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The archaeology of the first farmer-herders in Egypt : new insights into the Fayum Epipalaeolithic and Neolithic

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4. Explanatory and predictive models for the beginning of farming and herding in the Fayum

4.1. INTRODUCTION

Previous field research on the prehistoric Fayum carried out until the 1980s has principally employed a culture-historical approach, and has tended to explain the changes in subsistence and material culture by the arrival of a new farming and herding population from outside the Fayum, rather than by indigenous, autonomous development. Therefore, whereas several explanatory models of the beginning of food production, like the environmental stress model and the population pressure model, have been advocated by different schools of archaeology at that time in other parts of the world, there was little room in the Fayum for such models to be applied.

During the past few decades, a new discipline called evolutionary ecology has developed, and the adaptive design in the behaviour and morphology of organisms has been studied. According to evolutionary ecology, behaviour is adaptive when it tracks environmental variability in ways that enhance an individual's fitness. The subset of evolutionary ecology called human behavioural ecology studies the fitness-related behavioural trade-offs that humans face in particular environments by asking why certain patterns of behaviour have emerged and continued and by looking at their socioecological context. The transition between foraging and farming/herding and associated technological changes have increasingly been seen not as a progression from one subsistence type to another but as a set of alternative adaptive strategies with selective advantages and disadvantages that varied with socioecological circumstances (Bettinger 2006; Bird and O'Connell 2006; Hawkes and O'Connell 1992; Kaplan and Hill 1992: 198; Layton *et al.* 1991; Smith and Winterhalder 1992; Winterhalder and

Kennett 2006; Winterhalder and Smith 1992; 2000).

Optimal foraging models are the core of human behavioural ecology, and attempt to explain the changes in subsistence activities and related technologies in terms of increasing fitness to fluctuating situations. In this chapter, the basic ideas, implications, and related concepts of optimal foraging models are summarised and employed to refine the inductive, common-sense understanding of the ecological and archaeological data of the Fayum which were described in the preceding chapter. Moreover, it is also demonstrated in this chapter that the socioeconomic model and its related ideas would give some additional explanations about the economic and technological transition between the Fayum Epipalaeolithic and Neolithic.

4.2. ADAPTIVE MODEL

4.2.1. Optimal foraging models

Optimal foraging models consider a goal, a currency, and a set of constraints and options or alternatives when a forager exploits different resources. The goal refers to the improvement of foraging efficiency in terms of the maximisation of yield, and/or the minimisation of time and energy spent, and/or the avoidance and minimisation of risks. The currency refers to the measure to assess the costs and benefits of a resource that gives it value. The most commonly used currency is calories used up or taken in by foragers through foraging. Constraints refer to the socioecological circumstances that structure resource selection opportunities and prevent foragers from continuing to forage, like the density and distribution of potential resources in an

environment, the dangers associated with exploiting resources, the residential/mobility patterns of the foragers, and the foragers' knowledge of the environment. Constraints refer also to the foragers' technological abilities to forage and process resources and physical capabilities to survive in a given environment and to digest certain food items. Options or alternatives refer to the variability of potential resources available to foragers, and the range of possible behavioural actions, and choices of time spared for other activities. Optimal foraging models propose how a variety of resources would be used in given circumstances while considering the costs and benefits of procuring the resources, and aim to reconstruct the decision-making process of foraging. Although human foragers do not always behave optimally, the models have been substantiated by ethnographic observations (Bird and O'Connell 2006: 146ff; Kaplan and Hill 1992: 168-169; Kelly 1995: 73 and 97; Winterhalder and Kennett 2006: 11ff).

4.2.1.1. Prey choice model (Diet breadth model)

Optimal foraging models consist of two general models for practical application. The prey choice model or diet breadth model considers foraging individual resources (prey) in homogeneous environments, whereas the patch choice model considers procuring from clusters of resources in spatially heterogeneous environments. These models measure costs of foraging in terms of time expended on searching and handling. Search costs are the time spent looking for resources and patches, and are also understood as encounter rates. Handling costs are the time spent not only harvesting plants, pursuing/killing animals, and processing the plants and animals, but also making necessary tools and facilities. Foraging returns are measured in terms of calories obtained from resources, and are often described as a return per unit time like kCal/hr. Such measures are usually based on ethnographic field data or experiments. For example, according to ethnographically and experimentally derived return rates of various

resources from around the world, seeds and roots normally have lower return rates than small, medium or even large-sized animals, due to high handling costs. Search costs may change with changing resource densities depending on the seasons, and can lower with new technologies or information used to locate resources easier. Although new technologies may accompany additional costs, handling costs can lower and subsequently return rates can rise with the new technologies. Return rates can change with changing nutrition contents of plants and animals depending on the seasons. Return rates may also be different from person to person depending on their age and sex, their physical and mental condition, and their experience and skills of searching, hunting/harvesting and processing. Therefore, ethnographically and experimentally derived return rates of various resources should be referred to as relative measures (Kaplan and Hill 1992: 172ff; Kelly 1995: 78ff and 98-99).

The prey choice model assumes that foragers attempt to maximise overall returns with least effort while comparing the costs and yields of various resources based on their knowledge. Potential resources for a foraging group are ranked from high to low profitability, and profitability is determined by the quality, size, density, distribution of each resource, and the time spent and the tactics and technologies used to exploit the resource. The total number of resources in the diet counting from the top of the ranking is referred to as diet breadth. The model assumes that foragers exploit the most profitable resources first, and then add less profitable resources to their diet at a given moment. If high-ranked resources are abundant, search costs are low and the diet is relatively narrow. As high-ranked resources become less abundant, search costs increase such that lower-ranked resources are added. When foragers add new resources to their diet, the time spent for searching declines due to higher resource encounter rates, but handling costs required for different resources may rise. At some point, declining search costs are balanced by rising handling costs, and the addition of a new

resource would decrease the net foraging efficiency and return rate rather than increase them (Fig.4.1). This balancing point is an optimal diet, and it is assumed that foragers attempt to optimise their diet by choosing and combining the most profitable resources and ignoring the less profitable resources even if they are more frequently encountered than more profitable resources. The model predicts whether a resource should be taken or ignored by foragers when they encounter it during foraging trips based on this assumption. The decision to pursue one particular resource depends on foragers' perception or intuition about the improbability of encountering something else with a higher return rate during their trips (Bettinger 1991: 84-87; Bousman 1993: 61ff; Gremillion 1996: 185ff; Kaplan and Hill 1992: 169ff; Kelly 1995: 83ff; Winterhalder and Kennett 2006: 14-15).

It follows that the abundance of a resource cannot solely be used to predict whether it would be exploited, and that the decision to include a resource in an optimal diet depends on the relative abundance of high-ranked profitable resources. A decrease in the number of a high-ranked profitable resource and a subsequent increase in the search costs of the high-ranked profitable resource would diminish the net foraging efficiency and return rate, and would cause the diet breadth to expand to include lower-ranked, less profitable resources, regardless of their abundance. Conversely, if a higher-ranked, more profitable resource becomes available, lower-ranked, less profitable resources would fall out of the diet regardless of their abundance. Therefore, if climatic and environmental changes cause temporal scarcity of high-ranked resources and force the foragers to increase search time, then the diet on the whole should become more diverse, while including usually less-favoured resources which are regarded as famine food or starvation food. Although the less-favoured resources would temporarily become high-ranked and become worth pursuing when encountered, they would drop out of the diet as soon as higher-ranked, more profitable resources become available again. A seasonal increase of nutrition contents

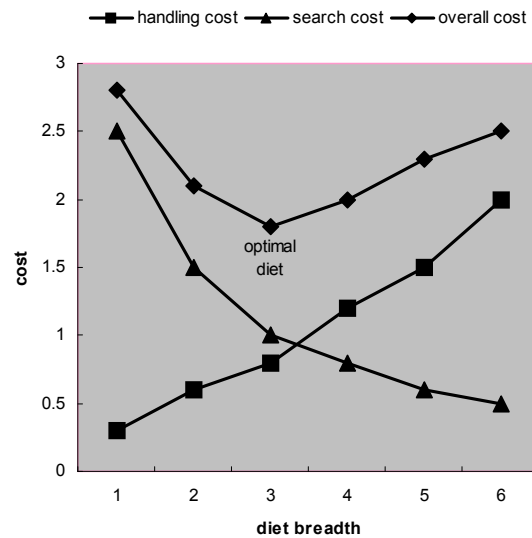


Fig.4.1. A model of foraging decision-making about diet breadth

may raise the profitability of a particular resource, and such a resource can be temporarily high-ranked and pursued. The model does not predict how frequently a high-ranked resource would be included in the diet, and only proposes that all high-ranked profitable resources would be pursued and taken when encountered, but if they are rarely encountered, they would make up only a small portion of the diet (Bettinger 1991: 87; Bousman 1993: 61-62; Kaplan and Hill 1992: 171-172; Kelly 1995: 86ff; Winterhalder and Kennett 2006: 14-15).

4.2.1.2. Patch choice model

The diet breadth model is based on the premises that resources are homogeneously distributed, and that foragers search their environment randomly and encounter resources in direct proportion to their density in the environment. However, such premises are rarely the case with many situations. Spatial distributions of resources are usually patchy and not sequential. Foragers normally embark on foraging while bearing in mind a particular goal, which is based on their knowledge of the present climatic and environmental conditions and the likelihood of encountering resources, and hence rarely move

at random. Therefore, the patch choice model serves to model other situations.

The patch choice model deals with foraging in spatially heterogeneous environments where resources are found in clusters described as patches. Patches are isolated areas of resource exploiting opportunities on such a scale that foragers may encounter several to several dozen in a daily foraging trip. A matrix of resource abundance, temporal availability, and dispersion in space characterise the resource structure in patches. Resource abundance is often regarded as edible resource density, but the size and bulkiness of resources are also important for subsistence decision-making, because these can influence search costs and handling costs.

The patch choice model is similar to the diet breadth model in that patches are ranked from high to low in terms of a return per unit time like kCal/hr, and it is predicted which resource patches are more profitable than others and thus should be included in a foraging trip. The model assumes that foragers choose the highest return rate patches at a given moment on the basis of their knowledge. The model also assumes that the net return rate is the highest when foragers first enter a patch, but the net return rate diminishes as foraging time in a patch increases, because plants are harvested to depletion and game animals become wary of foragers' presence and disperse. Since a long stay at a patch incurs low net return rates, at some point the foragers have to move on to another patch which offers higher returns in order to maintain high return rates even though temporarily. However, since moving on to another patch takes much time and energy, the cost of moving and encountering another patch must be balanced against the benefit of continuing to exploit resources in the present patch. The marginal value theorem specifies that foragers should move out of a patch when the net return rate in the patch falls below the average rate obtainable in the entire environment, rather than when all resources in the patch are completely depleted. The patch choice model also presumes that foragers do not return to a patch until its diminished resources are recovered, and that travel time between

patches is non-productive. Therefore, as travel time between patches increases, then the time spent foraging in a patch may increase in order to offset the increased search costs. As patch density increases, resource return rates rise, because foragers spend less time moving between patches and more time exploiting resource patches during the initial period of patch use when return rates are at the highest (Bettinger 1991: 87-93; Bousman 1993: 61-62; Kaplan and Hill 1992: 178-184; Kelly 1995: 90ff; Winterhalder and Kennett 2006: 15-16).

4.2.2. Related concepts of optimal foraging models

As described above, a focus of optimal foraging models is the profitability of different resources and resource patches. However, the value of resources and resource patches is actually to a large extent affected and conditioned by various costs, constraints, and other considerations. Such affecting and conditioning factors are summarised below.

4.2.2.1. Time allocation

A central idea in optimal foraging models is time allocation. Since the time spent pursuing one resource prohibits searching for other resources simultaneously, there is a potential loss of time and energy entailed in choosing to pursue one resource when another resource offering a higher return rate may be available. The time spent for one resource exploitation is regarded as the cost of activity, or in other words, opportunity cost. The allocation of time and scheduling of activities are important concerns for foragers. Optimal allocation of time makes foragers stand on a continuum with maximising resource exploitation at one end and minimising the time spent for resource exploitation at the other. Resource maximising foragers attempt to obtain food resources at the highest rate at all costs, whereas time minimising foragers attempt to spend as little time as possible in an activity, while still getting necessary amount of food (Bousman 1993: 62ff; Hames 1992; Kelly 1995:

83).

Resource maximisation and time minimisation are strategies which provide solutions to different resource problems and scheduling problems. Although foraging is a means of enhancing fitness, this goal is also achieved by non-foraging activities like seeking mates and allies, protecting mates and offspring, and monitoring resources and potential allies. Therefore, foraging and non-foraging activities compete for time and energy, but it is possible that losses in foraging are offset by fitness gains in non-foraging. Consequently, it is assumed that where resources are abundant, foragers would not maximise resource exploitation but would instead increasingly minimise the time spent on foraging and would spend more time on non-foraging activities that enhance overall fitness. Conversely, as resources become scarce, foragers would tend to increase foraging time (Bettinger 2006: 312ff; Bousman 1993: 62ff).

4.2.2.2. Responses to risks

Resources are usually not constantly available, but fluctuate from season to season and from year to year, or due to occasional catastrophic climatic and environmental events. Unpredictable variations in ecological variables are defined as risks, and the probability of the loss or failure of resources is called economic risk. Resource fluctuations and scarcity are the most serious problems for foragers, and the variability and predictability of food resources are important considerations in foragers' optimal diet. As mentioned, the prey choice model addresses how foragers add a new resource to their diet, and this can be understood in terms of risk-sensitive behaviour or risk management. Food scarcity is determined by local conditions and is relative to need. If the resource procurement by a forager group meets their daily requirement and they would like to reduce the expected variation in returns, they would choose risk-averse behaviour and exploit less variable resources. However, during food shortages, they would choose risk-prone behaviour, and exploit resources and resource patches with greater

variability, because the chances of getting sufficient resources are greater than those which are less variable and do not provide the minimum requirement. In fluctuating situations, foragers can shift from a risk-prone strategy to a risk-averse strategy or vice versa, according to the availability of resources. Division of labour in a foraging group and direct resource sharing between different foraging groups would also enable the foragers to combine the risk-averse exploitation of predictable and less variable resources like plants and fish and the risk-prone exploitation of unpredictable and variable resources like terrestrial mammals and to make a balance between them (Bousman 1993: 64-65; Kaplan and Hill 1992: 187-188; Kelly 1995: 99-100).

Risk is not a simple variable, but different levels of risk are related to variations in the structure of resources and to the predictability of those resources. Resource predictability is determined by varying multiple interacting temporal and spatial cycles of resource availability. In other words, resource predictability consists of constancy and contingency. If a resource is constantly available in known amounts at certain locations throughout the year and year after year, this resource has an extreme amount of constancy. By contrast, if a resource is available at a certain location and in known amounts during a specific season but totally absent in other seasons, then that resource exhibits a high degree of contingency. In terms of the economic risks of foragers, resources may be low-risk even if their seasonal availability is very cyclical as long as they are highly predictable from year to year, but risks are much greater if resource availability is highly unpredictable. Individual resources and sets of resources can be measured for their consistency and contingency. When viewed as an optimal set, the whole of the resources exploited by foragers should exhibit a high degree of constancy with few gaps in availability throughout the year (Bousman 1993: 66-67).

Economic risks among foragers can be divided into different components, and adaptive responses or strategies would be different

depending on the nature of the risk. In other words, different strategies employed by an individual group of foragers should reflect the nature and structure of the socioecological risks that it encounters. For example, the locations of resource patches may change from season to season and from year to year, and this stimulates foragers to move their residential base between locations. Resource storage is also an important strategy employed by those who depend on highly contingent resources with seasonal variations and gaps in availability. Whereas mobility and storage are responses to resource fluctuations and hence passive strategies, other strategies are more oriented to prevent economic risk. Changes and improvements in hunting weapons or collecting tools, invention or introduction of transportation aides, better organisation of labour force for cooperative resource exploitation, information sharing and exchange with other groups all can help prevent economic risk. It can be said that risk prevention strategies are linked directly with variations in resource structure, whereas risk responsive strategies are mediated to a larger extent by social variables and hence would not be realised by an individual's effort only (Bousman 1993: 68-69).

4.2.2.3. Central place foraging and mobility strategies

Mobility is an essential component of optimal foraging, because searching for resources or resource patches and exploiting them are impossible without foragers' physical moves across the foraging area. Most foraging can be regarded as individual moves, whereas moves in a group are regarded as residential moves. Both types of moves are subject to cost-benefit considerations by the foragers.

When humans forage, they usually locate a sleeping or activity place which is used also by other members of a residential group in an attractive and comfortable area, and then start foraging in a radial pattern from the place and return to the place. Such a place is called a central place in optimal foraging models.

Central place foraging varies between a random search and encounter and a targeted search and pursuit, and most foraging situations can be viewed as a continuum between these two extremes. Although it is ideal to locate a central place at the point which minimises foraging travel time to all accessible resource locations in all directions, finding a safe place to set up a camp would occasionally be more important than simply minimising foraging travel time. In deserts, both residential and individual foraging moves are constrained by the distribution of water sources and the sources of other essential items like wood for fuel and toolmaking. Foraging efficiency could be sacrificed in favour of remaining close to a water source, and water-tethered people would exploit all available resources within a foraging radius of the water source and leave only when net foraging returns reach nearly zero (Cashdan 1992: 250; Kelly 1992: 46-48; 1995: 126-127).

The central place foraging model adds travel time to the overall cost of foraging. When there is no travel time, a resource that requires one hour foraging would be preferred to another resource of the same or slightly higher caloric return that requires two hour foraging. However, with two hours of travel time, the latter would be preferred due to higher caloric return per hour. In other cases, increasing travel time can make a resource of low caloric return near at hand more attractive than resources of high caloric return at a distance, and hence such resources at a distance would drop out of the diet (Bettinger 1991: 96-97; 2006: 317-318).

Furthermore, in addition to the cost of going from and returning to a central place, the cost of carrying resources that are exploited at a distant location back to a central place for consumption must be considered. Since carrying a bulk of resources may decrease or preclude the foragers' possibility or ability to exploit more resources when encountered during their return trip, central place foraging apparently affects the choice of, search for, and handling of resources. The central place foraging model has shown that as the distance from a central place to the locations of encounter decrease, the

diet breadth increases and includes both more and less profitable resources, whereas longer distances narrow the diet breadth. It has also been suggested that when travel cost is high relative to handling cost and the capacity of transport aids like bags limits the maximum load, foragers would choose the resources that provide the highest return rates per the transportable load rather than the most profitable resources. It has further been suggested that when the costs of transporting a procured resource to a central place are high, foragers would remove low-utility parts of the resource in the field rather than transport the bulky resource intact even if the removed parts have some utility (Bird and O'Connell 2006: 153-155; Kaplan and Hill 1992: 184-186; Kelly 1995: 133-135; Lupo 2006; Metcalfe and Barlow 1992; Winterhalder and Kennett 2006: 16-17).

When the costs of travelling long distances for foraging and transporting procured resources back to a central place do not meet the benefits of maintaining the central place at a particular location, or simply when foraging returns within a foraging radius of a central place fall below acceptable levels, foragers would consider the costs of breaking down the present central place, travelling, and setting up a new central place, and would decide to move the central place to another location which makes foraging more efficient and makes higher return rates possible. Unless the anticipated return rates of the next location minus the costs of moving is greater than the anticipated return rate of the present location, the foragers would remain at the present location and give up moving residentially. Therefore, sedentism emerges under a condition of local resource abundance in a context of regional scarcity (Kelly 1992: 46-48 and 51-54; 1995: 135ff, 152 and 160).

Foragers' mobility strategies can be viewed as a continuum between moving resources exploited at distant locations to stable residential bases and moving residential bases close to resource locations, or between individual move and group move. These two extreme ends of a continuum of moves are not mutually exclusive, and a reduction in movement

as a group generally requires increased movement as individuals. In other words, sedentism does not emerge as people move less and less until they do not move at all. Sedentism may not reduce mobility, and no society is wholly sedentary (Kelly 1992: 49-52; 1995: 132ff and 160). Moving resources to residential bases by individuals is called logistical mobility and moving residential bases by groups is called residential mobility. For a descriptive purpose, the people who principally adopt a logistical mobility strategy and make few residential moves have particularly been called collectors and have been distinguished from foragers who are defined as people often moving their residential bases (Binford 1980: 5-12).

As for the manifestation of mobility in the form of material remains, it has been argued through ethnoarchaeological studies that different types of sites would be generated in relation to either the forager type of mobility or the collector type of mobility (**Fig.4.2**). Foragers generate two types of site: the residential base and the location. The location is where resource procuring and processing tasks like plant harvesting and animal hunting/butchering take place, and people leave for the residential base after the completion of their tasks. Therefore, the visibility of locations depends on the use condition and use frequency of the locations. On the other hand, due to the logistical character of resource procurement, collectors generate three additional types of sites; the field camp, the station, and the cache. A field camp is a temporary operational centre where a task group sleeps, eats, and maintains itself while far away from the residential base. A station is where a special-purpose task group is localised when engaged in ambushing and watching. A cache is where the large bulk of resources and raw materials obtained through foraging is temporarily stored, before it is transported to the residential base or task location. Such field storage is done in regular facilities (Binford 1980: 5-12).

As for the different levels of mobility, the economic zonation around a residential base has been argued on the basis of ethnographic studies

(Fig.4.3). The immediate surroundings of a residential base should be called the play radius for the children who reside in the residential base. Beyond the play radius, there is the foraging radius, which rarely extends beyond 10 km of the residential base. This is the zone searched and exploited by task parties that leave the residential base and return in a single day. Beyond the foraging radius is the logistical radius. This zone is exploited by special task groups that stay away from the residential base at least one night before returning. Beyond the logistical range lies an area which people are generally familiar with and attempt to monitor and to keep informed about resource distributions and changes in abundance, though they may not exploit the area at the time of monitoring. This regularly monitored area is called the extended range. Beyond the logistical or extended zone, there is the visiting zone. This is the area contemporaneously occupied by relatives and exchange partners, and hence within the foraging or logistical radius of another residential group. Trade, mating, information exchange and aggression take place there between different individuals and groups. Exploitation of resources in such a zone is

generally dependent on establishing temporary residence at another people's place, and the visitors may participate in foraging by the host group (Binford 1982: 6-8; MacDonald and Hewlett 1999).

The difference in the frequency of residential moves between foragers and collectors is mainly related to the density and availability of resources in their respective environments. Three patterns of residential moves are recognised (Fig.4.4). Where resources are homogeneously distributed and the resources are abundant and available all the year around, a forager's residential mobility strategy would predominate, because it is most efficient to disperse and not to be tethered at one place for a long period. The residential move in the environment of very dense resource patches could be a half-radius continuous pattern, in which the residential base is continuously moved to the outer perimeter of the foraging radius previously covered with no development of a logistical zone. On the other hand, the residential move in the environment of relatively dense resource patches could be a complete-radius leapfrog pattern, in which the residential base is moved to a distant place but the logistical zones of each residential base partially overlap. Where

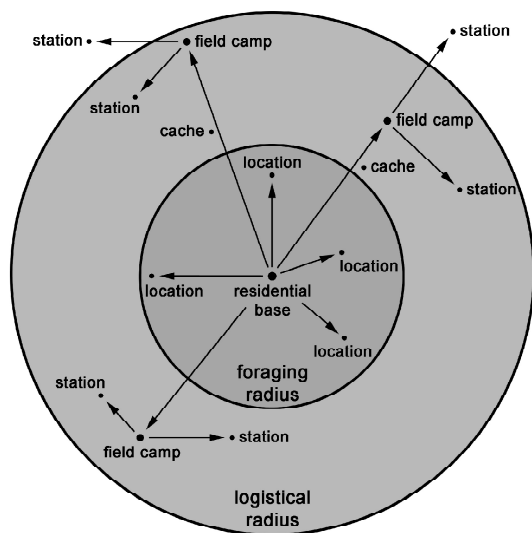


Fig.4.2. Manifestation of mobility in the form of different types of site

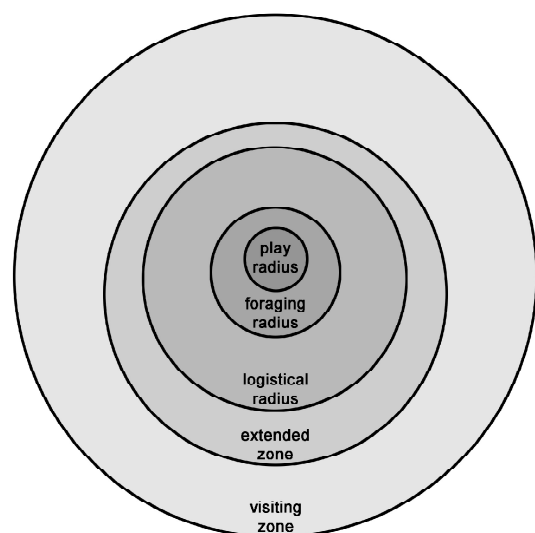


Fig.4.3. Economic zonation

resources are heterogeneously and patchily distributed and the resources are available only in specific periods of year, a collector's logistical mobility strategy would predominate, because it is most efficient to aggregate in a central place which is close to the primary resource location and to send out logistical task parties to the secondary and other lower-ranked resource locations. The residential move in the environment of sparse resource patches could be a point-to-point pattern, in which the residential base is moved to a fairly distant place with no overlap of the logistical zones of each residential base (Bettinger 2001: 154-156; Binford 1982: 8-11; Kelly 1995: 116-120).

4.2.2.4. Information acquisition and maintenance of kin networks

Optimal foraging models are based on assumptions that foragers always have good information about the distribution and yield of resources. However, the variability of foragers' diet is actually subject to the extent to which complete information regarding potential resources can be acquired. It has been known from ethnography that it is not uncommon for foragers to make information-acquiring or monitoring trips specifically to determine the location of resources or resource patches and when and where to move camp, and to travel very long distances. This kind of mobility has recently been termed informational mobility. Such non-foraging activities apparently diminish return rates at a given moment because other resource exploiting opportunities are precluded, but can provide information that ensures the procurement of resources later. In other words, information acquisition entails opportunity costs and may reduce short-term return rates, but provides benefits through increasing long-term return rates. Alternatively, such informational moves can be embedded in other kinds of moves, thereby reducing opportunity costs. It is difficult to assess how much effort made by foragers in information acquisition would be worthwhile, but it has been suggested that patchy environments which vary temporarily at an intermediate rate but in large scale should be where foragers expend the greatest effort in information acquisition (Kaplan and Hill 1992: 186-187; Kelly 1995: 97-98; Whallon 2006: 260-264).

Another non-foraging activity which often entails trips is visiting relatives and exchange partners in distant places. The trip itself is apparently non-productive, and hence it seems to diminish return rates at a given moment, because other resource exploiting opportunities are precluded. However, ethnographic studies have shown that foragers usually maintain a network of kin ties across wide regions and use a variety of mechanisms to reinforce reciprocity, and that the objective of visiting relatives and

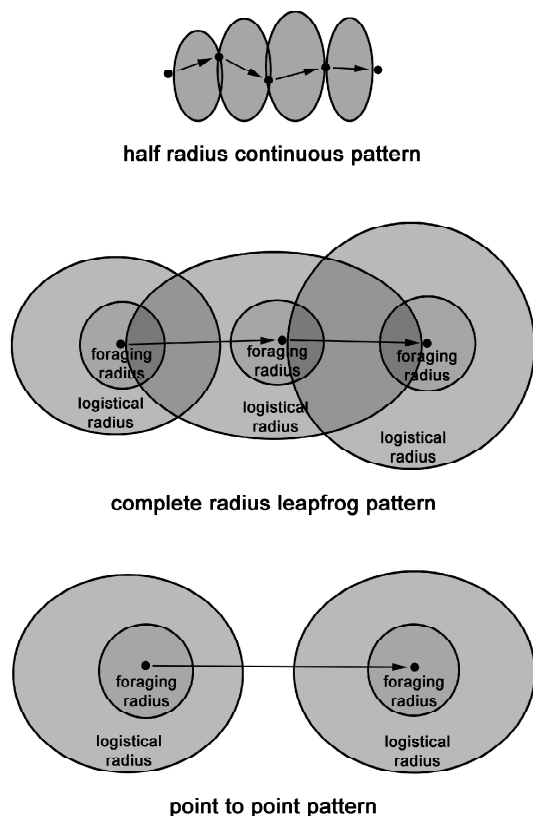


Fig.4.4. Different patterns of residential move

exchange partners in distant places is often to beg for food at times of local food shortages. This kind of mobility has recently been termed network mobility. Maintaining large kin networks and allowing mutual visits entail some opportunity costs on the visitor side and resource losses on the host side, but provide both sides with benefits in the long run, because the favour will be reciprocated when circumstances change. Moreover, visitors can benefit by learning about resource locations from the hosts, and both can benefit from sharing information and considering the others' foraging plans (Cashdan 1992: 248 and 255; Whallon 2006: 260-264).

4.2.2.5. Time investment in subsistence technology

Resource exploitation does not necessarily require special tools and facilities, but many human foraging activities need them. The diet breadth model has implicitly predicted that the changes in search and handling costs due to improvements of tools, facilities and vehicles would result in changes in diet breadth. New technological items which shorten the time for searching and handling high-ranked resources could increase foraging efficiency and return rate, and thus could decrease diet breadth while encouraging the foragers to ignore lower-ranked resources (Kelly 1995: 89).

An important point which must be stressed here is that subsistence technologies are not invariables. As foraging-related investment decisions like prey choice and patch choice vary with changes in the time available to forage and the nature of available resources, investment in subsistence technologies is also a decision variable. Technological decisions are motivated by the single important goal of improving return rates by reducing handling time, but there is always a trade-off in spending more time making a tool/facility in order to reduce the time spent for collecting/catching and processing a resource, or spending less or no time making a tool/facility while being satisfied with less efficient, time-consuming collecting/catching and processing the resource (Bright *et al.* 2002:

165-166; Ugan *et al.* 2003: 1315ff).

Following the idea of optimal allocation of time, it has already been suggested that foragers would switch either to maximising resource exploitation by means of productive but time-consuming technologies, or, to minimising the time spent for resource exploitation by means of less time-consuming technologies. Different technologies would be chosen on the basis of their time-efficiency and used for varying combinations of resource maximisation and time minimisation strategies. Accordingly, it has also been argued that exploitation of one resource or one patch would continue until the decline of a return rate reached the least time-efficient point. Below that point, particularly those who use time-consuming technologies should switch to another more productive resource or patch, or should change their technological strategies. However, those who employ less time-consuming technologies could continue to exploit the resource for a longer time after a return rate started to decline.

One implication for the interpretation of subsistence technologies in the archaeological record is that if handling costs are generally low due to less time-consuming technologies, the diet should be broader. In contrast, if more time-consuming technologies are employed and handling costs are high, then the diet should be narrower. Another implication is that foragers using time-consuming technologies would have needed to exploit resources whose return rates were high, although foragers exploiting high return rate resources would not necessarily employ time-consuming technologies (Bird and O'Connell 2006: 153; Bousman 1993: 63-64).

The tech investment model improves this intuitive argument and addresses the time trade-off in foraging more formally by formulating the relationship between time investments in technology and handling time. A forager's goal when making subsistence tools/facilities is to acquire resources in the most efficient way, either by maximising the calories gained in some fixed time or minimising the time required to meet a fixed caloric need. Both of these ways would be realised by maximising the net caloric return rate.

The time available to forage is fixed by constraints like resource availability, foraging schedule, or the use life of the tools/facilities. When the tools/facilities are tied to particular locations and thus immobile, foraging time would depend not only on the use life but also on the duration and redundancy of site occupation. Grinding stones, pottery vessels, hunting blinds and game drives are examples of such immobile tools/facilities.

The model assumes that total foraging time (total time available to forage) consists of search time, handling time, and the making and maintaining time of technology. The amount of time spent handling a resource in the absence of an associated technology is called the total handling time. A unit of time invested in tool/facility making and maintaining, which is called the tech time, cannot be invested simultaneously in another foraging-related activity such as searching for resources. The model also assumes that each resource has a unique piece of technology associated with it, and that there are no versatile tools/facilities. It further assumes that each unit of time invested in technology decreases the total handling time of a resource by an equal or larger amount, because it makes no sense to invest in a technology that increases handling time. The optimal amount of time to invest in tool/facility making is determined by such variables as the search time, encounter rate, and intrinsic handling time of a resource. Intrinsic handling times may vary with inherent abilities of foragers like physical size and strength or with the context in which resources are procured, and are thus the most difficult to measure (Bright *et al.* 2002: 167; Ugan *et al.* 2003: 1316ff).

A simple prediction of the model is that where technologies serve to reduce the effort spent handling resources, the time invested in technologies should increase with the total time spent handling a resource. Another prediction is that the increased emphasis on a particular resource should be accompanied by an increase of time investment in making tools/facilities which facilitate efficient exploitation of the resource through reducing either the processing

component or the collecting/catching component of handling time. Conversely, the decreased emphasis on other resources should be accompanied by a decrease of time investment in making tools/facilities for exploiting the resources. Such relationships between investments in technology and handling time in this model have an implication for the prey choice. Namely, the handling time and ranking of profitable resources depend on the efforts expended on subsistence technologies, and the efforts are subject to the amount of resources being handled. Thus, search time and encounter rates, which do not matter in the prey choice model, may become important components of prey choice decisions (Bright *et al.* 2002: 172-177; Ugan *et al.* 2003: 1321ff).

As has been known in ethnography, however, making and maintaining tools for foraging usually occur when the foragers stay at residential bases or field camps and not when they are on the move. Making and maintaining tools are possible while people are engaged in socialising activities like chatting, and in the evening when foraging is impractical. Therefore, the time trade-off assumption in the tech investment model has to take such non-foraging time into account. Nevertheless, foragers cannot make and maintain tools while sleeping, and thus the total time available to the foragers is certainly longer than the total foraging time but not infinitely long. Therefore, the time trade-off is still true in any case. Moreover, contrary to the model assumption, there are many subsistence technologies that are used to procure and handle more than one resource. The optimal time to invest in such a versatile technology would be subject to different encounter rates and intrinsic handling time of various resources, and thus would reflect the relative contributions of the various resources to the diet (Ugan *et al.* 2003: 1323-1324).

4.2.2.6. Foraging and technological organisation

Although the tech investment model assumes that foraging time depends on the use life of the tools/facilities, investments in making and maintaining tools/facilities can clearly affect the use life. Here is another trade-off of either making and maintaining an elaborate tool/facility that costs very much in terms of time and labour to procure and transport raw materials and to work on them meticulously but achieves the foraging goals without failure and/or lasts for a long period, or, making a crude, ephemeral tool/facility quickly by using readily-available raw materials and replacing it frequently or regularly by new ones. These technological trade-offs have been discussed as the expediency-curation alternatives in technological organisation and the reliability-maintainability alternatives in technological risk management (*e.g.*, Bamforth 1986; Bleed 1986; Parry and Kelly 1987), and also in terms of design theory (Hayden 1998: 3ff; Hayden *et al.* 1996).

The concepts of technological organisation and curation have gained popularity in archaeology since the rise of ethnoarchaeological studies in the 1970s (Odell 2001). Although not derived from optimal foraging models, the concepts of technological organisation and curation have a number of ideas in common with optimal foraging models. It has been understood that the designs of tools/facilities and the strategies for procuring raw materials, making, using, repairing/recycling and discarding/abandoning tools/facilities are considered and selected by makers/users depending on environmental, socioeconomic, technological, and task constraints (**Fig.4.5**). It has been emphasised that the sequence from raw material procurement to tool discard is closely related to and is particularly affected by the mobility of makers/users, and most arguments have centred on the difference between curated and expedient technologies in relation to the difference in mobility strategies. It has been argued that curated tools are made at residential bases in advance of expected tasks at distant locations, transported from location to location,

resharpened and used repeatedly, whereas expedient tools are made at task locations at the time of need, used and then discarded upon completion of the task. Such differences in technology have been explained in terms of the foragers' mobility patterns and access to raw materials, the transport costs which are measured by the weight of raw materials or tools, the utility which is defined by the potential of different raw material/tool forms to serve the arising needs, and the predictability and bulkiness of the resources which foragers exploited (Binford 1979; 1980; Kuhn 1994; Nelson 1991; Shott 1986).

The reliability-maintainability alternatives are important elements of design consideration and curation. Foragers who are characterised by a residential mobility strategy are concerned with the risk that tools may break very badly and cannot be used on the next occasion, especially while they are moving in an environment where lithic raw materials are not readily available. Hence tool maintainability is very important for them. In contrast, collectors who are characterised by a logistical mobility strategy are more concerned with the risk that tools may fail to serve expected tasks on specific occasions. Hence tool reliability as well as tool maintainability is critical. Therefore, highly specialised tools tend to develop among collectors in the context of logistical moves at the expense of maintainability or versatility (Bettinger 2001: 156-157; Bleed 1986; Torrence 1989).

4.2.2.7. Habitat selection and territoriality

The prey choice model and patch choice model simply assume that foragers can move from patch to patch in an infinitely large area and are free to move, but the mobility range of a forager group is usually limited not only by geographic barriers but also by the presence of competitors who do not welcome strangers. A habitat is a much larger unit than a patch and is defined by its aggregate resource base at a regional scale. Therefore, foragers reside in a habitat, make residential and logistical moves in the habitat,

4. EXPLANATORY AND PREDICTIVE MODELS FOR THE BEGINNING OF FARMING AND HERDING IN THE FAYUM

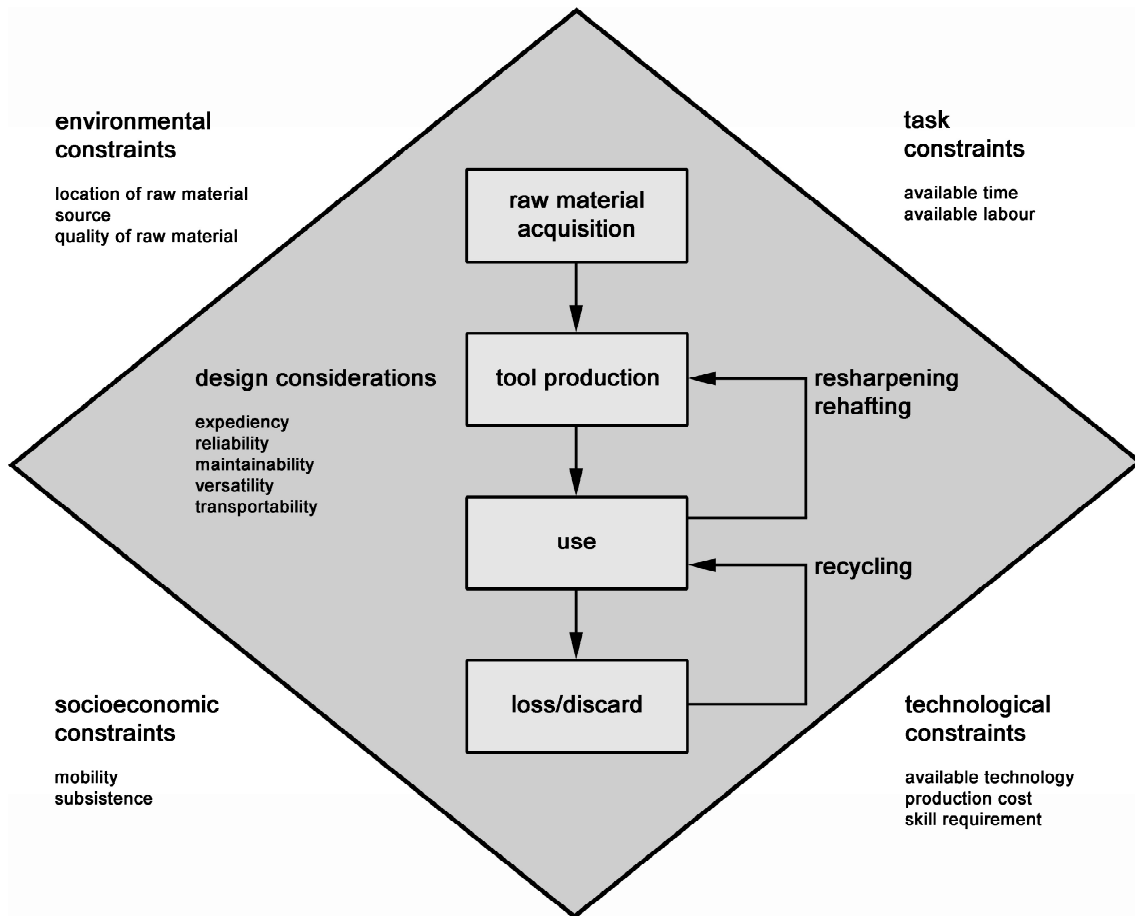


Fig.4.5. Technological organisation and various constraints

increase their population in the habitat, and migrate from a habitat to other habitats. The quality of a habitat depends not only on the abundance of resources but also on the density of the population that inhabit it and use the resources.

A significant question is what determines the size and location of residential groups. It has been known in ethnography that human foragers tend to live in large aggregated residential bases when they are exploiting highly-aggregated resources and to disperse into smaller groups when exploiting more solitary resources. It has been argued in other words that if the variance in total caloric returns between habitats was large, people should be aggregated in large groups at rich locations, but if the variance was small, people should be more

uniformly distributed in small groups. In addition to resource abundance, there are more circumstances to encourage people to aggregate, to the extent that co-residents increase the fitness of the entire group. Living in large aggregated residential bases has benefits such as enhanced reproductive opportunities, better predator avoidance, reduced risk of starvation due to food sharing, increased foraging efficiency through information sharing about resource locations, and cooperative group collecting and hunting that outweigh the costs of competition and increase return rates or success rates (Cashdan 1992: 249-252 and 255-256).

However, if a habitat is rich in resources but is crowded with too many people, a poorer but empty area may be more desirable. Declining foraging efficiency due to an imbalance between

population size and resource amount and increasing tension and fights between co-residents encourage the residential group to fission. After an optimal residential group size against the total amount of available resources is reached in a habitat and the habitat is no longer the most suitable and profitable in the region, then the second best habitat in the neighbourhood would be occupied. According to the ideal free distribution model, if future emigrants and immigrants who are all equal in competitive ability continue to select freely the best unoccupied habitat at the time of their fission or arrival, all occupied habitats would eventually become almost equal in profitability. On the other hand, the ideal despotic distribution model predicts that the best habitat would be occupied by people who are superior in competitive ability and would continue to be the best in profitability, and the residents of the best habitat would defend it against intruders from inferior habitats (Cashdan 1992: 252ff).

The difference between the ideal free distribution and ideal despotic distribution depends on whether the resources in given habitats are defendable, and whether the costs of defending the resources meet the benefits. An area which contains defendable resources and is defended against outsiders is defined as a territory. The major benefit of territorial defence is reducing competition for resources, but defending a territory entails costs in time and energy for monitoring and patrolling, and risks of being involved in fights against intruders. As the size of territory increases, the costs and risks of monitoring and patrolling increase and the benefits of exploiting more resources also increase as long as the resources are existent when needed and until the territory has more resources than the residents are capable of exploiting them efficiently. Therefore, territoriality would not be found where resources are mobile or transient but would be found only where critical resources are abundant, dense, predictable in time and space, and defendable. If a resource is so abundant that its availability or rate of capture is not limited to a population, there is no benefit to be gained by its defence

and hence territoriality is not expected to occur. An optimal territorial size is determined by the balance between the costs and benefits of defence as well as the balance between population size and resource abundance. Territoriality is also subject to the characteristics and behaviour of competitors outside one's territory, and the difference in the extent to which residents and intruders value access to the territory. The access to a territory by outsiders can be tolerated when they are relatives or reciprocal partners of the residents, or when the theft of some resources by outsiders does not significantly affect the foraging returns of the residents and the avoidance of fight over the resources is more beneficial (Cashdan 1992: 259-266; Dyson-Hudson and Smith 1978).

4.2.2.8. Traveller-processor model

The forager-collector distinction described earlier was developed to understand their response to environmental variations and the temporal and spatial distributions of resources. Resource shortages in given locations are caused by overexploitation and environmental fluctuations, and people respond to such resource shortages by mobility and storage. However, resource shortages are caused by imbalance between available amount of resources and increasing population that consume the resources. Whereas resource shortages due to environmental fluctuations are seasonal or temporal, resource shortages due to population growth are not temporal and hence are not easily mitigated. Furthermore, population increase reduces opportunities for both residential and logistical mobility because a given habitat is densely occupied. Therefore, population is an important variable when foragers' adaptation is considered.

Based on the premise that human population has an increasing tendency from low densities to high densities, the traveller-processor model modifies the forager-collector distinction through uniting the prey choice and patch choice models, in order to clarify how population increase and resource depletion affect the way

foragers allocate time, use a habitat, and acquire sufficient resources. When high-ranked, profitable resources are abundant and the population is small in a habitat, relatively more time is spent travelling between rich resource patches and searching for high-ranked, profitable resources within the patches, than is spent procuring and processing less profitable resources. As resources become locally scarce under these conditions, people move their residential base to richer patches. This is defined as the traveller strategy. Moving a residential base is less effective as more people compete for the same resources, because distant resource patches may already be occupied or their resources may be depleted. As an increasing population in a habitat reduces the advantages of moving residential base in the habitat, it makes foraging within a given patch increasingly less costly relative to other opportunities that require travelling. As a consequence, people should spend less time travelling between patches and expand patch choice to include low-ranked, less profitable patches where search cost and handling cost are higher. Furthermore, since more resources must be obtained in one large patch or a set of closely spaced patches, the diet breadth must expand to include lower-ranked, less profitable resources which require more handling time. Accordingly, less time is spent searching for high-ranked, profitable resources within the patch, and more time is spent procuring and processing low-ranked, less profitable resources. As these conditions grow more severely, logistical resource procurement becomes less economical, because resource procuring and processing are increasingly directed to low-ranked, less profitable resources. In the end, it becomes least costly to stay and consume resources within the patch despite their high handling cost. This is defined as the processor strategy (Bettinger 1991: 100-103; 2001: 164-166).

According to the model, the transition from the traveller to processor strategies is the transition from the time minimisation to resource maximisation strategies. Since resources are relatively abundant for travellers, they tend to

minimise the amount of time invested in subsistence activities and to devote more time to other social activities. However, when they are gradually pressed by increasing population density, they initially maintain existing patterns of resource use and patch use and intensify through time minimizing strategies like more specialised division of labour, logistical procurement, and making and using of more specialised tools in ways that waste raw materials but save time. When population densities rise further, it becomes difficult to procure resources logistically because free access to distant patches diminishes. Therefore, maximising resources that can be obtained from fixed amounts of space becomes far more critical than minimising time devoted to subsistence activities. Consequently, low-ranked, costly resources are added to the optimal diet and an overall increase follows in the size and elaboration of assemblages of tools that enable mass processing of the resources by the hands of many people (Bettinger 1991: 101; 2001: 166).

4.2.2.9. Showing-off behaviour and costly signalling

Whereas the value of a resource has been measured in terms of caloric returns in the prey choice model, it has increasingly been realised and emphasised that caloric returns are not the sole measure of resource value, because there are ethnographic observations of foragers' behaviour that deviates from the predictions of the prey choice model.

Ethnographic foragers sometimes ignore plant foods when the plants increase overall caloric return rates, but exploit animals even when the pursuit of the animals decreases foraging return rates. It has been widely known that foragers prefer and desire animal meat and highly value the act of hunting even though hunting frequently provides meagre returns and plant foods are very important in their diet. One reason why meat is highly preferred is because meat contains high quality protein and fat, which are essential nutrients and sources of energy for the human body. Foragers' obsessions with

animal meat and horticulturalists' special efforts to obtain meat by trade are well known in ethnography. Since fat is particularly valuable, animals that have little body fat are often considered as secondary resources or even famine food by ethnographic foragers. Another reason why animals are pursued at the expense of collecting plants is related to a gender-based division of labour. Even though men and women would do better by exploiting the same set of resources, in ethnography, men sometimes specialise on large game hunting and women specialise on plant collecting at the expense of increasing overall foraging efficiency. It can be said that since women are collecting carbohydrates, men may select resources for protein and fat rather than calories, thereby complementing food collected by women. It must be considered that foragers make trade-offs between carbohydrate, protein and fat acquisition (Kaplan and Hill 1992: 176; Kelly 1995: 101-107).

A further reason why protein/fat-rich animals are preferentially pursued by men foragers in spite of diminishing return rates may be because men can occasionally bring such a great nutritional and caloric package as large animal meat through risky hunting, thereby acquiring high status or prestige as excellent hunters and gaining great reproductive and social benefits. Hunters can signal through hunting physical quality such as strength, stamina, perception and risk taking, and cognitive skills involving the ecological and ethological knowledge needed to locate and capture game animals, as well as leadership skills including charisma and organisational abilities. The hunters who successfully exhibit their quality and skills acquire more and better mating opportunities and allies. Competitive display through hunting by men may play an important role in preferentially choosing the pursuit of animals. Such a showing-off behaviour in men's hunting has been commonly observed in ethnography and known to be quite unique to humans. Showing-off entails costs and risks, but it certainly brings benefits of increasing fitness in the social realm. Therefore, it is understood as

costly signalling (Bird and O'Connell 2006: 164-166; Hawkes and Bliege Bird 2002; Smith *et al.* 2003).

Seemingly wasteful and uneconomical farming activities of ethnographic foragers are also known. Among Melanesian societies, men often concentrate on growing a few yams which are as large as possible. Yams can become extremely large depending on the depth and quality of soil, but such large yams are woody and inedible. Men tend to devote time to taking care of yams in special gardens, and the yams are grown primarily for display at feasts, for gift giving, and for trade, whereas women plant yams for daily consumption. Since considerable time investment, skill and esoteric knowledge are needed for growing large yams, men gain through growing large yams not only a reputation as skilled and knowledgeable men but also much social attention and a measure of influence in public decision making processes (Bliege Bird and Smith 2005).

It can be concluded that the choice of which resources are exploited depends not only on their caloric returns and ecological constraints but also on risk and prestige associated with their capture and use. This conclusion lets the narrow economic concern of optimal foraging models turn to social issues like gender, prestige and power that structure and affect economic activities (Kelly 1995: 107-108; Winterhalder and Kennett 2006: 17-18). An interesting question is not whether men consistently favour costly signalling over maximisation of caloric return rates while foraging, but under what conditions men tend to prefer one or the other (Bird and O'Connell 2006: 166).

4.2.2.10. Reproductive interests

As already mentioned in the description of how foragers allocate their time to foraging and non-foraging activities, seeking mates as well as foraging food resources is vital for fertile adult individuals to reproduce themselves and to ensure the prosperity of their kin groups. According to a life-history model, individual life effort consists of somatic effort and reproductive

effort. Somatic effort refers to ensuring one's physical survival through securing shelter and protection from predators and obtaining food. Reproductive effort refers to getting one's copies into subsequent generations, and includes mating effort, parental effort and nepotistic effort. Therefore, the reproductive interests of foragers may affect the purely subsistence concerns of foraging activities, but may also be constrained by the spatial range and time allocation of foraging activities. In other words, there are trade-offs between somatic and reproductive efforts. However, there are no ethnographic data to show how and to what extent foragers' subsistence is influenced by their parental and nepotistic efforts.

A cross-cultural study has revealed that mating distances tend to be longer among mobile foragers whose population density is low and much shorter among sedentary horticulturalists whose population density is high, and that adult males tend to travel farther than adult females. However, it has seldom been made clear how these facts are linked to the reproductive interests of the people in question, because people travel for multiple reasons. On the other hand, some ethnographic data have shown that there is a significant relationship between foraging and mating ranges for males but not for females, and that young adult male foragers tend to travel farther and more frequently than females and other age groups. Evolutionary theory has also suggested that there is competition among men for mates and hence men tend to take risks in order to find and obtain mates. Therefore, it is argued that the foraging range of males is in part a function of their search for mates, though reproductive interests may not replace subsistence interests and may not constitute the prime mover of the travels. It is also argued that most individuals of foragers find mates in the logistical radius, but some other individuals of foragers with few close kinsmen are likely to travel long distances to the extended or visiting zone in order to find mates (MacDonald and Hewlett 1999).

4.3. SOME CONSIDERATIONS ON THE FAYUM DATA IN THE LIGHT OF OPTIMAL FORAGING MODELS

In the light of optimal foraging models and related concepts, it is necessary to re-evaluate the ecological and archaeological data of the Fayum. Firstly, it is possible to assess to some extent the relative value of food resources which were available or are supposed to have been available in the Fayum. However, it is very difficult to estimate encounter rates and the net return rates, because it is often unclear by what means and under what conditions a given resource was procured, and because modern experiments cannot replicate all the factors which must have affected foraging efficiency and foraging decisions in the past (Bettinger 1991: 103-104). Thus, the relative value of the Fayum food resources would be assessed mainly in terms of their nutrients and potential risk. In addition, it is worth reconsidering the mobility patterns of the Fayum inhabitants in terms of residential/logistical moves, emergent sedentism and territoriality. Moreover, lithic technological changes at the transition between the Fayum Epipalaeolithic and Neolithic should not necessarily be understood as the evidence of population replacement but could alternatively be considered as an indication of optimisation in technology.

4.3.1. Optimal diet of the Fayum inhabitants

Concerning plant foods in the Fayum, as described earlier, seeds and roots normally have lower return rates than small, medium or even large-sized animals due to high handling costs. Although not explicitly based on the diet breadth model, a cross-cultural, statistical study of the proportions of terrestrial animals, aquatic animals and plants in the diet of ethnographic foragers has found that the availability of aquatic resources is clearly of prime importance in determining the role of plants in the diet. The reliance on aquatic resources is negatively correlated with the reliance on plants, and where there are severe constraints on the availability of aquatic

resources, the proportion of plants is maximised accordingly (Keeley 1995; 1999). Therefore, no matter how abundant and how rich in carbohydrate the tubers of nutgrass and clubrush and the rhizomes of catstail and reed were in the Fayum, it may be that they were not usually or preferentially exploited because of time-consuming and labour-intensive peeling, grinding/pounding and grating in order to render them edible, especially when there were other sources of calorie or carbohydrate that provide higher returns.

The rarity of grinding stones at Epipalaeolithic sites in the Fayum stands in sharp contrast to the abundance of grinding stones at Late Palaeolithic sites in Wadi Kubbaniya, where tuber grinding/pounding by using grinding stones has been well attested (Hillman *et al.* 1989: 190-191). Hence the exploitation of tubers in the Fayum Epipalaeolithic is not certain, though reusing of Epipalaeolithic grinding stones by Neolithic people has been suggested (Wetterstrom 1993: 190). If the Fayum inhabitants had actually been accustomed to spend time and energy grinding/pounding tubers since the Epipalaeolithic, they would not have felt reluctant to adopt wheat and barley which also required grinding.

However, adding domesticated wheat and barley to the diet is not as simple as harvesting other previously-ignored wild plants. Wheat/barley farming certainly reduces search time within the total foraging time but instead requires investments of time and labour for sowing, weeding and protecting as well as threshing. In the light of cost-benefit considerations, the increase in handling costs and the risks of bad harvest due to droughts, pests and infectious diseases must be rewarded by the increase in yield, but the high crop yield requires extremely time-consuming and labour-intensive grain processing. In this sense, it can be said that domesticated wheat and barley were not very profitable initially, and it is probable that they were fairly low-ranked in the diet breadth.

The diet breadth model has suggested that the adoption of novel resources could be expected to occur under conditions of either

scarcity or abundance with different goals. In a resource-rich environment where high-ranked resources are abundant and a narrow diet maximises efficiency, a new resource is likely to replace one or more existing resources only if it is profitable. Also in a resource-rich environment where the required minimum return rate is much lower than the expected average and the minimisation of risks is a goal, the adoption of a new resource is less contingent on its profitability and should occur by addition rather than replacement. In a resource-poor environment where a narrow diet composed of high-quality resources minimises risks, a new resource should be ignored unless it is highly profitable. In a resource-poor environment where a broad diet maximises efficiency, a new resource is likely to be added even if it is of low quality (Gremillion 1996: 189 and 199-200).

Therefore, according to the diet breadth model, it is assumed that the initial adoption of domesticated wheat and barley in the Fayum Neolithic was intended either for replacement of more costly sources of carbohydrate or for substitution for some temporarily-unavailable sources of carbohydrate, thereby optimising the diet. Considering that no other possible sources of carbohydrate in the Fayum seem to be more costly than domesticated wheat and barley, it is most likely that when the Fayum people introduced wheat and barley, they were eager to minimise risk under a basically resource-rich condition while knowing that opportunity costs of farming were low. Alternatively, it is also probable that people were put in the situation where they had no other choice but to take such less profitable resources for survival. However, optimal allocation of time to producing wheat and barley would have remained low until its profitability was enhanced, and/or constraints on the benefits of additional time allocation were removed by technological innovations to reduce handling time. From a long-term perspective, it may be said that the introduction of domesticated wheat and barley was a moment to shift to a strategy that reduced the expected variation in returns, or a strategy that maximised the yield of less profitable resources.

Concerning the sources of protein and fat, wheat and barley provide some protein, and legumes like vetch could have provided rich protein if they had actually been harvested, but oily seeds like olives are not known in the prehistory of Egypt. Thus it is likely that protein and fat were obtained from animal and fish meat. In the Fayum, examples of resources with high measures of constancy include aquatic resources like fish and shellfish. Resources with high measures of contingency include migratory waterfowl. Resources with low predictability due to both low constancy and contingency include terrestrial mammals like gazelle. Therefore, as mentioned in Chapter 3, fish in general seem to have been the most reliable resource for the Fayum inhabitants throughout the Epipalaeolithic and Neolithic periods.

According to a comparison of nutritional returns from different fish species, catfish species offer substantially more fat returns than perch species (Gifford-Gonzalez *et al.* 1999: 407-408). If this was also the case with the Fayum ichthyofauna, clariid catfish could have been preferred to, and higher-ranked, than Nile perch. Given these assets of catfish, it may be assumed that catching deep water fish was fortuitous in nature during the two possible fishing seasons, and was supplementary in nature during low lake water. In addition, according to a comparison of nutritional returns from other aquatic resources, crocodile offers relatively high fat returns and far more calories per unit of flesh than turtle and fish like catfish and perch do (Gifford-Gonzalez *et al.* 1999: 407-408). Therefore, crocodile may have been the highest-ranked prey in the Fayum where all these aquatic resources were available to hunter-fishers.

Although the presence of small mammals like hares as potential food resources in the Fayum Epipalaeolithic and Neolithic diet should not be ignored, it is not certain whether such small mammals occupied a permanent position in the diet breadth of the Fayum inhabitants, firstly because small mammals are generally not rich in fat and hence are not preferred, and secondly because exploiting small mammals is usually not cost-efficient, as mentioned earlier. According

to a comparison of the amount of edible meat obtained from various Nilotic mammals on the premise that the percentage of edible meat is approximately 50 percent of live weight (Hassan 1974: 152-154 and table 44), whereas a hare weighing 1.5 kg provides only 0.75 kg meat, a dorcas gazelle weighing 22 kg provides 11 kg meat and a hartebeest weighing 165 kg provides 82.50 kg meat. An aurochs weighing 300 kg provides 150 kg meat, and a hippopotamus weighing 1500 kg provides 750 kg meat. As described in ethnography, the reward of successful hippopotamus hunting is extremely great, and its nutritional contribution eclipses those from all other taxa available in a lacustrine environment (Gifford-Gonzalez *et al.* 1999: 402). Therefore, it is reasonable to assume that small mammals may have been ignored no matter how often they were encountered around a camp, and that they may perhaps have been added to the diet only when other most commonly-hunted animals like dorcas gazelle and hartebeest were not readily available.

It is difficult to know whether the introduction of domesticated sheep and goats in the Fayum Neolithic was intended as substitution for some vanishing wild animals. However, adding domesticated sheep and goats to the diet is also not as simple as catching other usually-ignored wild animals. Sheep/goat herding certainly reduces search time within the total foraging time, but instead requires investments of time and labour for feeding and protecting. In the light of cost-benefit considerations, the increase in handling costs and the risks of loss due to disease or accidents must be rewarded by the increase in meat yield. In this sense, domesticated sheep and goats do not seem to be more profitable than other medium to small-sized wild animals.

As mentioned in Chapter 3, another notable change in the animal resource exploitation in the Fayum Neolithic is slightly more frequent exploitation of crocodile and hippopotamus. It can be said on these grounds that the Fayum Neolithic people attempted to ensure the procurement of protein and fat from animals other than dorcas gazelle and hartebeest, regardless of the advent of domesticated sheep

and goats. The reason for the introduction of domesticated sheep and goats may thus be not necessarily to obtain meat but to obtain nutrient-rich dairy products and wool/hair, which are definitely the additional and special value of these animals. However, since it was recently revealed that sheep and goats had actually been slaughtered at a young age at Kom K and Kom W (Van Neer and Linseele 2007), it must be assumed that obtaining meat was the primary reason for the adoption of sheep and goats by at least the inhabitants of Kom K and Kom W in the Fayum Neolithic. It may be considered that whereas sheep and goats have been kept for the stable supply of meat, hunting of crocodile and hippopotamus has developed as a kind of showing-off behaviour by male hunters who wanted to acquire prestige as brave hunters and good providers of meat.

The possible rank or position of wheat/barley and sheep/goat in the Fayum Neolithic diet in the light of the diet breadth model is illustrated in **Fig.4.6**.

4.3.2. Risk prevention/responsive strategies of the Fayum inhabitants

Given the difficulty of evaluating the value or asset of domesticates in terms of nutrition and handling costs, the study of the introduction of wheat/barley farming and sheep/goat herding in the Fayum Neolithic would have to consider how variations in resource structure occurred when they arrived in terms of risk prevention and risk responsive strategies of Fayum inhabitants. An asset of wheat and barley is apparently that they provide seeds which are storable for a longer period, and an asset of sheep and goats is also that fresh meat can be kept alive for a long period. If the Fayum Epipalaeolithic people had actually preserved and stored an excessive amount of fish and tubers for the consumption in lean seasons, it can be assumed that the subsequent Neolithic people enhanced such a risk responsive strategy and diversified the food storage by introducing wheat/barley and sheep/goats, because it is unclear whether fish and particularly tubers consequently dropped out of

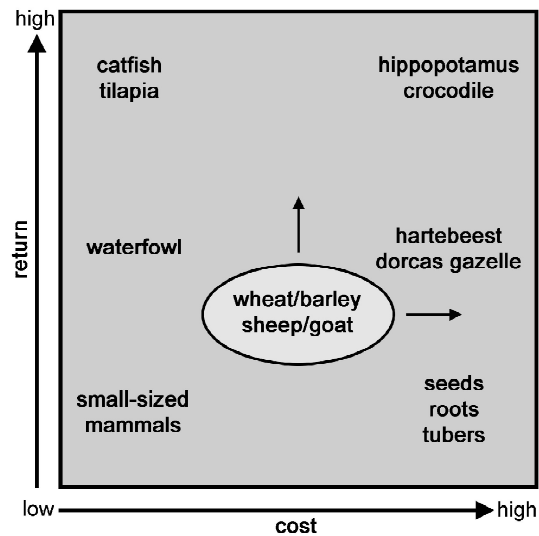


Fig.4.6. The possible rank or position of wheat/barley and sheep/goat in the Fayum Neolithic diet in the light of the diet breadth model

the stored food items.

On the other hand, the drawbacks of wheat/barley farming and sheep/goat herding are undoubtedly that people had to pay more attention to preventing risks of wasting their time and labour investment by losing or failing these resources due to droughts, pests and infectious diseases. Therefore, dividing the herds of sheep and goats and keeping them separately at different places, and sowing/planting wheat and barley at different places at different times, for instance, are necessary strategies to diversify investment risks and to average losses (Cashdan 1992: 247). Such strategies also make farming and herding quite costly.

The introduction of foreign domesticates must have made a new infector-infected relationship in the Fayum pathology and a new predator-prey relationship in the Fayum ecology, and the losses of the farming/herding yield could have been occasionally caused by infectious organisms and predators other than humans. The Fayum people may have seen their crops and herds killed by bacteria, fungi, viruses and predators in the early stage of adoption. It must have taken extra time for people to let the crops and herds gain resistance/immunity against

infectious organisms and to get rid of predators before making farming and herding a reliable subsistence. For instance, red fox, jackal and striped hyena could be predators of lambs and kids, though such predation has not been attested archaeologically. The interesting coincidence of the increase of crocodile and hippopotamus in the faunal assemblages with the beginning of wheat/barley farming and sheep/goat herding in the Fayum Neolithic may be explained from a viewpoint of risk prevention. That is, crocodile may have been hunted because crocodile attacks and eats almost any animals that come to take a drink at the edge of the water and hence was one of the dangerous predators of sheep and goats in the Fayum. Hippopotamus may have been hunted because hippopotamus was a voracious eater of grasses, devastating farmland which is supposed to have been near the lakeshore. Hunting hippopotamus not only for meat but also for protecting farmland has been argued on the basis of numerous hippopotamus bones at Neolithic sites of Merimde Beni Salama and El Omari (Boessneck and von den Driesch 1990: 100-101; von den Driesch and Boessneck 1985: 41), and this may also be the case in the Fayum.

4.3.3. The mobility and residential patterns of the Fayum inhabitants

It has been argued that the diet breadth of a group of people in the archaeological record can be an indicator of their occupation intensity of a locus or a resource patch (Stiner and Munro 2002). The intensity of the occupation of a locus or a patch is a combined function of the length of stay, the frequency of visits, and the size of inhabitant population at a locus or a patch per unit time. As any or all of these factors increase, the intensity of inhabitants' resource exploitation must also increase, and they have to include more lower-ranked resources in their diet in order to substitute for decreasing high-ranked resources. Therefore, it is assumed that high intensity occupations should create assemblages with high proportions of low-ranked resources whereas low intensity occupations should create

assemblages with high proportion of high-ranked resources. Following this assumption, it can be considered that most Fayum Epipalaeolithic and Neolithic sites which yielded faunal assemblages with high proportions of high-ranked prey like catfish and medium to large-sized mammals and with very low proportions of low-ranked prey like small mammals were not occupied intensively. However, such a consideration does not sufficiently explain the residential patterns of the Fayum inhabitants.

One problem of previous arguments about the residential patterns of the Fayum inhabitants is that the mobility patterns of the Fayum inhabitants have not explicitly been considered. As described earlier, mobility strategies for resource procurement can be chosen between moving residential bases to the resource locations and moving resources exploited at distant locations to stable residential bases, and mobility patterns can be viewed as a continuum between these two extreme strategies. There is little doubt that the Fayum inhabitants had to aggregate around the lake and pools fed by Nile floods in summer and rainfall in winter, in order to maintain a close link to drinking water. Therefore, a certain degree of water-tethered sedentary life should have been quite natural in the Fayum Epipalaeolithic and Neolithic. It is quite likely that the Fayum inhabitants first located their residential bases near water sources and then started foraging around residential bases, even though no substantial dwelling structures of the Epipalaeolithic and Neolithic periods have so far been found in the Fayum.

It is not easy to understand the occurrence, spatial scale, and frequency of the foraging, logistical, and residential moves by the Fayum Epipalaeolithic and Neolithic inhabitants through looking at the known archaeological sites on the north and southwest sides of the lake in the Fayum, because the contemporaneity of the sites is not always clear. However, the site distribution pattern seen in the archaeological record certainly shows a repetitive long-term pattern in the positioning of adaptive systems in a given geographic space by its inhabitants (Binford 1982: 6). Therefore, it is not irrelevant

to read site patterning which has been maintained for a length of time by referring to sound theoretical models. An important question is which location was favoured when a residential base was established. In the light of the central place foraging model (Bird and O'Connell 2006: 154), this question can be answered by (1) identifying the resources or resource patches potentially available to Fayum people, (2) isolating those which were most likely to be exploited, (3) plotting their distribution across the landscape, and then (4) determining which location maximised the flow of resources to the people on a daily basis. Alternatively, it is possible to assume intuitively that Fayum Epipalaeolithic people maintained large sites like Site E29H1 as a residential base and visited nearby locations in a radial pattern for procuring resources on a daily basis. Likewise, Fayum Neolithic people may have maintained large sites like Kom K, Kom W and Site E29G3 as residential bases and visited nearby locations in a radial pattern for procuring resources on a daily basis. It must be worthwhile to draw 1-10 km foraging radii around a possible residential base and to see which geographical features and resource localities are included in the radii. Such a spatial analysis may give a clue to better understand the mobility and residential patterns of the Fayum inhabitants.

Considering the very short distance between the known sites around each Basin and the short distance between the Basins on the northern shore, it can be speculated that the situation in the Fayum Neolithic as represented by some large sites with high artefact density like Kom K, Kom W and Site E29G3 and many small, supposedly temporary sites in their surroundings does not indicate frequent residential moves on a daily or weekly basis but suggests individual foraging moves from residential bases. The residential bases may have been moved depending not only on transgressing and regressing lake margins but also on the changing distribution and profitability of resource patches and the changing comfort of the bases on a seasonal and annual basis. As mentioned in Chapter 3, previous researchers have described

that three different types of Fayum Neolithic sites might represent different subsistence activities and different durations of stay (Kozłowski and Ginter 1989: 177; Wetterstrom 1993: 209-210). However, this description lacks an explanation of mobility patterns in relation to a principal residential pattern, which must be subject to the availability of resources and desirable localities for farming and herding. Likewise, the situation in the Fayum Epipalaeolithic as represented by some large sites like Site E29H1 and other small, supposedly ephemeral sites in their surroundings may also not indicate frequent residential moves on a daily or weekly basis but suggest individual foraging moves from residential bases. The residential bases may have been moved for the same reasons. Previous researchers' descriptions that all Fayum Epipalaeolithic sites were the remains of occasional or seasonal encampments (Hassan 1986b: 496; Wetterstrom 1993: 187) are rather simplistic.

Moreover, the occurrence of either logistical moves or long distance residential moves can surely be detected by focusing on the presence of locally-unavailable material items. As mentioned in Chapter 3, long distance moves of Fayum Epipalaeolithic people to Gebel Qatrani for lithic raw material and to the Nile Valley for some seasonally-available resources have been suggested (Wendorf and Schild 1976: 311 and 317; Wetterstrom 1993: 191), with a connotation that the former was a logistical move whereas the latter was a seasonal residential move. However, this suggestion has not been substantiated. In contrast, there is clear evidence for very long distance moves of people, such as the presence of non-local material items at Neolithic sites. The spatial scale of their moves ranges from at least 10 km to more than 100 km. The non-local material items could arrive in the Fayum either through return trip by the Fayum inhabitants or through outsiders' visit to the Fayum. Therefore, it is necessary to elucidate whether the transport of non-local material items to the Fayum Neolithic habitat was likely to be realised by logistical moves by individuals, residential moves in groups, or outsiders' visit in individuals or in groups, through studying the

4. EXPLANATORY AND PREDICTIVE MODELS FOR THE BEGINNING OF FARMING AND HERDING IN THE FAYUM

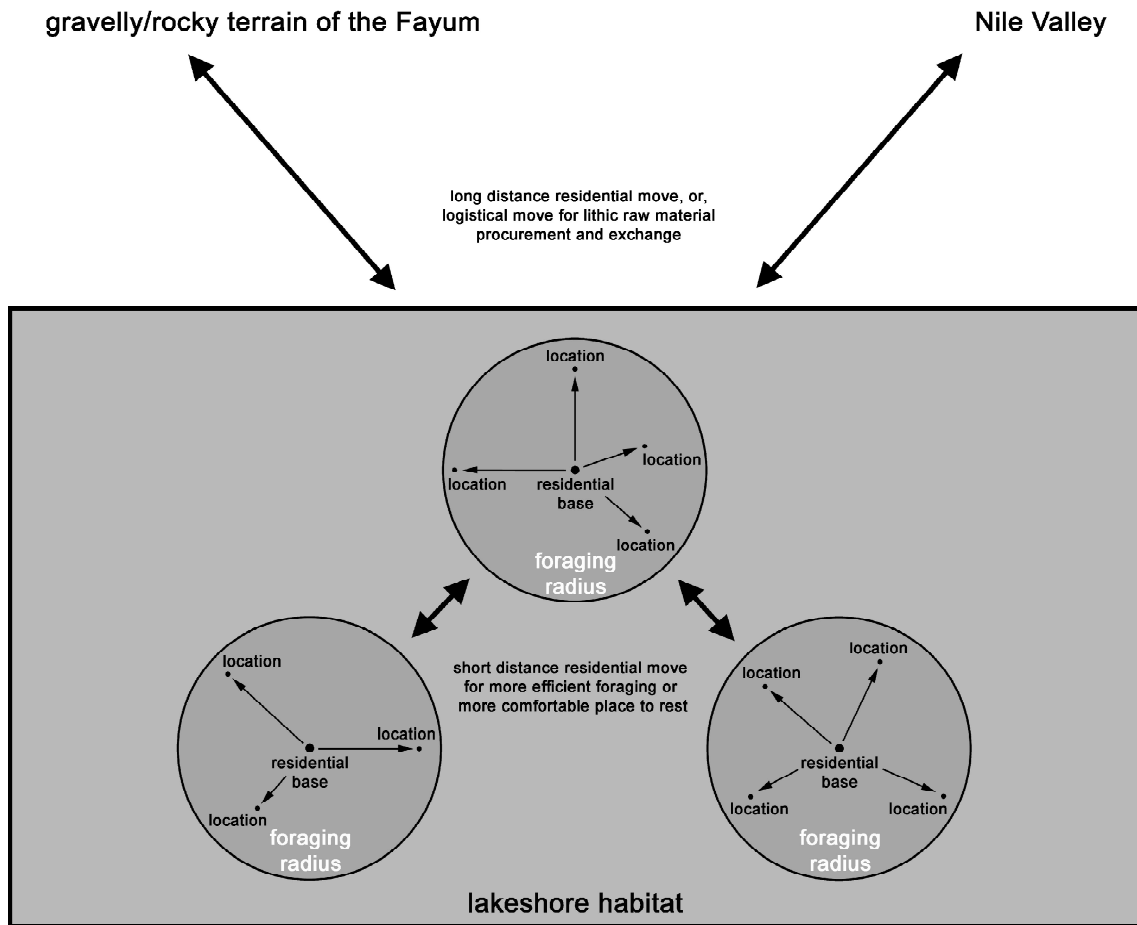


Fig.4.7. The possible mobility patterns of the Fayum inhabitants

non-local material items. Such a study may give a further clue for understanding the mobility patterns of the Fayum Neolithic people.

The possible mobility patterns of the Fayum inhabitants are illustrated in **Fig.4.7**.

4.3.4. Habitat selection and territoriality of the Fayum inhabitants

Although many prehistoric sites found to date in the Fayum show the traces of overlapping occupations by Epipalaeolithic and Neolithic people, there seems to be an increase in the number of occupation sites in the Neolithic period. Thus it is possible to assume that population in the Fayum was gradually growing, or grew suddenly due to the inflow of new

populations from outside the Fayum caused by the desiccation of the Western Desert around the onset of the Middle Holocene.

If more strangers aggregated around a large body of water in the Fayum perennially or seasonally, the right to critical resources may have become more specific and rigid, and the notion of territoriality may perhaps have been generated. It is uncertain which resources were actually defensible, and how large an area could be recognised as one territory owned by one band of foragers in the Fayum, but patches of dense and predictable resources like good fisheries and natural stands of edible marsh plants could be defended against strangers. In such circumstances, freedom of foraging activities elsewhere must have become gradually

hampered, even though the right to visit each other's territory were ensured by socioeconomic ties like marriage and reciprocity, and permission to enter other's territory would not be refused. Consequently, stressful situations within and between territories must have occasionally occurred. In the case of the Fayum, annual and long-term fluctuations of lake level and the subsequent appearance and disappearance of edible plant stands could be another cause of such stressful situations.

As described in Chapter 2 and also suggested by the traveller-processor model, in such circumstances, much labour may have become increasingly invested to ensure sufficient yield from one's own territory and to increase the storage of the harvest, because it was burdensome to visit and exploit another's territory. Such an intensification of food procurement in circumscribed habitats has the potential to lead to the beginning of food production and sedentism, especially if predictable, relocatable and tameable food resources are available and if technological innovations which would permit efficient utilisation of the resources arise. It is important to assume such a situation as a reason for the introduction of farming and herding in the Fayum.

4.3.5. Changes in subsistence technology at the Fayum Epipalaeolithic-Neolithic transition

Given that technological decisions are motivated by the single goal of improving return rates by reducing handling time, lithic technological changes at the transition between the Fayum Epipalaeolithic and Neolithic may be understood not only as changes in raw material availability, mobility, and gender roles, for instance, but also as the shifting focus on resources and resultant change in time invested to handle the resources. As described in Chapter 3, the most obvious change in lithic technology in the Fayum is the shift from the microlithic industry in the Epipalaeolithic to the retouched flake industry in the Neolithic.

The increasing predominance of microlithic

artefacts during the Late-Terminal Pleistocene and Early Holocene, which is called microlithisation, and the deviation from this tendency after the Early Holocene are global phenomena (Kuhn and Elston 2002). Lithic industries of North Africa have also been dominated by backed bladelets through the Late Pleistocene and Early Holocene. Backed bladelets appeared suddenly out of nowhere all across North Africa from Morocco to Egypt about 21000-22000 years ago, and endured for at least ten thousand years (Close 2002a: 31-34). It has been argued that decreased seasonality under glacial conditions and low human population density allowed foragers to minimise the time spent on foraging and toolmaking and to be satisfied with expedient, simple microliths for composite tools, whereas increased seasonality and human population density after the Early Holocene forced foragers to maximise the exploitation of seasonally-abundant resources and costly resources either by more time-saving, expendable tools/facilities or by more specialised tools/facilities (Bettinger 2001: 158-166). This argument must generally be the case with the Fayum.

The idea of risk prevention must also have played a role in developing new technologies to handle resources. In this case, avoiding or reducing the risk of failure at the time of tool/facility using activity was the motive to invest time and energy to make specialised, reliable tools/facilities. There is little doubt that more frequent exploitation of crocodile and hippopotamus in the Fayum Neolithic was not made possible without lowering the high risk of exploiting these aggressive animals. The high nutritional value of crocodile and hippopotamus may perhaps have already been recognised by the Fayum inhabitants through scavenging their carcasses fortuitously, but it is probably not until innovations in hunting tactics and technologies occurred that the Fayum hunters could exploit these most profitable animals whenever encountered alive on the lakeshore. Such innovations may include not only more tactical hunting by a group rather than an individual but also hunting weapons which have better killing

power. This topic will be discussed further in Chapter 7.

4.4. SOCIOECONOMIC MODEL

As exemplified by men's showing-off behaviour mentioned earlier, foragers' behaviours cannot always be explained in terms of the optimisation of diet. Considering that increasing fitness is the ultimate biological goal of life, it is understandable that social interaction between individuals and between groups through food resources may play an important role in achieving reproductive success. Apart from anthropological studies that particularly focus on foragers living in harmony with nature and optimising their diet by various adaptive strategies, it has been gradually recognised that some ethnographic forager groups around the world have developed complex societies characterised by sedentary settlements with food storage facilities, a large number of people, the presence of social ranks and outstanding leaders, and the occurrence of lavish feasts. Such seemingly extraordinary examples have drawn special attentions from anthropologists, and have been classified as a distinctive type of society through the studies on the background of the emergence of such phenomena.

4.4.1. The socioeconomic competition model

According to Hayden, who studied many ethnographic examples (Hayden 1995b; 2001), socioeconomic equality and reciprocity tend to be dominant in regions where wild food resources are generally poor. Conversely, socioeconomic competition using food resources tends to occur in regions where wild food resources are abundant. In such regions, ambitious individuals acquire control of food resources, creating reciprocal relationships with others, and eventually generate debt relationships with members of the community. Any ethic of sharing and equality is weakened and status quests through food provisioning do not need to be repressed. Ambitious individuals may distribute food generously and

competitively on occasions such as feasts, thereby raising their status. Such an act facilitates the ambitious individuals to find mates and allies. Recipients become indebted to providers such that they become subordinate to the providers, and this leads to the emergence of fixed socioeconomic inequality.

An implication of such anthropological observations for the study of social developments in prehistory is that only in such complex, trans-egalitarian forager societies, emerging socioeconomic competition between ambitious individuals could drive them to gain exclusive control of rich wild food resources and give them motives to start food production, either by domestication of indigenous plants and animals or by adoption of domesticates from others. In other words, ambitious leaders in societies would have been competitively willing to adopt novel things in order to interest their followers, to check their rivals and eventually to consolidate their positions, and such leaders would also have first adopted domesticates in order to please people by serving a large amount of crops, meat and dairy products on occasions such as feasts, rather than to compensate for the shortage of food provided by foraging. This argument has been formulated as the socioeconomic competition model for the beginning of food production (Hayden 1990; 1992). It must be noted that although this model has developed through cross-cultural anthropological observations, its theoretical basis is actually very close to the idea of costly signalling in human behavioural ecology described earlier (Bliege Bird and Smith 2005; Bird and O'Connell 2006: 167-168).

What is new about this socioeconomic competition model for the study of the beginning of food production is that it pays explicit attention to the motives of foragers to attempt farming and herding for acquiring prestige and high social status through the distribution of the farming and herding products as luxury or costly foods. Another notable thing is that this model is claimed to be applicable to most cases of the beginning of food production around the world. However, it has been pointed out that in many

cases in world prehistory initial attempts of food production actually began long before ample evidence of population increase and social complexity appeared in the archaeological record. Therefore, the socioeconomic competition model might be applicable to the later stages of social development, and would better explain the intensification of food production or initial adoption of food production as a coherent system from others (Bettinger 2006: 309-310; Keeley 1995: 268ff; Winterhalder and Kennett 2006: 6-7).

An important question is under what conditions costly and status-related food production and distribution may be expected to develop. Most scholars concur with the assertion that a baseline of richness in wild food resources is essential for the concentration of population which is associated with increasing social complexity. However, controversy remains whether constant rich conditions or occasional stressful conditions provided the primary stimulus for socioeconomic competition and the emergence of ambitious food providers. Based on the assumption that there must have been periods when overall resource richness was occasionally diminished by temporary climatic or environmental events, some have asserted that such periods were never times of emerging socioeconomic competition. Others have been of the opinion that such periods were precisely the times that inequality increased and consequently certain members of society were able to stimulate the reorganisation of labour (Arnold 1993: 82-89; Arnold 1996: 96-101). Although it is difficult to determine which conditions may have indeed prompted the socioeconomic competition, it is possible that climatic fluctuations under generally mild Early-Middle Holocene conditions may have occasionally provided certain persons in societies with opportunities to reorganise subsistence, and eventually, ambitious and competitive persons who were willing to display their status appeared.

4.4.2. The social meaning of technology and the emergence of prestige technologies

As described earlier, the study of subsistence technologies has been preoccupied with the idea of optimal technological organisation that was subject to environmental, economic and social variables, and the mobility of tool/facility makers/users has been regarded as the most important factor to determine the choice of technology and design. However, there is a growing interest in the anthropology of technology within archaeology. Ideas obtained from anthropology have illuminated the study of cognitive and behavioural processes of tool/facility making and their social contexts (*e.g.*, Lemonnier 1992; Pfaffenberger 1992). Anthropologists have advocated that technological activities are a fundamental medium through which social relationships, power structures, world views and other social productions are represented and defined. They have focused on the role of agents in the continuity and transformation of social structures which enabled and constrained individual actions. Consequently, a number of archaeologists have begun to highlight human agency in technological activities and to discuss how technology was structured within culturally and historically specific contexts of dynamic social interaction and meaning-making. Thus, it is stressed that the goal of technological studies is not only to describe tool/facility using activities in the past, but also to understand these activities in relation to social processes involving individuals and groups (*e.g.*, Dobres and Hoffman 1994: 211-235; Hegmon 1998: 264-271; Sinclair 1990; 1995; 2000).

An interesting archaeological and ethnographic observation is that technological advances like pottery production and metal working have occurred first in the non-subsistence realm among complex, trans-egalitarian forager societies that resided in resource-rich environments, and later evolved into more practical, subsistence applications. Another observation in such societies is that inherently practical tools have sometimes been

made in so elaborate forms that they seemed to lose their utility in the realm of subsistence activities. Thus the presence of outstanding persons who used novel technologies for non-subsistence goals has been argued for the technological advances. Following a recent trend of technological studies, it has been proposed that the technologies for showing-off or status display should be defined as prestige technologies and should be separated from practical technologies (Hayden 1998; 2001). Furthermore, such technologies can also be considered as a sort of costly signalling (Bird and O'Connell 2006: 163-164; Bliege Bird and Smith 2005). It can be said on the ground of the latter observation that competition for prestige or high social status would be represented not only by acts controlling food resources like domestication and generous distribution but also by the technologies that do not necessarily enable efficient foraging but rather impress other people by the visible elaborateness and make them want to possess such items, thereby creating reciprocal or debt relationships with others, and eventually enhancing fitness in an evolutionary sense.

Even in socially and technologically less complex forager societies, similar things would have occurred in the realm of seemingly practical technology. Toolmakers usually determine the form of their tools for daily use by closely imitating the ways in which their parents and close relatives make them, but individual needs also lead to new forms of tool (Hitchcock and Bleed 1997: 350). Therefore, variation in the form of tool derives from necessity as well as convention. Such convention has often been called 'style' in archaeology, and the conception of style has been one of critical issues for understanding past human behaviour (*e.g.*, David and Kramer 2001: 168-224; Hegmon 1998; Thomas 1999). Wiessner (1983), discussing how variation in the form of material culture carries with it a message concerning the identity of a certain person or group, termed the variation to be style, and subdivided style into the emblematic style and the assertive style. The emblematic style carries a message of conscious affiliation to or identity with a certain group and

would likely appear in a limited area when the solidarity of a group must be emphasized. On the other hand, the assertive style carries the message that the maker or owner is different from others and that the maker or owner is concerned with new things beyond his or her descent group or ethnic group. Such styles would likely appear randomly and change quickly. Style does not always appear in every material culture but is likely to appear in artefacts which are difficult to manufacture, used for a long time, and exposed to the public.

Archaeologists have accepted that styles in archaeological material culture could carry information about the identity of individuals or groups while marking the division of age and/or gender groups, the social stratification within a group, or the social boundaries between groups. They have also understood that style did not simply carry information about personal or group identity but also functioned as an active tool used in social strategies. Therefore, in addition to taking into consideration the shape or decoration of artefacts, a crucial question deals with the circumstances under which artefacts were made and used in such social strategies (Lemonnier 1992: 91-103).

As an interesting example of the recognition of artefact style, ethnological research on the Kalahari Bushmen has revealed that they used the projectile points of a common style in a band cluster and regarded the projectile points which were made by unknown person but shared the common style with theirs as the products of affiliated people while they regarded the projectile points which did not share the common style as made by alien and felt uneasy if they encountered a dead animal with such strange projectile points in their own area. Furthermore, it was also revealed that projectile points were frequently exchanged in the circle of a band cluster, sometimes travelling over 100 km, in order to solidify socioeconomic ties between bands so that stylistic variation in projectile points became apparent between language groups. It was concluded that the mixing and blending of styles in border areas would be minimal in spite of frequent interaction, and that

the mixing of styles would simply result from wounded animals crossing the border and dying in another area (Wiessner 1983: 259-269).

Such an example can be used to help an interpretation of archaeological data. The Ceramic Late Stone Age culture in Ghana is known to have a very small number of bifacially-retouched formal projectile points among basically expedient tool assemblages. It is interpreted that the bifacially-retouched formal projectile points may probably have been made by male hunters who had sometimes gone out of their own territory. The hunters may have encoded some messages regarding their personal and group identity in the uniquely-made projectile points, expecting that people living in neighbouring territories would happen to pick up stray projectile points on the ground and know about the presence of neighbours. In a sense, widely-distributed and visible items like projectile points would have functioned as business cards and occasionally claimed territorial expansion (Casey 1998).

Another ethnographic example relating to the social significance of technology demonstrates that when Inuit hunters carve 'tourist art', they try to embody boldness, perseverance and exactitude in their carvings. The choice of a complicated design means boldness, while the care which carvers take in rendering the carvings stresses exactitude and the hardness of the stone material emphasises perseverance. The reason why they engage in such craft activities is that showing these qualities is considered to be important for the success of an Inuit hunter, and indeed, the Inuit hunters attain personal status through possession of these qualities (Sinclair 1990: 77; 1995: 58; 2000: 205).

This Inuit example of the relationship between practical activities and social qualities has been considered in the interpretation of bifacial lithic technology in Upper Palaeolithic Europe. Based on the fact that elaborate Solutrean bifacial stone tools are exclusively associated with hunting and butchering, it is argued that personal qualities, such as carefulness, perseverance and exactitude, were

important for both successful hunting and successful bifacial tool making so that a correspondence may have been created between similar skills exercised in different activities. Consequently, those tools became not only utilitarian objects but also symbolic items which communicated meanings about both the nature of the tasks for which they were used and the persons who undertook the tasks. The reason why symbolic meanings were explicitly given to bifacial stone tools would be because people were living in the severe environment of the Last Glacial Maximum, where personal qualities such as carefulness, perseverance and exactitude displayed in hunting were very much appreciated (Sinclair 1995; 2000). It has also been argued that the reason why anatomically pre-modern Acheulian hominids made fine symmetrical handaxes would be because of attracting mates by showing their ability to make high quality tools and proving themselves intelligent and physically healthy. They were living in large, complex and competitive societies in which sexual selection pressures and inter-male competition for mates were intense. Therefore, handaxes would have played an important role in the social realm as well (Kohn and Mithen 1999).

Ethnological research has found more reasons why toolmakers were enthusiastic about acquiring good appreciation. The Kalahari Bushmen greatly enjoy discussing their arrows and evaluating the makers. Skilled arrow makers, who are admired as 'professionals' by members of the community, express pride in their abilities. They tend to be much more enthusiastic than other community members in discussing the details of their craft not in terms of the making of specific shapes but in terms of precision and quality within a common style. The skilled arrow makers are not necessarily the best hunters. The reason why they are very much concerned with arrow making is because excellent arrow makers either receive a large portion of meat procured by bow hunters or are responsible for the distribution of the meat. The arrows are widely exchanged in order to fill the need of meat sharing and to solidify socioeconomic ties

(Wiessner 1983). The food quest can provide not only hunters but also toolmakers with great opportunities to raise their status through procuring and distributing food (Wiessner 1996). In this sense, it is no wonder that bifacial technology was applied to butchering tools like large knives in the Solutrean as mentioned above, because butchering was another important concern of ambitious food providers. Butchering knives are quite visible to many people waiting for the distribution of meat, and hence some symbolic meanings are likely to be given to the knives.

All of these examples strongly suggest that innovations in seemingly practical technology do not necessarily appear as a consequence of gradual technological developments but are closely related to socioeconomic circumstances. In other words, innovations in seemingly practical technology may reflect changing socioeconomic circumstances. Furthermore, it can also be suggested that differences in the extent of time/energy investment in the technologies for showing-off or status display in different places and time periods may reflect differences in the intensity of interpersonal and intergroup competition as a function of differences in population density. The appearance and development of symbolic items may be driven not only by an increase in human cognitive capability but by increases in human population density and competition. The absence of the technologies for showing-off or status display in certain places and time periods may be related to demography rather than the cognitive or behavioural capabilities of people (Bird and O'Connell 2006: 164). These suggestions are important when technological developments in the period of the adoption of farming and herding in Egypt are studied.

4.5. SOME CONSIDERATIONS ON THE FAYUM DATA IN THE LIGHT OF THE SOCIOECONOMIC MODEL

Despite apparent problems in its applicability to the cases of the initial attempts of domestication, the socioeconomic competition model certainly gives some interesting

assumptions which can be tested using archaeological data. An assumption of the model that an environment with rich wild food resources is definitely a precondition for the emergence of complex, trans-egalitarian forager societies and the subsequent beginning of food production, may be applicable to regions like the Fayum. It is significant to examine whether the beginning of food production in the Fayum can be better explained by using this model as well as optimal foraging models. A problem here is how the presence of complex, trans-egalitarian forager societies is reflected in the archaeological record. Many material features of such societies listed by the proponent of the socioeconomic model, such as cult-related objects, ritual or feasting facilities, elaborate burials and violent deaths (Hayden 1995b: table 1 and fig.6; 2001: fig.7.10), did not exist, or have not yet been found in the Fayum. On this basis, it is very difficult to say that domesticates were adopted in the Fayum in order to serve at feasts. The reinterpretation of old data and the discovery of new evidence in the field are vital.

Regarding prestige technologies, as mentioned in the preceding chapters, it has been observed that decorative elements were generally quite few in the material cultures in Egypt before the Predynastic period. The material cultures of Epipalaeolithic and Neolithic Fayum are not exceptional in terms of their general crudeness. Therefore, it is difficult to find items which may represent some social meanings in the Fayum. Nevertheless, it is significant to keep such a perspective in mind when subtle changes or variations in supposedly practical technologies are studied. In the following, in order to understand the changes and variations in subsistence technology at the Fayum Epipalaeolithic-Neolithic transition from this perspective in a wider geographical and chronological context, the environmental and socioeconomic circumstances in the Egyptian Western Desert in the Early-Middle Holocene, which have been described in Chapter 2, will be reinvestigated with special reference to lithic technology.

4.5.1. Bifacial lithic technology in the Western Desert in the Early-Middle Holocene

A curious thing about microlithisation in North Africa is that although there were some interregional variations, the basic form of backed bladelets was so standardised across the continent and millennia, irrespective of the availability and variability of raw materials and the purposes of use. Therefore, one is even tempted to assume some social factors behind this extreme consistency of backed bladelet (Close 2002a: 38-39). Given this historical and geographical background, a question arises as to why the toolmakers in Egypt in the Early-Middle Holocene gave up their obsession with backed bladelets and started to make a variety of bifacially-retouched stone tools.

As far as we know, the earliest bifacially-retouched formal projectile points appeared in regions such as Dakhleh Oasis, Abu Tartur, Djara and Farafra Oasis after 6500 cal.BC (Barich and Lucarini 2002; 2005; Bubenzer *et al.* 2007; Gehlen *et al.* 2002; Hassan *et al.* 2001; Kindermann 2002; 2003; 2004; McDonald 1991a; 2008; Riemer 2007b). The specimens from the Bashendi A (around 6400-5600 cal.BC) of Dakhleh Oasis include concave-based, tanged, and leaf-shaped points of various sizes. The Abu Tartur specimens consist mainly of small points with only a few large (more than 5 cm long) concave-based or tanged points throughout the phases named the Abu Tartur B (around 6500-6000 cal.BC) and the Abu Tartur C (around 6000-5200 cal.BC). The Djara specimens do not include large points at all in the earlier phase named the Djara A (around 6400-6100 cal.BC), but large tanged ones appeared in the later phase named the Djara B (around 5800-5400 cal.BC) after a short interval around 6000-5900 cal.BC. The specimens from the Phase B (around 6200-5800 cal.BC) and Phase C (around 5500-5200 cal.BC) of Farafra Oasis include small leaf-shaped points, and it was not until the Phase D (around 5200-4800 cal.BC) that small tanged points appeared there. Other bifacially-retouched items like large knives are also notable in Dakhleh Oasis and

Djara, and their date seems to be the Late Bashendi A (around 5900-5600 cal.BC) and the Djara B respectively.

Bifacially-retouched formal projectile points flourished after 5900 cal.BC in neighbouring regions such as Abu Gerara and Kharga Oasis (Caton-Thompson 1952; Holmes 1992a; Reimer 2003; Smith *et al.* 2004). Surface surveys at sites along the margin of the Great Sand Sea such as Siwa Oasis, Sitra and Lobo, and sites around the Abu Ballas scarp land such as Mudpans, Eastpans, Chufu and Meri also yielded small bifacially-retouched, leaf-shaped or tanged projectile points which could be dated to around this period (Cziesla 1989; Gehlen *et al.* 2002; Hassan and Gross 1987; Klees 1989; Riemer 2007a; 2007b). All of them are collectively named the '(bi)facial techno-complex' of the northern half of the Western Desert in the late 7th - early 6th millennia cal.BC (Riemer 2007a; 2007b).

Further to the east, an investigation at Sodmein Cave in the mountainous terrain near the Red Sea coast yielded a certain number of bifacially-retouched, leaf-shaped projectile points which could be dated to around 6000-5300 cal.BC (Vermeersch *et al.* 1994; 1996). Further to the south, intensive surveys and excavations in the Nabta-Kiseiba region revealed that the first appearance of bifacially-retouched formal projectile points was in the Middle Ceramic Period (5900-5500 cal.BC) though they were quite rare, and that the number and variety of bifacially-retouched formal projectile points slightly increased in the subsequent Late Ceramic period (5400-4600 cal.BC) (Wendorf and Schild 2001; 2004).

It seems that the elaboration of bifacially-retouched tools culminated in the Fayum in the middle of the 5th millennium cal.BC. Large projectile points, axes, knives, and sickle blades were made by bifacial technology. Slightly after that, similar items appeared in neighbouring sites like Merimde Beni Salama and El-Omari, and this lithic tradition persisted in the Badarian culture of the 5th-4th millennia cal.BC in the Nile Valley of Middle Egypt.

In summary, given the present data, the

origins of bifacially-retouched formal tools seem to be somewhere in the middle of the Western Desert between the Great Sand Sea and the Nile Valley around the end of the Early Holocene, and the development and dispersal of bifacially-retouched formal tools continued through the Middle Holocene. It is noted that studies so far have tended to treat bifacially-retouched formal tools and particularly projectile points as cultural markers or subsistence markers, and that the frequencies of projectile points of whatever sizes and shapes in a tool assemblage at a specific site has been considered as reflecting the relative importance of hunting activity at the site (*e.g.*, Holmes 1992a; Riemer 2007b). However, the question as to why a limited percentage of stone tools started to be made in different sizes and shapes by employing bifacial technology within basically flake tool industries in this particular area at that particular time have not been answered.

As archaeology has recently come to be concerned with elucidating what kind of human behaviour had left artefacts rather than simply putting artefacts in temporal and spatial order, various studies of projectile points have appeared (Knecht 1997; Nelson 1997). Consequently, differences in shape of projectile points are presently interpreted not only as indicators of specific places and time periods but also as delineating differences in technology, function, and style. Since it is difficult to suppose the function and style of prehistoric projectile points, experimental methods and ethnological data are employed to mitigate this difficulty. Experimental methods include examining flying distance and killing power by using a variety of replica projectile points with various arrows and shafts. While experiment makes it possible to compare the function of projectile points of various size and shape, it cannot explain why such a wide variety of projectile points existed. Ethnological data are not sufficiently concrete evidence to explain the functions and styles of prehistoric projectile points. However, ethnological data can provide many otherwise unanticipated suggestions concerning the reasons for the size and shape of projectile points

and insights into what people think about the projectile points as well as under what conditions and how the projectile points are used. With the aid of ethnological data, the archaeologist can gain a deep understanding of the functions and uses of projectile points, provide better interpretation of prehistoric projectile points, and make suppositions as to how prehistoric people thought about their projectile points. Keeping these perspectives in mind, the environmental and socioeconomic circumstances of the Western Desert will be overviewed.

4.5.1.1. Natural preconditions for the appearance of bifacial stone tools in the Western Desert

The first point to be explained is why such a new set of bifacial stone tools as those observed in the above-mentioned sites in the Western Desert had not appeared in the Late Pleistocene but developed in the Early-Middle Holocene. It is assumed that something was different between the Pleistocene and the Holocene, and that the difference gave the possibility for the development of such unprecedented tools. As described in Chapter 2, there was a considerable change in the vegetation cover of the Western Desert in the Early Holocene due to the improvement of atmosphere and pluvial regime, and it is likely that the fauna also changed accordingly. Therefore, the explanation of the appearance of unprecedented bifacial stone tools in the Western Desert in the Early-Middle Holocene must take account of the spread of new vegetation. It may be assumed that the development of bifacial projectile points was triggered by the beginning of the hunting of previously less-encountered animals which were attracted by the spread of pasture plants, or the beginning of more intensive hunting of familiar animals in the Western Desert.

Major game animals in the Nabta-Kiseiba region in the Early-Middle Holocene were dorcas gazelle and hare, both of which are desert-adapted and water-independent species, and it seems that the Nabta-Kiseiba region was never wet enough to attract more water-dependent animals like hartebeest and

hippopotamus even in the Early Holocene climatic optimum (Gautier 1984; 2001). Therefore, the former assumption that the beginning of the hunting of previously less-encountered animals triggered the development of bifacial projectile points is apparently not the case in the Nabta-Kiseiba region. An important fact is that the number of dorcas gazelle in the archaeological record of the Nabta-Kiseiba region decreased through the Early-Middle Holocene while the number of hare increased. This may possibly imply that bifacial projectile points were inventions to raise the success rate of the hunting of dorcas gazelle which were going extinct. In the Nabta-Kiseiba region, it has been reported that the first appearance of bifacially-retouched projectile points was in the Middle Ceramic period (*ca.* 5800 cal.BC onward), and this is almost coincident with the decrease in the number of dorcas gazelle.

However, flake points are not necessarily inferior to bifacially-retouched points in terms of flying distance and killing power, especially if other attributes such as shape and weight are equal. In the Middle and Late Ceramic periods, bifacially-retouched points seem to have been very few, and less-retouched flake points were never replaced by bifacially-retouched points. Therefore, the appearance of bifacial points in this region cannot be explained in terms of functional superiority but rather in terms of differences in hunting strategy as to whether it is on a stalk basis or an ambush basis, and such differences may have affected the time spent to make and repair points.

In Dakhleh Oasis, there is very scarce evidence for the fauna in the Early Holocene, but it has shown the presence of common ungulate species like dorcas gazelle and hartebeest. The presence of the Sudano-Ethiopian fauna including elephant and giraffe has also been suggested in the Middle Holocene (Churcher 1999a; 1999b; Churcher *et al.* 2008). There is some doubt as to whether the remains of the Sudano-Ethiopian fauna derived from the Middle Palaeolithic context and were accidentally associated with the Holocene artefacts, because both of them are surface finds

(Close 1992: 171). If the Sudano-Ethiopian fauna in question was actually associated with the Middle Holocene environment, it was certainly a new addition to the fauna in this part of Egypt and hence previously less-encountered. Although it is not certain whether these new large animals became the prey of hunters in Dakhleh Oasis in the Middle Holocene, the number, variety and size of bifacial projectile points became large through the Bashendi A and B (McDonald 1991a; 2008), and interestingly, it seems that elephant and giraffe went extinct during the Middle Holocene. It is possible that their extinction was caused not only by increasing aridity but also by overhunting. It can be assumed that large bifacial projectile points which first appeared in the Bashendi A played a role in this, because hunting large and tough animals must have required special tactics and technologies.

Ethnographic data show that there are few examples of hunters changing the size and shape of projectile points according to the size and species of hunted game. It is more typical for hunters to take spears tipped by large and heavy projectile points that cannot fly long distances but have greater killing power, as well as arrows tipped by small and light projectile points that can fly long distances but have lesser killing power, and to choose according to the conditions of their encounter with specific game (Christenson 1997; Ellis 1997). It is well known that spears are able to impart a knock-down force and to open severe wounds and hence are superior for killing large, slow-moving animals, though spears must be delivered at closer range. On the other hand, arrows are suitable for shooting at cautious, fast-moving animals from a distance, though arrows are not able to kill the animals immediately even if the arrows are poisoned (Hitchcock and Bleed 1997). It follows that any variation of projectile points that cannot be explained as resulting from the conditions of specific encounters with certain types of game animals should be interpreted as arising for other reasons.

As for possible targets, one important question is why there were large concave-based

or tanged bifacial projectile points in the sites of Djara and the Nabta-Kiseiba region, where the existence of large game animals like elephant and hippopotamus has not been attested. Large and heavy concave-based or tanged bifacial projectile points are apparently not suitable for tipping arrows, because arrows tipped by such heavy points would be seriously unbalanced and their flying performance would not be good. Even though such large projectile points did tip hand-held spears or throwing spears, spears would not be suitable for hunting fast-moving animals like dorcas gazelle, which were the most common in those sites, but would be most effective against large aggressive animals which tend to counterattack rather than flee. Therefore, different explanations about the targets of large bifacial projectile points are necessary. One possible explanation is that those large projectile points were designed to kill humans and not game animals. This possibility will be discussed later in relation to social circumstances.

The second point to be explained is why such a new set of bifacial tools had not appeared first in the Nile Valley but developed first in the middle of the Western Desert. It is assumed that something was different between the Nile Valley and the Western Desert, and that the difference gave the possibility for the development of such unprecedented tools. It is widely recognised that procurement of lithic raw materials is absolutely essential for making stone tools, and the availability and quality of lithic raw materials critically affect and condition the making of stone tools (*e.g.*, Andrefsky 1994; Bamforth 1986). Therefore, the distribution of sources of lithic raw materials in the Western Desert and the Nile Valley must have offered possibilities and constraints for tool making.

The main area where bifacially-retouched formal tools developed in the Early-Middle Holocene is a vast rocky plain on the Limestone Plateau which abuts the Nile Valley to its east, between the latitude of Esna in the south and the Fayum in the north. Extensive scarps of the Limestone Plateau are seen in the southwest, and major oases are located at the foot of the scarps. Wherever bifacially-retouched formal tools

appeared in the Early-Middle Holocene, such as in Siwa Oasis, Farafra Oasis, Dakhleh Oasis, Kharga Oasis, Djara, Abu Gerara, Sitra and Lobo, good quality lithic raw materials like flint in nodular form were abundant locally or available in the vicinity, and there is no evidence for long distance transport of exotic raw materials. It must be noted that the remains of lithic workshops have been reported in some of these regions (Barich 1996; Caton-Thompson 1952; Cziesla 1989; Hassan and Gross 1987; Kindermann 2002; 2003; 2004; Klees 1989; Kuper 1996; 2002). They indicate that lithic raw material procurement and subsequent reduction took place locally and tools were also made locally.

In contrast, the Nabta-Kiseiba region, which was another major centre of Early-Middle Holocene cultures, is characterised by a flat or undulating desert plain on the Nubian sandstone bedrock with a number of playas, a series of sandstone escarpments capped by thin flint layers, named the Kiseiba Scarp, and some sandstone outcrops like the Gebel Nabta. The vast area next to the Kiseiba Scarp is dominated by the Selima Sand Sheet. It has been revealed that it was not uncommon for the inhabitants of playa sites in the Nabta-Kiseiba region in the Early-Middle Holocene to bring good quality lithic raw materials like flint from remote scarps, even though they exploited locally-available, coarse-grained raw materials like quartzitic sandstone, and there were few bifacially-retouched formal tools (Wendorf and Schild 2001; Wendorf *et al.* 1984). In the sites of Bir Safsaf, where the ground surface is completely covered by sand and no rock outcrops are readily available, people who used this area seasonally while harvesting wild grasses and herding cattle in the Early-Middle Holocene, had no other choice but to bring all lithic raw materials and tools with them from outside the area, and no elaborate tools developed (Close 1990; 1996a).

On the basis of these contrasting geographical and geological conditions between the north and south of the Western Desert, it may be assumed that easy access to the sources of fine-grained

flint on and around the Limestone Plateau in the north of the Western Desert could be an advantage for the development of bifacially-retouched formal tools earlier than that in the south, where the sandstone bedrock predominates. Since there are few comparable contemporaneous archaeological sites in the Nile Valley, it is hard to argue whether accessibility to good quality nodules or cobbles of flint in the Nile Valley affected the development of bifacially-retouched formal tools. In the Nile Valley, flint nodules occur not only on the upland surface but also in consolidated deposits exposed at the rock wall of the valley. In addition, it is also possible to exploit secondary deposits of rolled flint cobbles which were eroded out from the valley wall and transported downslope to the streambed. It seems that this situation was favourable enough for the development of bifacially-retouched formal tools which require fine-grained raw material of a certain size. Therefore, it may be that the lack of such tools in the Nile Valley in the Early-Middle Holocene is simply due to the problem of site preservation, but other possible reasons will be discussed later.

4.5.1.2. Interpretations of bifacially-retouched stone tools in the Western Desert

Given these natural preconditions, the next step is to investigate and interpret the appearance and development of bifacial stone tools in the Western Desert in the Early-Middle Holocene in terms of adaptive strategy and emergent social complexity.

Raw material economy is the first concern of the adaptive strategy of forager-herders. According to the idea of economising behaviour (Odell 1996), toolmakers make the most of hard-to-obtain or scarce lithic raw materials not only by obtaining as many usable flakes as possible from a lithic core but also by making tools and then using, resharpening, and recycling them repeatedly, in case the raw materials at hand are depleted and access to the sources is unpredictable. Such behaviour may foster the ability to make labour-intensive bifacial tools. An important observation is that bifacial tools

tend to develop among highly mobile people who forage in environments where the availability of good lithic raw materials is occasionally limited. In contrast, it has been argued that in environments where good lithic raw materials are everywhere and readily available, toolmakers tend to waste the materials and to prefer expedient cores and tools, and thus time-consuming and labour-intensive stone tools do not always develop. Such contrasting situations have been discussed as the tool expediency-curation alternatives, and the economising behaviour mentioned above is also one of curatorial adaptation.

However, the cases of the Nabta-Kiseiba region and Bir Safsaf seem to contradict the idea of economising behaviour. It has been considered that Early-Middle Holocene people would have visited the sites of the Nabta-Kiseiba region and Bir Safsaf after summer rainfall and stayed there for a short length of time, and hence that they would have been quite nomadic. One study in a playa site in the Nabta-Kiseiba region has revealed that more than half of all lithic raw materials used there derived from source areas some 100 km away from the site. The preferred raw material, flint, was brought there in the form of unworked cobble as well as partly decorticated core, but no bifacially-retouched formal tools developed there (Kobusiewicz 1984). Another study in some playa sites in the Nabta-Kiseiba region has revealed that people used flint cores in a rather wasteful manner, despite a burden of obtaining flint from distant source areas (Close 1999). In Bir Safsaf, people not only carried large flakes as blanks for making partly-retouched tools but also carried cores and struck off a series of flakes when the occasion arose, and they sometimes brought unimaginably heavy unworked blocks of quartzitic sandstone, presumably for future use (Close 1990; 1996a). Although they made a certain variety of tools, most tools remained simple, and no bifacially-retouched formal tools developed.

These facts seem to suggest that making bifacial tools in advance and resharpening during use and move are not necessarily the only means to economise the use of hard-to-obtain or scarce

raw materials. Toolmakers could find it better to carry lithic cores than to carry completed tools, probably because they adopted a circulating mobility strategy on a seasonal basis and their lithic raw material procurement had been embedded in their routine move. It may also be concluded that the abundance of good quality lithic raw materials was a necessary but not a sufficient condition for the development of bifacial stone tools in the Western Desert. In addition to toolmakers' consideration on raw material economy, some other socioeconomic circumstances must have required or allowed the development of bifacial stone tools.

In the Western Desert in the Early-Middle Holocene, informal flake tools include sickles, scrapers, perforators, notches and denticulates, which seem to be related to food gathering and craft working tasks, whereas bifacially-retouched formal tools include arrowheads, spearheads and large knives, and they seem to be related to hunting and butchering. This suggests that curation was mainly applied to hunting and butchering tools, and that hunting and butchering were logistically organised. In other words, the development of highly-specialised tools like bifacially-retouched projectile points and knives in basically expediently-made tool assemblages in such regions as Dakhleh Oasis, Farafra Oasis and Djara in the Early-Middle Holocene may indicate the decline of encounter hunting and the emergence of a certain degree of sedentism combined with logistical mobility.

It must be noted that the people in Nabta Playa and Farafra Oasis were equipped with bifacial stone tools just before, or by a curious coincidence with, the adoption of domesticated sheep/goats. A similar phenomenon is observed in Djara and Dakhleh Oasis as well, though the time gap between the appearance of bifacial tools and the adoption of domesticated sheep/goats seems to be a little wider. Therefore, the explanation of why bifacial stone tools first appeared and developed in the Western Desert in the Early-Middle Holocene must take into account the possibility of increasing unprecedented socioeconomic stress, which may

have been caused by growing population and emerging rigid territoriality and may have somehow been mitigated by the adoption of domesticated sheep/goats. Considering such possible socioeconomic circumstances, the presence of unreasonably large bifacial projectile points and the absence of probable target animals in Djara and the Nabta-Kiseiba region may imply that those projectile points were designed to kill enemy humans, as mentioned earlier. However, since there is no clear evidence for the violent death of humans in the Western Desert in the Early-Middle Holocene, it is hard to know whether large projectile points were actually used to attack people. No evidence of violence seems to suggest that people became smart enough to reconcile territorial conflicts in different ways.

An alternative interpretation about the development of bifacial stone tools in such possible socioeconomic circumstances is that the bifacial stone tools had some symbolic meanings and some significance for the establishment and maintenance of intra/inter-group relationships. As discussed earlier, it may be said that both less-retouched informal flake tools and bifacially-retouched formal tools can serve for cutting or thrusting tasks in almost the same manner. The question is why toolmakers took the trouble to make time-consuming bifacial tools even if informal flake tools were able to serve the same purpose. The toolmakers' concern about the tool reliability-maintainability alternatives must be one reason, but the non-utilitarian function of bifacial stone tools must also be taken into consideration.

As described at length, it can be said that essential tools for survival are likely to become the media for the representation of personal or group identity. Using Wiessner's terms, the assertive style, which carries the message that the maker or owner is different from others, as well as the emblematic style, which stresses conscious affiliation to a certain group, can appear in such tools. It should be noted that bifacial technology was initially applied exclusively to hunting and butchering tools in the Egyptian Western Desert in the Early-Middle

Holocene. Therefore, it can be assumed that bifacial stone tools in the Western Desert in the Early-Middle Holocene were not merely utilitarian objects but also symbolic items, which represented personal or group identity and delivered social messages to other people in and outside their community. In other words, the appearance and development of elaborate bifacial stone tools in the Western Desert in the Early-Middle Holocene may be interpreted as a reflection of internally and externally stressful circumstances and the resultant competitive aestheticism among toolmakers.

It has also been known in ethnological studies that the Kalahari Bushmen liked to obtain projectile points that varied in material, size and shape from experienced hunters and skilled toolmakers of other group because they believed that well-made projectile points could kill game animals more easily, even though the knowledge of locations where certain species of game animals live is much more important than the quality of projectile points, and actually the success or failure of hunting is dependent on how a hunter encounters game animals. Hence the projectile points could move over long distances by inter-group exchange (Hitchcock and Bleed 1997). If such an ethnological example was the case in the Egyptian Western Desert in the Early-Middle Holocene, the presence of unreasonably large and elaborate formal stone tools without possible target animals may be explained in terms of symbolic and stylistic behaviours by hunters who wished the success of hunting and satisfied their vanity, rather than bloody conflicts between aggressive men.

4.5.1.3. The implications of the development of bifacial stone tools for the beginning of animal herding in the Egyptian Western Desert

As described earlier, whereas most scholars are coming to agree that a resource-rich environment is an essential condition for the emergence of social complexity and the beginnings of food production, there is still controversy over what conditions could drive prehistoric people to

intensify food procurement and to compete with each other. In the case of Egypt, it seems plausible that moderately stressful and circumscribed situations under periodically or seasonally resource-rich conditions in the Western Desert in the Early-Middle Holocene caused recurrent population/resource imbalances on an unprecedented scale and drove the inhabitants to enhance food security through storage, sedentism and territoriality. In contrast, the Nile Valley seems to have escaped such stressful and circumscribed situations and failed to encourage its inhabitants to intensify their subsistence, even though a degree of inflow of refugees from the Western Desert may have caused some social tensions and reorganisation of territories.

If bifacial stone tools in the Western Desert in the Early-Middle Holocene were a reflection of emerging socioeconomic competition among individuals, who were enthusiastic about raising their status by procuring and providing food through using elaborate stone tools, then the introduction of domesticated sheep/goats into several regions may also be interpreted to have been motivated by such competition as well as a need for reliable back-up food. The lack of elaborate stone tools in the Nile Valley in the Early Holocene may also probably be interpreted as an indication that less stressful situations retarded the adoption of domesticates. Novel food like the meat of domesticates and their dairy products may have enabled ambitious food providers to get ahead of the competition. The reasons why elaboration of bifacial projectile points and knives continued after the period of the initial adoption of domesticates, may be because hunting was still a prestigious task in most regions regardless of the availability of domesticates, and because bifacial stone tools did not easily lose their value as the media of social representation or the means of status display.

4.5.2. The origin and development of bifacially-retouched stone tools in the Fayum Neolithic and their implications for the beginning of farming and herding in the Fayum

Following the observation and interpretation of the appearance of bifacial stone tools in the Western Desert, the next focus is on bifacial stone tools in the Fayum. As mentioned earlier, the appearance of bifacial stone tools in the Fayum seems to be later in date, but the elaboration and sophistication of bifacial stone tools culminated in the Fayum Neolithic. As described in Chapter 3, during the Fayum Neolithic, bifacial technology was employed mainly to make arrowheads, spearheads, knives, sickle blades and axes, all of which are related to hunting, butchering, harvesting, wood carving and probably ploughing. There is little doubt that these bifacial tools were first and foremost invented according to arising needs to perform a new variety of tasks in the Neolithic period and hence can be viewed as a part of adaptive strategies. However, considering that some classes of bifacial tools like arrowheads, spearheads and knives seem to be overdesigned against functional requirements, it should be assumed that those Fayum Neolithic bifacial stone tools were not merely utilitarian, but should also be considered that their manufacture involved additional meanings.

If the Fayum Neolithic data are considered in the light of ethnological examples of social meanings attributed to artefacts, it is possible to suggest that Fayum Neolithic bifacial tools embodied similar personal characteristics and skills, such as carefulness, perseverance and exactitude. Indeed, all of these attributes are essential for successfully undertaking subsistence activities, including the making of the tools used in these activities. Therefore, it may be argued that such characteristics and skills would have been recognised socially as favourable for the survival of individuals and groups. Individuals who were engaged in subsistence activities in the Fayum Neolithic may have acquired personal status by

emphasising their skills in making good quality stone tools.

Considering that minimal tool morphological requirement for a specific task may be fulfilled with marginal retouching or unifacial retouching, Fayum Neolithic toolmakers would not necessarily have taken the trouble to make such elaborate bifacially-retouched tools. However, it can be argued that the cost of making and maintaining elaborate bifacial tools did meet the benefit of increasing one's status. For instance, if the Kalahari Bushmen example is taken into consideration, the elaboration of bifacial tools in the Fayum Neolithic may reflect competitive aestheticism among individuals in obtaining prestige as excellent toolmakers, rather than the pursuit of a purely functional improvement. In this sense, Fayum Neolithic bifacial technology may be regarded as prestige technology, as well as practical technology.

The coincidence of the florescence of bifacial technology with the advent of wheat/barley farming and sheep/goat herding in the Fayum Neolithic may imply a relationship between them. According to the socioeconomic competition model, provided that the circumstances became favourable for the abandonment of the ethic of socioeconomic equality and novel food resources became available, ambitious food providers would have had various motives for attempting farming and herding which could provide a large amount of novel food, in order to impress other people and to wage competition. If some classes of Fayum Neolithic bifacial stone tools reflect competitive aestheticism in the quest for higher social status, it is suggested that the first step toward the adoption of farming and herding as part of subsistence activities may also probably have been motivated by competition in the quest for increased status among individuals. The socioeconomic competition model for the beginning of food production does not make clear who could become an ambitious food provider, but it is plausible that these might be exceptionally skilled toolmakers, or persons who used their exceptional ability to please others who were ambitious. It remains possible that

these processes initially occurred at an earlier date among social groups in neighbouring regions, which, led by ambitious persons, came to the Fayum with domesticates.

A further study of the processes which led to the emergence of skilled toolmakers as possibly represented in the development of Fayum Neolithic bifacial technology and the emergence of ambitious food providers is necessary in order to support the interpretation proposed above. Although it may not always be possible to discover the intentions of Neolithic toolmakers, consideration of the social implications of the development of bifacial technology is able to offer further perspectives on the beginning of farming and herding in the Fayum. Emergent social complexity in the Western Desert in the Early-Middle Holocene has been inferred on the basis of the spread of a limited number of pottery vessels after the 9th millennium cal.BC (Close 1995) and the appearance of monumental stone structures after the 6th millennium cal.BC (Wendorf and Schild 1998; 2001; 2002a; 2004). The innovation in lithic technology after the middle of the 7th millennium cal.BC must also be considered as a symptom of incipient socioeconomic complexity, which eventually led to the adoption of foreign domesticates.

4.6. SUMMARY

It has been demonstrated in this chapter that optimal foraging models and related concepts have better explanatory power than intuitive arguments and are useful to better understand the Fayum archaeological and ecological data obtained by previous research. These models and concepts also give some predictions about foragers' responses to environmental and demographic changes and their consequences, and future archaeological research is expected to see whether such predictions are really the case. Moreover, the socioeconomic model and related ideas give a further insight into the possible socioeconomic circumstances in which food production would be needed and the motives of foragers who eventually adopted farming and herding. In the following chapters,

the optimal land uses by Fayum Epipalaeolithic and Neolithic people will be described on the basis of new field survey results, and the adaptive technological behaviour of Fayum Epipalaeolithic and Neolithic people will be illustrated by focusing on their lithic technological organisation. Through these studies, it is expected that the reasons for, and the process of, subsistence change from foraging to farming and herding at the Epipalaeolithic-Neolithic transition can be revealed.