incubator is no longer a bugbear today, thanks to the modern progress achieved by [p. 52] antisepsis and the improvements made in the construction of the apparatus itself.

The study of the dangers of the incubator, how to avoid them, the method of using the incubator, and the choice of a good incubator: such will be the principal chapters of this third part.

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CHAPTER ONE

Objections to the Incubator: Its Dangers

Many objections have been raised against the artificial incubator; in fairness it must be acknowledged that this was almost inevitable, since the apparatus was still in its period of creation and transformation. We shall pass over in silence the objections drawn from the irregularity of the incubator's temperature, the difficulties of monitoring, etc., and move at once to the most important ones.

1. The first serious objection raised against the artificial incubator is that of EROS, a physician of Prague, who, noting that premature infants had a temperature below normal, reproached it for not allowing the fetus to produce sufficient heat by itself and, as a second objection, for creating too great a difference between this artificial temperature and the already lowered temperature of the fetus, which could be a cause of multiple dangers for the infant. This very subtle objection was refuted by BERTHOD: "The cause of the hypothermia of premature infants does not lie, for Eros, in their losing too much heat, but rather in their producing too little. The therapeutic indication is therefore not so much to prevent the fetus from losing its heat as to supply it artificially."

2. A new objection was drawn from the poor [p. 54] circulation of air in the incubator. This objection was all the more serious in that it applied to the old models. Since then, apparatus with quite sufficient draught have been built, not to mention the incubator-rooms such as the one operating at the Lyon Maternité, where the air is renewed as abundantly as in the best-ventilated hospital ward! The incubator we propose as a model offers, we believe, every sufficient guarantee in this respect, since the air, taken from outside or from the room itself, enters it at the rate of 5 to 6 liters per second; the incubator having a capacity of 250 liters, the air in it is renewed constantly, minute by minute.

Moreover, apart from experience, physiology has shown that the newborn easily withstands asphyxia, and all the better the further it is from term, which is easily explained, since the infant, still in the fetal state, moves little air at a time, being provided with barely developed lungs.

3. It has also been said that the sudden change of temperature to which the infant was exposed when taken out of the incubator to be cleaned or fed was a cause of danger; but we know from experience that it suffers no ill effect from it; moreover, nothing is easier than to carry out this change in a room at a sufficient temperature.

4. The incubator as a source of infection.

We now come to the most serious objection, the only one that deserves our attention.

Why can the incubator be, or why is it, a cause of infection?

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The matter is easy to understand.

1. *On the side of the fetus.* The infant shut up in an incubator is, in short, condemned to live amid the septic products it often manufactures itself: emanations produced by its excreta; the ever-present septicemia produced by putrefaction owing to the separation of the cord, always delayed in a premature infant; not to mention the other infections that may arise in it if it is affected by some microbial disease, such as pneumonia, or a small phlegmon of the umbilicus, etc.

2. *On the side of the incubator.* The first danger comes from the heat itself.

Heat: a source of benefit for the fetus, but an eminently favorable medium for the production and multiplication of the microbial cultures generated by the fetus or of those that may arise there.

The incubator preserves these dangerous products and may transmit them to other fetuses that were unaffected before being placed in it.

The air draught, despite all improvements, is always insufficient and is a further aggravating cause.

It is evident that these objections are serious and give food for thought. They were above all so in former times when, for example, in the first TARNIER incubator, two fetuses placed together could fatally share an infection and thus create harmful microbial associations; they were so again with this same incubator because of the difficulty of disinfection, for despite all the precautions taken, this wooden apparatus, with its corners and cracks, may always harbor a germ [p. 56] which, under the influence of heat, will multiply with sufficient rapidity.

Modern incubators built of metal, with as few corners as possible and no more cracks or fissures, but as if cast in a single piece, easy to clean and even to flame, reduce this cause of infection to a minimum and reduce the objection almost to nothing. Besides, one need only set out the results obtained by the incubator, even before the progress achieved in our day, to show its effectiveness, which should no longer be in doubt for anyone.

The chances of peril for the newborn will be further diminished by taking all sufficient precautions when placing the infant in the incubator, which will always be easy to do by drawing on acquired experience: the study of the most important of these precautions will be the subject of what follows.

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CHAPTER II

Required Temperature: Stay in the Incubator and Its Duration

What is the action of the incubator on the physiological functions of the infant?

Most authors who have dealt with this question agree that its influence is rather slight.

The pulse and respiration, which at first undergo a slight increase in frequency, return to the normal figure around the sixth day, except that respiration remains always a little more frequent than in the physiological state.

There is a rise in temperature more marked and more rapid than in the open air: "the axillary temperature is higher relative to the rectal temperature than in the open air. This influence of the incubator on the peripheral temperature truly shows its action on the circulation of the superficial parts of the body and particularly of the skin" (AUVARD).

We think it unnecessary to show what benefits can be drawn from this action in some of the affections we have already discussed, such as sclerema and even edema of the newborn.

1. TEMPERATURE OF THE INCUBATOR. What should [p. 58] the temperature of the incubator be? Can a fixed rule be accepted, or should it vary according to the condition of the subject?

Let us see what practice has been followed up to now. TARNIER, who had adopted an average of 32° at the Maternité, adds that it may be varied from 30° to 37° and "that it should be all the higher the weaker the infant."

Professor PINARD had taken a temperature of 34° as the average at the Lariboisière Maternity.

Questioned on this point during a discussion at the Société des sciences médicales of Lyon, M. COLRAT replied that a temperature of 30° is sufficient. "When it rises higher, the infants suffer and cry."

Not having sufficient experience in the matter to give a personal assessment, we shall content ourselves with that of our teachers; let us nevertheless be permitted to state what we were able to see during our year as *externe* at Lariboisière. Our teacher, M. BONNAIRE, following the precepts of TARNIER, adopted 32° as the average temperature, and the infants generally do well with it. The temperature of the incubator must be regulated according to that of the infant. This is, moreover, we believe, simply a matter of trial and error, and the condition of the subject will in short be the best rule

to follow: it is necessary to give averages only if the physician cannot watch the subject himself or have it watched by an experienced midwife.

We shall not speak of the course to follow during the infant's stay in the incubator. It will be dictated by all the care that cleanliness and hygiene demand.

2. DURATION OF THE STAY IN THE INCUBATOR. What should [p. 59] be the duration of the newborn's stay in the incubator?

This is a much more complex question than the preceding one; it has never been thoroughly elucidated, perhaps because here again it is difficult to give even approximate rules; we give further on some interesting observations on this subject. Can one rely on weight to take an infant out of its incubator? At first sight it seems that a valuable indication might be found there; well, no! Here, for example, is the information drawn from a statistic of AUVARD in 1883, the only one, moreover, that has considered the question:

Of 136 infants born before term and placed in the incubator, only 10 left with a variable increase in weight; five had the same weight as when they were placed in the incubator; 22 had decreased and weighed less than on admission.

And this after a stay varying from three to forty days.

We took up this study again at Lariboisière, but on too limited a number of subjects for the figures to be conclusive. We observed on average an increase in weight, but most of the time so slight that it cannot be relied on as a faithful indicator.

Here again, we believe, one must rather be guided by the general condition of the subject. One must look at the various advances made by its physiological functions, its physiognomy, the state of its integuments, the timbre of its voice, the way it feeds and develops, etc.: so many things that are seen and appreciated from day to day, even through the mother's observation, but that cannot be described, [p. 60] or at least cannot be erected into precepts.

When one is not certain of the course to follow, we believe it is better to prolong this stay than to shorten it. In this way one will avoid some of those accidents we have had occasion to observe, of which it would be easy to give many examples, so frequent are these cases of premature infants removed too soon from the benefits of the incubator who succumb, when every appearance of survival was on their side. It is above all in hospital practice that the most curious examples are usually met. We have thought it useful to publish, from among those we observed, four rather striking cases.

OBSERVATION I

Mme Félicie M..., twenty-three years old, gives birth at Lariboisière on 8 April to twin girls in a rather mediocre state of vitality.

One weighs 1650 g and measures 45 cm in length; the other weighs 1700 g and measures 46 cm.

Both infants are well formed: ruddy skin, hair very developed, above all on the lower limbs, wrinkled face, etc.

Both are placed in the incubator.

With assiduous care and the usual treatment, the two infants manage to thrive; their general condition improves visibly; their temperature is 36.2° for the first and 36.5° for the other. They feed at the breast, and a slight increase is noted on the weight chart.

For unknown reasons, and despite the usual remonstrances, the mother leaves on 18 April taking her two infants with her.

The next day, the 19th, she brings them back in a deplorable state, with generalized edema; they are completely chilled. They are hastily put back in the incubator.

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They are even given an injection of serum.

The first dies the same day; the second gradually regains her vitality and leaves after four weeks in a satisfactory general condition.

We were unable to learn her weight at discharge.

OBSERVATION II

The woman Brst... gives birth at Lariboisière to a premature infant (7 months) weighing only 1300 grams. The infant is well formed, but its general condition is rather poor, and despite being placed in the incubator it presents the symptoms of incipient sclerema.

But soon, thanks no doubt to the incubator, the sclerema gradually diminishes and even disappears; the infant, which at first was fed by spoon, begins to take the breast. In short, it does very well.

The mother, obliged to leave, takes it away and lavishes the best care on it at home: two hot-water bottles in its cradle, etc. But the infant visibly wastes away and the sclerema reappears.

She brings it back to the hospital as quickly as possible; it is put back in the incubator, and its condition is at once seen to improve again.

The infant leaves in good health 3 weeks after this second stay at the Maternity: it weighs 1950 grams.

OBSERVATION III

M. X..., 16 years old, no known morbid history, gives birth on 25 October last, for the first time, to an infant of six and a half months weighing 1670 g. Puny condition, but good appearance. It is placed in the incubator; it takes 10 g at the breast per day, as its daily weight indicates.

The mother takes it away on the 12th day (5 November), when the infant, after falling to 1150 g, had risen again to 1300 g and was in very good condition.

She brings it back on 16 November, eleven days later, in a desperate state: the infant no longer suckles, it has signs of sclerema, it weighs 1050 g, and its temperature has fallen to 34.5°. In addition it has thrush filling its mouth, with constipation that the mother dates back 3 days.

The infant is immediately put back in the incubator, after being [p. 62] lightly rubbed with alcohol. It is given an enteroclysis with naphtholated water; in a word, all the care its desperate condition requires.

We see it again four days later, completely transformed; it takes the breast eagerly and its temperature is 37° centigrade. Everything gives hope that the infant is out of danger.

OBSERVATION IV

This is a premature infant of seven and a half months. The mother is albuminuric.

The infant weighs 1950 g. Given its puny condition, it is judged advisable to place it in the incubator, where it does very well, since it takes the breast every 2 hours; its stools are normal, its temperature is 37.2°.

On the 7th day the mother takes her infant away in good health. She brings it back on the 10th day, saying that it is always cold and no longer feeds. It is hastily put back in the incubator.

But it dies in the evening. Its temperature, taken a few hours earlier, was 32.6°.

The autopsy, performed by us, gives no precise information on the causes of death.

We shall add only a word on how one should manage a *couveux* (incubator infant).

During the last days of treatment, the temperature of the incubator must be lowered so as to arrive gradually at 25°, and the duration of the infant's outings must be progressively lengthened.

In the first weeks of life in the open air, the incubator will still be the best of cradles at night, above all in cold and damp seasons.

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CHAPTER III

The Incubator to Be Used

What apparatus should be used?

We have seen in many places that, far from being a matter of indifference, this is of the greatest importance; indeed, it is on the proper functioning and perfection of this apparatus that one's efforts must be concentrated in order to achieve a satisfactory clinical result. Let us first see what a good incubator consists of: an incubator is an apparatus intended to provide a warm temperature that is regular and easy to adjust. It must ensure the constant renewal of warm air, without abruptness and without jolts. Finally, it must be built in such a way as to permit the absolute cleaning of all its various parts, in order to avoid contagion through the incubator, which is one of the worst drawbacks.

The three great factors to be considered are therefore *heating*, *ventilation*, and *disinfection*. Any apparatus that does not ensure the perfection of these three factors must be pitilessly rejected. Any negligence in one or another of the conditions we have just given as essential may be the cause of the

gravest accidents. We have therefore sought, among the considerable number we have had to examine, the incubator that could meet all the requirements.

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Before naming the model we prefer and giving our reasons, we shall briefly review the various models most in use and show at the same time the aspects that seemed to us defective.

We need not, of course, put on trial the first incubators, such as those of DENUCE or CREDE, which are described in all the classic texts and which should now be found only in a museum.

Besides, in the short history that opens our work, we said a word about each of the various models proposed or used from the invention of the incubator to modern times; we shall speak only of the models currently used in the great maternity hospitals of Paris and the provinces.

THE TARNIER INCUBATOR. The first that offers itself for examination is obviously the TARNIER incubator, which was the first improved apparatus; it is still regarded as an excellent model, since it is still used at the TARNIER Clinic and in several other great maternity hospitals of Paris.

What reproaches do we have to make of it? We have said that its wooden construction was already a defect, for wood, despite all the care that can be taken in its manufacture, is not a stable material: it works, splits, warps, and slits or fissures appear that make disinfection and also heating difficult. Needless to say, it cannot be flamed. Disinfection, if possible at all by means of certain antiseptics, is therefore very defective.

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Incubators of this model have reportedly been built in glass, which answers this first reproach, but the other objections remain no less valid.

It is easy to conceive how irregular the heating is, despite all the improvements that have been made to it.

To be convinced of this, the observer need only visit an establishment where five or six incubators are operating at once, in which it was intended to obtain the same temperature, and he will see that none of them shows, on the thermometer placed inside, that same desired and intended degree of temperature; and unless supervision is perfect, which is not the absolute rule, this irregularity of heating may well have caused many accidents.

Moreover, we can affirm as a principle that an incubator not provided with an automatic regulator cannot fulfill the conditions necessary for this purpose.

And ventilation? Well, it is entirely defective, for even supposing that the air circulates freely inside the incubator, which is not at all demonstrated, it is always the same air that circulates in this apparatus, namely that of the hospital ward where the infant is beside its mother and often beside other infants and other mothers.

In a word, the TARNIER incubator, which has certainly rendered the greatest services and may still be useful if need be, must be rejected, because something better can be found by way of improvement.

THE HUTINEL INCUBATOR. In the same category we examined the incubator currently in operation at the Hôpital des Enfants-Assistés and at the Pitié Maternity.

These incubators are enameled inside and consequently easy to disinfect. Is the ventilation sufficient? We are willing to believe so. It is therefore, it seems, a better apparatus than the preceding one. But here again we hardly see how the heating can be regulated, the incubator not being provided with an automatic regulator. Second defect: the air still comes from the ward.

THE DIFFRE INCUBATOR. DIFFRE of Montpellier proposes a model that we have not seen, but whose description seems perfect: ease of ventilation and of disinfection, and perfection in the form of the apparatus itself, which we do not consider completely negligible, above all in private practice; the parents of a newborn prefer to see their infants in an apparatus that looks like anything other than a coffin, which is somewhat the case with all the preceding models.

But here again, how is the heating regulated? Where does the air that enters and circulates in the incubator come from? Always from the common ward.

THE COLRAT GIANT INCUBATOR. We now come to a kind of incubator that at first sight appears to be the latest improvement. This is the giant incubator in operation in Lyon, at the Maternité, of which M. COLRAT has given a complete description. Here everything seems perfect. The heating is easy to regulate, since it is done by means of sufficiently improved apparatus that heat the whole room uniformly. Ventilation, for the first time, is perfect, or at least the best possible, since it is achieved by means of a vast current coming from outside and constantly renewed.

Where is the defect? If it escapes one at first sight, it is easy to conceive on a little reflection. It is, [p. 67] as we have said, a single incubator, a vast room in which all the newborns of the Maternité have been gathered.

Well then, should an epidemic break out, all the infants will be affected and the incubator will at once be immobilized.

Should even a single one of them be affected by a contagious disease not recognized at first: the contagion will quickly spread to its neighbors and will soon have invaded all the occupants of the incubator.

It is therefore an incubator that we consider defective for this reason alone.

Moreover, it does not meet every need; we mean isolated cases, an apparatus that can serve individually, whether in a family, or even for a private crèche or even a small maternity hospital.

Which incubator, then, shall we propose?

We are not going to describe a new model to add to the already very long list of apparatus proposed up to now. For besides those we have just mentioned, there exist many others in France and abroad: we could almost say that every obstetrician has proposed one, which he has advocated as superior to all the others.

THE LION INCUBATOR. We shall simply describe a very well-known model, already used in a great number of maternity hospitals both in France and abroad, and which we have seen operating at the Baudelocque Clinic and at the Lion Maternity in Paris.

We shall content ourselves with giving a succinct description of the apparatus, which will spare us any commentary on it. The reader will be able to see for himself that the three great factors, *heating*, *ventilation*, [p. 68] *disinfection*, which we have designated as indispensable, have here reached almost their final stage of perfection. Even the form of the incubator

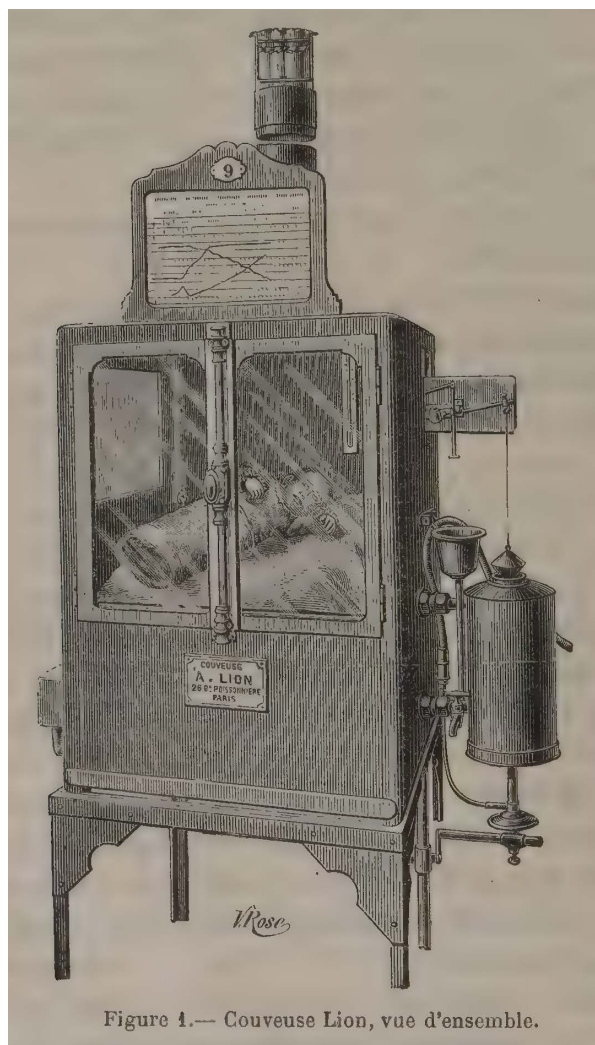


Figure 1. The Lion incubator, general view.

has been the object of particular care on the part of the engineer.

[p. 69]

Here, moreover, are the details that M. LION himself kindly gave us.

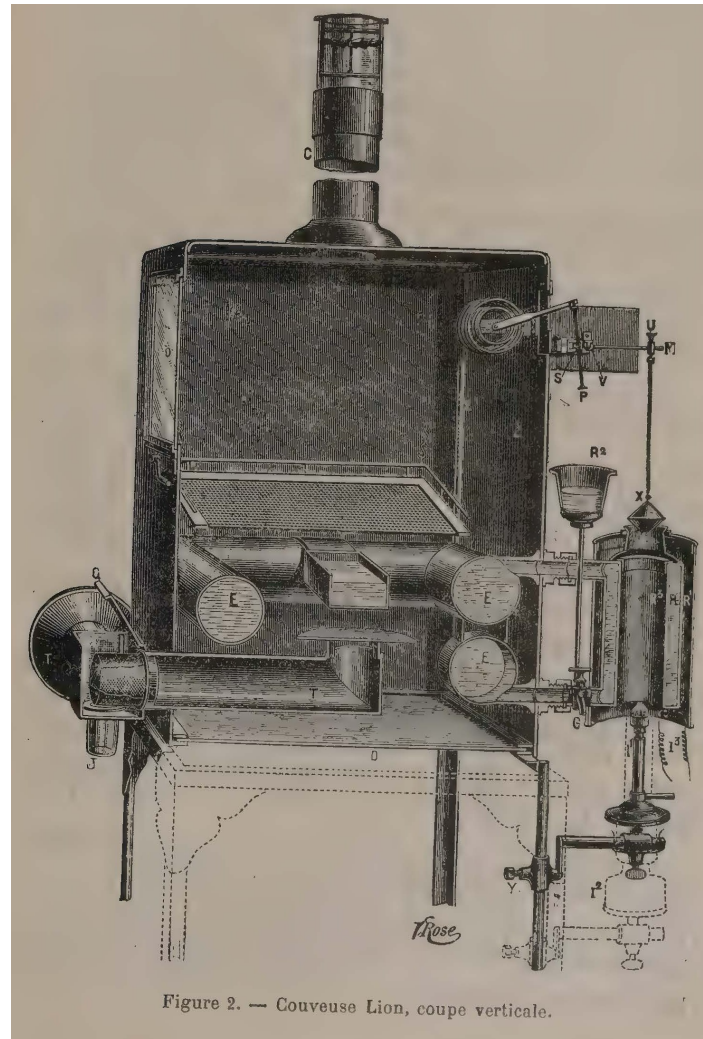


Figure 2. The Lion incubator, vertical section. (Letters refer to the parts named in the text: R², filling funnel; R³, central channel; X, obturator cone; M, lever; P, adjusting screw; G, drain tap; Y, burner support; T, air-intake channel; C, chimney.)

[p. 70]

1. Description of the apparatus. Professor PINARD was the first to have the idea of using metal for the construction of incubators; it is on this principle that M. LION based his apparatus.

The Lion incubator consists of a metal parallelepiped mounted on an iron stand. It can be disinfected without deterioration in the pressurized steam sterilizer and with chemical disinfectants. Its ventilation is ensured by a tube 8 centimeters in diameter opening at the base of the apparatus and by a draught chimney of the same diameter. A propeller placed at its top indicates, by its rotation, the strength of the air current.

The front of the incubator is fitted with a glazed frame with two leaves and an espagnolette fastening. On the left side opens another glazed frame allowing the mother or the nurse to follow the infant's movements and to take it out when needed, the apparatus being placed beside the bed.

The floor slides and is removed by gliding in its grooves, like the tray of a birdcage.

Placed in the middle of the incubator on a hammock of wire mesh, the infant is isolated on all sides, and the warm air can circulate freely around it. A thermometer placed at the level of its head allows the functioning of the apparatus to be followed.

Heating is ensured by a circulation of hot water in a coil communicating with a reservoir placed alongside. This thermosiphon can be heated indifferently by gas, petroleum, electricity, or any other fuel.

[p. 71]

A special system of piping makes it possible to bring outside air, purer than the air of apartments and wards, directly into the apparatus, to filter it moreover before it enters the incubator, and to conduct it to the outside through a chimney.

By these arrangements the air can be supplemented, according to the physician's instructions, with medicinal gases: oxygen, ozone, balsamic essences of pine, of eucalyptus, fir buds, etc.

In addition, the dangers that may result from crowding are avoided.

A regulator transmits the movements of the temperature to a lever and increases or decreases, as needed, the strength of the heat current.

Regulation of the temperature is ensured automatically and invariably.

2. Adjusting the apparatus. (1) Set the incubator level on its stand and put the regulator in place.

(2) Fill the thermosiphon with hot water through the funnel R² and light the gas or the lamp. (This funnel must always contain water to compensate for the slight evaporation that occurs.)

The heat source must be placed 5 centimeters below the water container and in line with the channel R³, which passes through it over its entire height.

The support Y allows the heat source to be moved in every direction.

The obturator cone X must close the opening of the channel R³ until the degree of heat one wishes to obtain is shown by the thermometer placed inside the incubator.

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To keep the channel closed, it suffices to give a little freedom to the lever M by gradually turning the adjusting screw P from right to left. In normal operation, the cone X must be a few millimeters above the channel and in equilibrium with the action of the regulator on the lever M.

3. Operation. (1) With the obturator cone X lowered and completely closing the upper opening of the channel R³, the action of the heat source is exerted on the entire surface of the inner and outer walls of the water container R. Hence a rise in temperature.

(2) As the temperature rises in the incubator, the cone rises and lets pass the quantity of heat that would be in excess of the set degree.

By means of the adjusting screw P one raises the temperature by lowering the cone, that is, by turning this screw from right to left. One lowers it by the reverse movement.

The heat can also be maintained by renewing the water.

For this it suffices to draw off from time to time, through the tap G, two or three liters of cooled water and to replace them with the same quantity of hot water, pouring it in through the funnel R.

It is recommended that the gas burners and lamps be kept in the greatest state of cleanliness.

If, as a result of an excessive drop in atmospheric temperature or for any other cause, the intensity of the heat source became insufficient, this could be remedied by partially or totally cutting off the entry of outside air. In that case one should open the lid of the box to allow the air of the room to enter the incubator.

[p. 73]

Place the cylindrical wire gauze, surrounded with cotton wool or any other material forming a filter, at the entrance of the channel T on the wall of the apparatus.

The container placed between the tubes of the thermosiphon, intended to give the air the necessary degree of humidity, must always contain water.

4. Methods of heating. Heating by gas, heating by petroleum or other essences, or heating by an electric heat source may be used indifferently.

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CONCLUSIONS

From all that we have just said, it seems to follow:

1. That the origin of the incubator goes back much further than has been believed until now.
2. That in order to place a newborn in the incubator, one cannot rely solely on its weight, its age, or any one of its physiological functions taken in isolation, but should use them only as useful indications. Far better use will be made of the infant's general appearance, which never deceives a practiced eye.
3. That the temperature of the newborn is a valuable indication, often an absolute one. Every infant whose rectal temperature is below 32° centigrade should be placed in the incubator.
4. That the incubator must be used in congenital debility, sclerema, edema of the newborn, and almost all the affections that lower its temperature.
5. That it is contraindicated in most infectious diseases.
6. That, as a general rule, the temperature of the incubator must be regulated according to that of the infant. The infant's rectal temperature should ordinarily be maintained at 37° to 37.5°, and one should always aim to lower that of the incubator.
7. That the duration of the stay in the incubator cannot be fixed; one must be guided by the general condition of the infant.

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8. That the apparatus to be used is the one that offers the best guarantees of heating, ventilation, and disinfection.

Seen: *The Dean*,
P. BROUARDEL.

Seen: *The President of the Thesis*,
PINARD.

Seen and approved for printing,
The Vice-Rector of the Academy of Paris,
GRÉARD.

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