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Beluga (*Delphinapterus leucas*) Novel Bubble Helix Play Behavior

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Abstract - Cetaceans demonstrate considerable ingenuity in their play with bubbles. Both wild and captive cetaceans have been reported to manipulate self-produced bubbles (Delfour & Aulagnier, 1997; Gewalt, 1989; Kuczaj, Makecha, Trone, Paulos, & Ramos, 2006; Kuczaj & Walker, 2006; McCowan, Marino, Vance, Walke, & Reiss, 2000; Pace, 2000; Paulos, Trone, & Kuczaj, 2010; Tizzi, Castellano, & Pace, 2000). The spread of unique and novel play behaviors across a group may involve social learning as well as trial and error learning (Kuczaj et al., 2006; Kuczaj, Yeater, & Highfill, 2012; McCowan et al., 2000; Pace, 2000). We report on a form of bubble play in belugas *(Delphinapterus leucas)* that has not been previously reported. Four belugas at the Shedd Aquarium were videotaped producing bubble helices, smooth, long "helical tubes" that were created by the animal producing a pressure vortex that caused bubbles to merge and elongate based on pressure variation in the vortex (Marten, Shariff, Psarakos, & White, 1996). These observations revealed that belugas create novel bubble play behaviors that are transmitted among members of the group through social learning. When a beluga engaged in bubble helix play following the play of another beluga, it often acted on the bubble in the same manner as the most recent player, consistent with the notion that the second beluga was mimicking the behavior of the first beluga. Kimalu, a calf, was more likely to both observe and interact with Miki, his older brother, during bubble helix play bouts than with Naya (no relation), or Mauyak, his mother. Dolphin calves have also been found to be more likely to imitate the play behaviors of older more competent peers (Kuczaj et al., 2006; Kuczaj et al., 2012). Consistent with previous analyses of cetacean play (Kuczaj et al., 2006), belugas also varied the complexity of the play behavior in order to keep the game stimulating.

Keywords – Beluga, play, social learning, Delphinapterus leucas, bubble play, bubbles, helix, imitation

Play is difficult to define, but is generally considered a pleasurable activity that benefits well-being and development (Bekoff & Byers, 1981; Burghardt, 2005; Fagen, 1981; Kuczaj et al., 2006). For at least some species, play may have evolved to facilitate an individual's ability to adapt to new environments by encouraging both behavioral and cognitive flexibility (Kuczaj et al., 2006; Kuczaj & Walker, 2012). Play provides a context that allows the individual to explore the consequences of specific behaviors in a relatively non-threatening environment (Burghardt, 2005; Kuczaj & Makecha, 2008).

Cetaceans of all ages play, although young animals are more likely to play than are older animals (Gewalt, 1989; Kuczaj et al., 2006; Paulos et al., 2010). Play behavior sequences involve the modification of a behavior, the imitation of a behavior, or the repetition of the player's own behavior, each of which serves different ontogenetic functions (Kuczaj, 1998). Cetacean play may be solitary or social. Parallel play is a form of solitary play that occurs in a social context (Bakeman & Brownlee, 1980). For example, two dolphins in the same location that are playing with their own bubbles but not interacting with one another would be engaging in parallel play. In such cases, the players may be aware of each other's actions and even influence one another's play behaviors, but the absence of interaction is what makes parallel play solitary rather than social. Both social and solitary play behaviors can be, cognitively challenging, but the presence of potential models in social and parallel play facilitates imitation and observational learning (Kuczaj et al., 2006; Kuczaj & Makecha, 2008).

Several species of cetaceans (e.g., Amazon river dolphins, bottlenose dolphins, and belugas) have been found to play with bubbles they produce by expelling air underwater (Delfour & Aulagnier, 1997; Gewalt, 1989; Hill, 2009; Kuczaj et al., 2006; Kuczaj & Walker, 2006, 2012; McCowan et al., 2000; Pace, 2000; Tizzi et al., 2000). Dolphin calves typically learn to play with bubbles by observing their mothers (Kuczaj & Walker, 2006; McCowan et al., 2000). In addition to modeling bubble play behavior, mothers sometimes provide their calves with bubbles with which to play (Kuczaj & Walker, 2006, 2012). But mothers are neither the only models nor the only providers of bubble toys. Calves learn some forms of bubble play from older calves or juveniles (Kuczaj et al., 2006; McCowan et al., 2000; Pace, 2000). Sometimes dolphins other than the mother provide bubble toys for younger animals. For example, an Orinoco freshwater dolphin constructed bubble toys that were then given to a younger relative to play with (Gewalt, 1989).

Pace (2000) described a bubble play behavior in which bottlenose dolphin calves produced bubble rings using a swift motion with their flukes. This novel technique for producing bubble rings was imitated by another young dolphin, a clear case of novel play behavior being transmitted from young animal to young animal (see also Kuczaj et al., 2006). Once they have learned to produce bubble rings, calves quickly learn to manipulate their bubble creations. They sometimes watch the bubble ring until it reaches the surface and disintegrates. But calves are more likely to destroy the bubble ring by biting it, hitting it with the fluke, or swimming through it (Delfour & Aulagnier, 1997; Kuczaj et al., 2006; McCowan et al., 2000; Pace, 2000).

The focus of this report is on the creation of bubble helices and the subsequent play with these bubble forms by belugas. This behavior begins when a beluga emits a burst of bubbles near the bottom of a pool and then creates a tight corkscrew shape by swiftly flipping their bodies in a circular motion while usually using a pectoral fin (sometimes used the fluke) to initiate the trail of bubbles, creating the bubble helix (see Figure 1 for complete description of this behavior). The resulting bubble helix consists of a continuous string of interconnected spinning bubbles, and so is quite different from the typical bubble stream produced while exhaling underwater. After creating the bubble helix, the belugas floated toward the surface while in a crunched position in order to watch their bubble creation float upward. Bubble helices were sometimes destroyed by a beluga before it reached the surface, and sometimes simply watched until it disintegrated at the surface. This is the first description of this creative bubble play behavior by belugas, and only the second mention of it in the literature. Marten et al. (1996) reported that a bottlenose dolphin sometimes blew bubbles and then brushed past them with her dorsal fin, creating a helix of bubbles coiled in the vortex created by her movement.

Method

Four belugas housed at the Shedd Aquarium in Chicago, Illinois were the subjects of this study (see Table 1 for subject details).

Video recordings of underwater beluga behavior collected during the summer months of 2013 were analyzed for instances of bubble helix play. All recordings were filmed through an underwater viewing window during times in which the facility was closed to the public. The 19 hrs, 14 min, and 34 s of video data were analyzed using the ethogram and coding scheme (shown in Tables 2 and 3 respectively).

Our analyses focused on bubble helix play behavior. There were two components to this analysis. First, we wished to describe the behavior and its frequency in as much detail as possible. Second, we hoped to determine the role of social learning in the calf's acquisition of this behavior. All approximations of this behavior by the calf (i.e., the calf participating in one or a number of the “steps”) were included in this analysis.

The relationship of a bubble helix event to another bubble helix event was assessed for all bubble helix events that occurred within one minute of each other, the exception being bubble helix events that overlapped with one another. A “bout” of bubble helix behaviors consisted of all bubble helix events occurring within five minutes of one another.

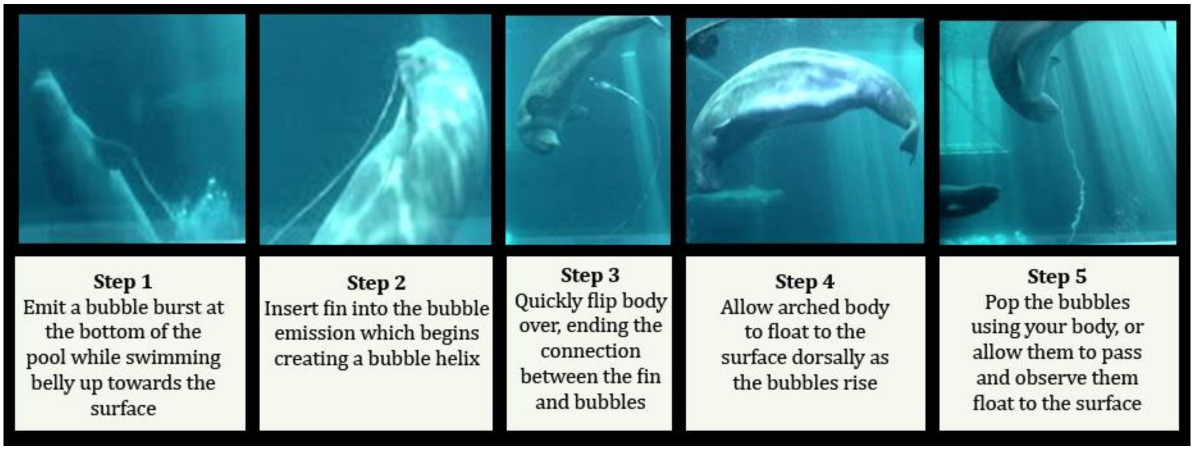

Figure 1. Beluga Helix Play Behavior Sequence. This shows the typical sequence of behaviors involved in bubble helix play behavior.

Table 1

Subject Specifications

Animal	Adult/Juvenille/Calf	Sex	Kinship
Naya	Adult	Female	None
Mauyak	Adult	Female	mother of Miki and Kimalu
Miki	Juvenille	Male	offspring of Mauyak, brother of Kimalu
Kimalu	Calf	Male	offspring of Mauyak, brother of Miki

Table 2

Example Ethogram

#	Video	Animal	Time	time interval	Method to pop bubble	Same or different	Observation/Interaction
34	61713	Mauyak	0:44:16	0:00:43	mouth	different	Naya observing
35	61713	Miki	0:44:49	0:00:33	mouth	same	
36	61713	Naya	0:45:17	0:00:28	mouth	same	

Table 3

Operational Definitions for Ethogram

mouth/fluke/pec	using a body part (e.g., mouth, flukes, pec fin, face to cause the bubble helix to pop, or change directions from its trajectory
unknown	part of the animal was out of frame for the behavior, or it is unclear what part of the body was used to pop the bubble
did not pop	animal observed the bubble as it floated up towards them, but chose not to pop the bubble and let it float past them
other	all other deviations from the norm, for example: Kimalu swimming through their bubbles and popping them first
same	the same popping behavior as the previous one, unless the previous one is <5s before this one, at which point we went to the one before that because they are going simultaneously and could not have observed one <5s before
different	used a different technique than the one previously used by the last animal to pop the bubbles
time interval	the time elapsed since the last bubble helix play behavior by any animal
observation	any animal orienting at an individual throughout the majority of the bubble helix play behavior
interaction	imitating a portion of the behavior simultaneously (only demonstrated by the calf), or participating in popping another animals bubbles.

Results

There were a total of 186 complete bubble helix play behaviors. All of these behaviors occurred during two consecutive days. Of these, all but four comprised bubble play bouts, the remaining four each being a single event that was not preceded nor followed by another bubble helix behavior within the one-minute criterion. Kimalu (the calf) performed 20 approximations of the behavior during this time period. He also produced two more approximations about a month later, these attempts occurring when no other animals were playing with bubble helices.

As shown in Figure 2, the three adult animals differed in terms of how often they engaged in bubble helix behavior, $F(2, 297) = 29.03$, $p < 0.05$. Miki, the juvenile male, produced the most bubble helix behaviors, the next most being produced by the eldest female, Naya. Games-Howell post hoc tests revealed that the difference between Miki and Naya was not statistically significant ($p = 0.17$), but also revealed that they were more likely to produce bubble helix behaviors than was Mauyak ($p < 0.05$). Mauyak, did produce and play with bubble helixes, but did so relatively infrequently. Moreover, she never initiated a bubble helix play bout, but instead only engaged in such behavior after another animal had demonstrated the behavior. Miki was less likely to initiate a bubble helix play bout than was Naya. She did so on four occasions, while Miki initiated a play bout only once.

Figure 3 shows that the mouth was the body part most commonly used to manipulate or destroy the bubble helix, $\chi^2(3, N = 144) = 171.94$, $p < 0.05$. As shown in Figure 4, there were individual differences in the body part most commonly used to interact with the bubble helix after it was formed. Naya and Miki each were more likely to use the mouth when engaging a bubble helix, $\chi^2(3, N = 57) = 84.82$, $p < 0.05$ and $\chi^2(3, N = 80) = 89.20$, $p < 0.05$ respectively. In contrast, Mauyak did not prefer one bubble popping method, $\chi^2(3, N = 7) = 2.5$, $p > 0.10$.

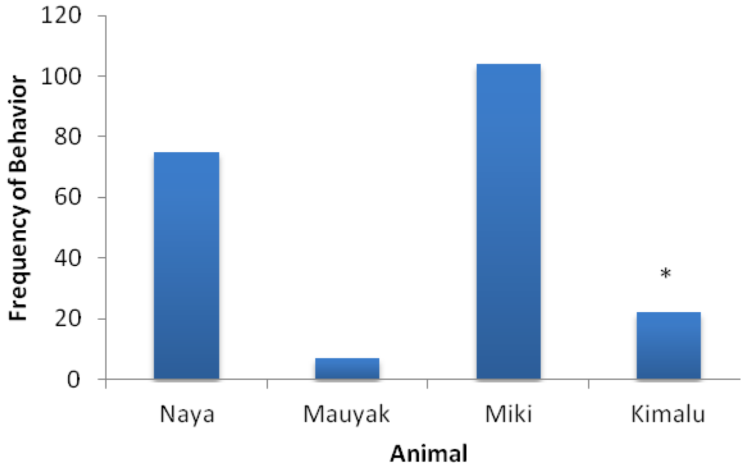

Figure 2. Frequency of bubble play behaviors for each beluga. *Kimalu's bubble helix play behaviors were typically approximations of the behaviors he observed.

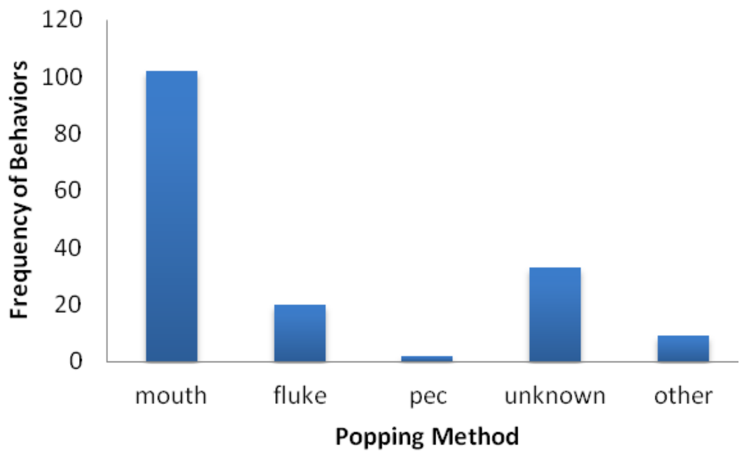

Figure 3. Body parts used to "pop" the bubble helix.

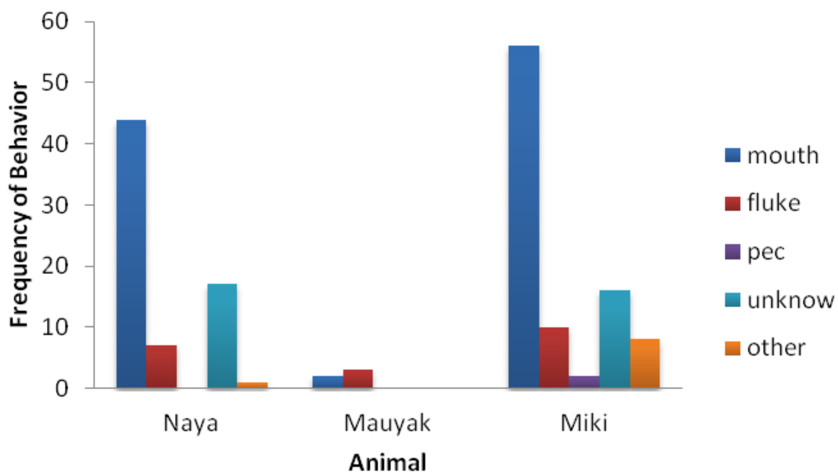

Figure 4. Body part used by each animal to pop the bubble helix.

We also scored the frequency of replications and imitations in bubble helix play bouts. A replication occurred if an animal repeated its bubble helix behavior within one minute of the previous behavior. Imitations involved an animal reproducing the bubble helix behavior of another animal within one minute of the original behavior. As shown in Figure 5, there was not a significant difference in the relative frequency of replications and imitations $\chi^2(1, N = 79) = 2.139$, $p = 0.15$, although imitations were more common than replications, suggesting that observing an animal engaging in bubble helix play often stimulated another animal to engage in the same sort of play.

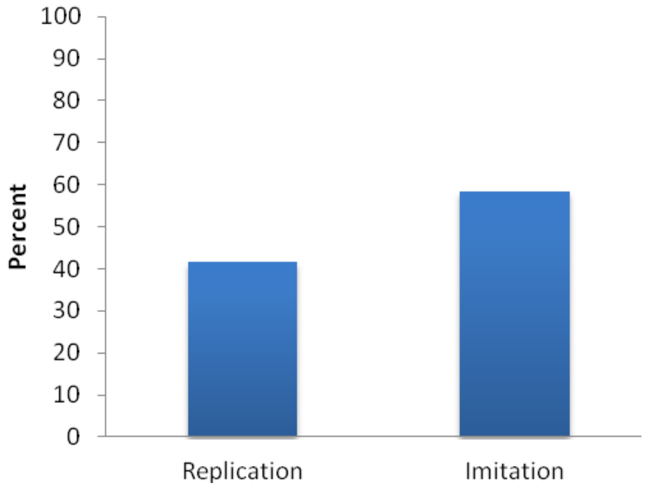

Figure 5. Percentage of bubble helix play behaviors that were replications of an individual's most recent behavior or imitations of another's previous behavior.

Kimalu, the calf, often observed Miki and Naya producing and playing with bubble helices (see Figure 6). He also participated in the play by either mimicking the modeled behavior (e.g., floating to the surface, body postures and positions) or popping the bubbles. Curiously, he did not watch nor interact when his mother, Mauyak, played with a bubble helix, perhaps because she rarely engaged in such play. Of the two whales to which he did attend, Kimalu was more likely to both observe and interact with his brother, Miki, than with Naya, to whom he was not related, $\chi^2(2, N = 32) = 20.6875$, $p < 0.05$.

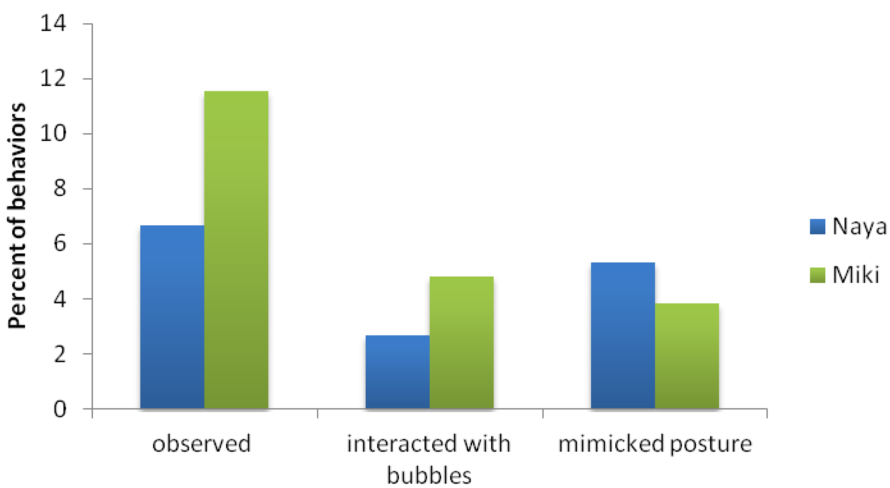

Figure 6. Kimalu observed or imitated the bubble helix behaviors of two other belugas. This graph shows the percentage of each individual's bubble helix behaviors in which Kimalu either observed or engaged.

Discussion

Although we have focused on bubble helix play, all four animals also engaged in other bubble play behaviors including the formation and manipulation of bubble rings. However, bubble helix play was the most common bubble play behavior during the time period of this study. Of the 187 instances of observed bubble helix play, only 4 did not result in a replication or an imitation within a one-minute time period. For example, on one occasion, Naya produced a bubble stream while observing her bubble helix rise to the surface. The following two bubble helix play behaviors performed by Miki also contained bubble streams produced while watching the helix float to the surface. This combination only occurred in these three consecutive behaviors, and strongly suggests that Miki had mimicked Naya's behavior.

We suspect that the belugas changed aspects of the bubble helix behaviors (e.g., bubble popping method) in order to keep the game challenging (see Kuczaj et al., 2006; Kuczaj & Eskelinen, this issue) for more detailed discussions of the significance of self-challenging play). The most common bubble popping method involved the mouth, but the precise way the mouth was used varied. The whales sometimes bit their bubble creations, but also "blew" or "sucked" their bubble creations using their mouth to create water currents. The animals also used their flukes to pop the bubbles, a seemingly more difficult behavior because it required that the individual complete a front flip with its body and then slap at the bubbles with its fluke as the bubbles floated behind the whale. Despite this added complexity, the animals were usually successful at popping part of the rising helix with their fluke.

Social learning is an important component of dolphin behavioral development (Kuczaj, et al., 2012; Kuczaj & Yeater, 2006; Yeater & Kuczaj, 2010), and our observations suggest that belugas are also intrigued by the activities of others (also see Hill, 2009). Each of the animals in this study observed other animals engaging in bubble helix play behaviors, and oftentimes participated in the play activities. For example, Naya intervened during one of Miki's play bouts by observing his behavior and popping his bubble helix with her mouth while he watched from the surface. The calf, Kimalu, was quite interested in the bubble helix play of the other whales, and was commonly observed alternating his attention from one whale to another as the animals took turns playing with bubbles. However, Kimalu was most likely to observe and interact with Miki, his older brother. Previous research has documented the selectivity of dolphin calves in their choice of models (Kuczaj et al., 2006; Kuczaj et al., 2012), with older dolphin calves typically being the preferred models for play behaviors. The same sort of process appeared to be operating with Kimalu and Miki, Kimalu being more intrigued by the activities of his older brother than by those of any other animal.

Regardless of which animal he was mimicking, Kimalu often reproduced the models' body positioning and behavior, oftentimes without interacting with a bubble helix. For example, after watching another whale flip over and fluke the bubble helix, Kimalu practiced this behavior as he swam ventral side up and flipped his body over without producing or interacting with bubbles. Kimalu also interacted with Miki and Naya's bubbles by popping them with his mouth, fluking them, or swimming through them. Gewalt (1989) reported that older dolphins created bubble constructs, or "bubble beds," for younger animals to play with, and mother dolphins sometimes produce bubbles, bubble streams or bubble rings that their calves bite or otherwise manipulate (Kuczaj et al., 2006; McCowan et al., 2000). Although we cannot determine the extent to which the older animals in our study were "intentionally" providing Kimalu with "bubble toys," Miki and Naya did allow Kimalu to interact with their bubble creations, and never aggressed towards him as he destroyed the toys they had created.

Kimalu's imitations of the other whales' behaviors and his subsequent practice of these behaviors resulted in improved performance over the course of the study period. By the end of this time, he had learned to produce imperfect variations of each of the five steps shown in Figure 1, albeit without the associated bubbles. He was observed one month later practicing the behavioral sequence associated with bubble helix play at a time in which no other animals were producing such behaviors. His ability to remember past modeled behaviors and then attempt to reproduce them suggests a capacity for deferred imitation, and demonstrates that his behavior was not simply a consequence of what was happening in his immediate environment.

In summary, the behaviors we have described are consistent with previous reports and interpretations of cetacean play. Beluga bubble helix play is creative and dynamic, and the animals keep their play interesting by adding components and modifying their behavior. Other animals appear to learn bubble helix play behaviors by watching others, but the manner in which the originator of this sort of play discovered how to make a bubble helix is a mystery. We suspect that something similar to what Piaget (1952) called "secondary circular reactions" was involved. A secondary circular reaction occurs when an individual accidentally does something that produces an interesting result in the environment. In this case, a whale may have accidentally produced a bubble helix, found this interesting, and then attempted to recreate this interesting phenomenon. Piaget also described "tertiary circular reactions," which involve an individual purposely modifying his behavior to determine the effect these modifications have on the subsequent outcomes. These sorts of behavioral modifications were observed in the present study, and are a characteristic of play in both human and non-human animals. Thus, even though bubble helix play is a relatively complex form of bubble play, it shares characteristics with play in general and adds to the growing body of evidence about the importance of play across species.

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