We have additionally $\partial T/\partial \dot{q}_k = p_k$ or $\nabla_{\dot{q}} T = p$, T being the kinetic energy. One notes that diagonally opposite corners of figure 1 are essentially scalars and vectors, respectively, and the variables in H are indicated by the diagram.

2. Point transformations, where $Q_k = f_k(q_1 \cdots q_n)$, follow the same rules as given in figure 2. Thus $\nabla_P H = \dot{Q}$; $\nabla_Q H = -\dot{P}$; $P = \nabla_{\dot{Q}} T$ with the variables in H indicated as before.

3. A similar diagram is available to show the conditions under which canonical or contact transformations are admissible. In figure 3, F is a qQ function such that the canonical conjugates are $\nabla_q F = p$ and $\nabla_P F = -P$; whereas F' is a qP function, the conjugates appearing as $\nabla_q F' = p$ and $\nabla_P F' = -Q$. Thus the diagram shows the variables in F and F', but both may also contain time, t, explicitly.

With the new Q and P so defined, the diagram figure 2 is again at hand for use with the understanding that $H + \partial F/\partial t$ or else $H + \partial F'/\partial t$ are in general to replace H, as for instance in the adiabatic and perturbation phenomena.

4. In case of varied action a function corresponding to F' and which turns out to be the characteristic function $S = \int_0^t 2T\,dt$ may be made free from explicit time. Moreover if cyclic coordinates are in question P and Q may, as shown in Figure 3, be replaced by $J = \S p \cdot dq$ and the cyclic variable w. This cyclic integral $\S$ is here to be taken in a vector sense (much like

a ∇) so that $i_1 J_1 + i_2 J_2 + \cdots = i_1 \S p_1 dq_1 + i_2 \S p_2 dq_2 + \cdots$ whence generally $J_k = \S p_k dq_k$. Moreover $J = \S \nabla_q S \cdot dq = \Sigma \S i_k (dS/dq_k) dq_k$ is thus the vector sum of the increments of S in cycles of all the q_1, $q_2 \cdots$ in q; *i.e.*, $J_k = \S (dS/dq_k) dq_k$.

Finally in the present case, figure 2, is replaced by figure 4, where H (αJ) and $J(\alpha W)$ are free from explicit time. Thus $\Delta_w H = -\partial J/\partial t = 0$ since by definition H does not contain w, and $\Delta_J H = \partial w/\partial t$ is constant or $w_k = \nu_k t + w_0$.

If the system varies adiabatically conformably with a slowly changing parameter a, H is to be replaced by $H + \phi\,da/dt$ where H and ϕ contain the same variables. Hence $\nabla_w H = -\dot{a}\,\Delta_w \phi = \partial J/\partial t$.

5. Jacobi's transformations start with the same time free characteristic function $S(q_1 \cdots q_n \alpha_1 \cdots \alpha_n)$ supposedly integrated, and the partial differential equation $H(q_1 \cdots q_n \partial S/\partial q_1 \cdots \partial S/\partial q_n \alpha_1 \cdots \alpha_n) = W = H(q_1 \cdots q_n \beta_1 \cdots \beta_n \alpha_1 \cdots \alpha_n)$ integrated, but they then vary the constants, *i.e.*, treat the parameters α, β, as variables However, as α_1, the last of the arbitrary constants (therefore additive and vanishing in the differentiations) is to be replaced by the time free energy W, the condition for contact transformations is conveniently forked at S as shown in figure (5), where $\Delta_q S = p$; $\partial S/\partial W = \beta_1$; and $\partial S/\partial \alpha_k = \beta_k$.

Figure 2 is now replaced by the duplicated square distorted for clearness, figure 6, conformably with the forked figure 5. All the differential coefficients of H here are necessarily zero except (since $H = W$), $\partial H/\partial W = \partial \beta_1/\partial t = 1$, whence $\beta_1 = t_1 + t_0$, which is the time specification of the motion. Hence $\beta_k = \partial S/\partial \alpha_k = \text{const.}$, since $\partial \beta_k/\partial t = 0$, give the orbital equations in $q_1 \cdots q_n$ with the constants specified, there being thus in all n equations for the $n + 1$ variables including t.

In case of perturbations, H is replaced by $H + \phi$, expressed as functions of α, β, W, ϕ vanishing for the unperturbed motion. Thus, for instance, $\partial \beta_1/\partial t = 1 + \partial \phi/\partial W$; $-\partial \phi/\partial \beta_1 = \partial W/\partial t$.

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THE GERM CELL CYCLE OF THE DIGENETIC TREMATODES[1]

THE life cycle of the digenetic trematodes has been a subject for both conjecture and investigation by zoologists for more than a century. Metagenesis, paedogenesis, metamorphosis extending over several generations, dissogenie and heterogony have been put forward as explanations on either theoretical or cytological grounds. Since the investigations on the

cytological background of this life cycle have usually been incidental to some other subject and have in every case been based on the study of one or a very few forms, it seemed worthwhile to attack the problem by making a more extended study and one which would be comparative in nature. The cercaria-producing sporocysts or rediae of twenty different forms well distributed through the trematode classification were used in the investigation. From these studies the former theories were tested and some new evidence bearing on the nature of the life cycle was derived.

Metagenesis is no longer seriously considered as a possible explanation of the life history of this group because it implies that the hermaphroditic adult generation alternates with one that reproduces by a purely asexual method such as budding or fission. Likewise paedogenesis can be ruled out because this term, as used in its original sense, applies only to cases where a larva with sexually mature reproductive organs gives rise to functionless adults. The arguments for a metamorphosis extending over several generations[2] were based largely on the structural homology of the various stages. Although such a homology is easily recognized, this theory lacks the necessary cytological basis to establish it as an acceptable explanation of this life cycle. Since both dissogenie and heterogony require that a maturation process takes place in the reproductive cells of the sporocysts or rediae, polar bodies or other maturation phenomena must be found in these pre-cercarial stages before either of these explanations can be accepted.

Reuss,[3] Haswell,[4] Tennent,[5] Cary[6] and Faust[7] have reported finding polar bodies in the reproductive cells of the cercaria-producing sporocysts and rediae, but disagree with one another in regard to the time and manner of their production and the number of polar bodies resulting. Looss,[8] Coe,[9] Rossbach,[10] Dollfus[11] and Mathias[12] have reported searching for polar bodies without finding them. This point was made the principal objective of the present study. In none

of the twenty forms investigated were polar bodies or other maturation phenomena found. This result, together with the work of the men listed immediately above and the disagreement among those who reported finding polar bodies, is considered to be good evidence that maturation does not take place in the cells that produce cercariae within the sporocysts and rediae and that the life cycle, therefore, can not be either dissogenie or heterogony.

Another point that has an important bearing on the interpretation of this life cycle is the origin and location of the germ cells in the pre-cercarial stages. Instead of being produced in ovaries, as reported by a number of previous authors, the germ cells were discovered in the body cavity of the sporocyst or redia while these stages are still quite immature. The germ cells were found to multiply by division without undergoing maturation to produce loosely organized masses of cells which have been called "germ-masses." It is believed that previous investigators either have failed to distinguish between these germ-masses and the ordinary "germ balls" (*i.e.*, embryos of cercariae) or have interpreted them to be ovaries. The germ-masses eventually dissociate and each cell undergoes cleavage to form the embryo of a cercaria. The formation and dissociation of the germ-masses is considered to be a typical case of polyembryony. This process provides a means of germinal multiplication which is much needed on account of the plurally parasitic existence of the worm.

For the previous explanations of the trematode life cycle, a substitute hypothesis is offered interpreting the life history as one in which the germinal lineage passes through successive larval stages in which polyembryony features as a mode of germinal multiplication. The activating factor responsible for the unusual sequence of stages in this life history is thought to be a tendency of the cells of the germinal line to undergo precocious cleavage. This factor is operative first in the miracidium whose somatic development to form a typical adult is restrained by the early impetus of germinal multiplication so that it becomes a "mere reproductive sac" after entering its snail host. The germ cells within this miracidium-mother-sporocyst stage undergo a similar process to form mother rediae or sporocysts. The same procedure is repeated as many times as there are intercalary stages, stopping only when the cells of the germinal line have attained sufficient physiological age and morphological differentiation to produce a form (the cercaria) in which the germ cells are normally restrained and in which the somatic elements can therefore go on to develop a true adult.

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